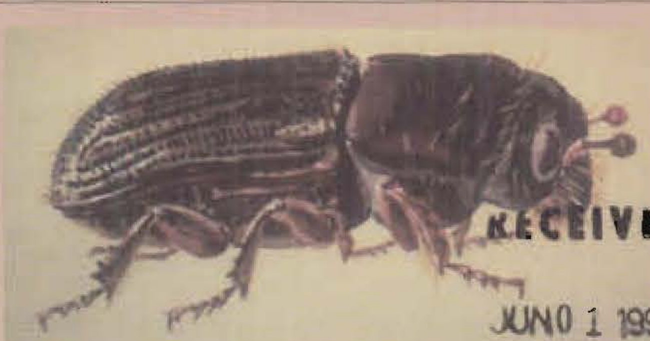
AgroBorealis

School of Agriculture and Land Resources Management
Agricultural and Forestry Experiment Station

Vol. 29, Number 1
Spring 1997



Restoration: battling the spruce beetle

University of Alaska Fairbanks

Acting Director's Letter

Dr. Allen Mitchell (AFES photo)

As this issue of *Agroborealis* goes to press, the 1997 Alaska legislative session is drawing to a close. With the falling of the final gavel, the citizens of Alaska were also witness to what some feel is the beginning of what our state leaders hope will be a more sustainable fiscal policy for the future. Few hold any illusions that the transition will be pleasant, but most agree that it is necessary. Similarly, our national Congress struggles with developing fiscal policies that will pursue a balanced budget and will, hopefully, avoid unmanageable debts falling on future generations. However, economic indicators tell us that, while we have problems that cannot be ignored, economic growth continues and the sky is probably not falling.

Agricultural and forestry research and education depends on, and obviously is impacted by, both state and federal funding reallocations and reductions. The Agricultural and Forestry Experiment Station has suffered funding loss and the elimination of some important land resources programs including the dairy and beef programs, food science, turf and forage grass breeding, selection agricultural engineering, and others. We still have very strong programs in horticulture, agronomy and soils, reclamation and revegetation, forest science, animal science, outdoor recreation, natural resources policy, and natural resources management. In promoting our programs, as well as providing accountability to legislators and the Governor, we have attempted to emphasize the range of research information we produce and its importance to Alaska as a natural resource state.

Most of our customers are familiar with the traditional agricultural research the Station has carried out since early in this century, but some may not be familiar with the diverse range of "other" research we do. The "other" research, highlighted in this issue of *Agroborealis*, is, by definition, agricultural research. However, it is, as Dean Victor Lechtenberg of Purdue University says, "Agriculture with a capital A." Federal funding to land-grant university experiment stations across the country supports initiatives that include: agricultural competitiveness, a safe and secure food and fiber (including forest products) systems, establishing harmony between natural resources use and environmental concerns, and society-ready graduates. This means that research and education programs in such diverse areas as native vegetation for reclamation to restoring spruce beetle impacted forests to using geographical information systems and geographical position systems to inventory Alaska's land resources and many others come under the purview of the Agricultural and Forestry Experiment Station and the School of Agriculture and Land Resources Management.

Agricultural research, whether it's spelled with a capital A or the lower case version, touches the lives of all Alaskans every day. A significant portion of our research in forest science and natural resources management benefits all Americans that have access to and use our national forests and parks and other federal lands. In this regards, we continue to work closely with federal partners in the National Parks Service, the Natural Resources Conservation Service, Forest Service, and other federal agencies that have land resource management responsibilities in Alaska.

We encourage all our stakeholders to read this issue and our Fall 1997 issue which will highlight each of our current projects. Then please take a few minutes to drop us a line and let us know if we are on track or need to change directions to address other problems you may see the state facing. While we cannot do everything, we do need input to assist us in setting our priorities for the 21st Century.

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Agroborealis Contents

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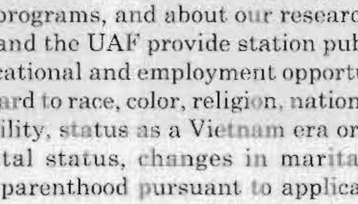


Dendroctonus rufipennis

About the cover

Since 1986 the spruce beetle (*Dendroctonus rufipennis*), the most destructive forest insect in Alaska, has infested nearly 3,000,000 acres of Alaska forest. See page 18 for the complete article.

The cover photo depicts a severly infested area from the Chugach National Forest. Both the cover photo and the beetle photo to the left are by Skeeter Werner.

Accredited: Forest Science Department

Forestry staff: (back row) Dr. John Fox, Jr., *Associate Professor of Land Resources and head of the Department of Forest Sciences;* Dr. Glenn Juday, *Associate Professor of Forest Ecology;* Dr. Dave Verbyla, *Professor of Geographical Information Systems;* Dr. Ed Packee, *Associate Professor of Forest Management;* Mr. Tom Malone, *Forestry Research Assistant;* (front row) Dr. John Yarie, *Associate Professor of Silviculture;* Dr. John Alden, *Affiliate Associate Professor of Forestry;* Dr. Dave Valentine, *Assistant Professor of Forest Soils.*

The School of Agriculture and Land Resources Management's forestry option degree program recently earned accreditation from the Society of American Foresters (SAF). The Department of Forest Sciences administers the forestry program. This degree focuses on the multi–resource management of forests and associated ecosystems preparing students for forestry related employment. Curriculum specializes in forest inventory, protection, utilization and regeneration necessary for rational forest management. The forestry option leads to the first professional degree in forestry, the Bachelor of Science in Natural Resources Management/ Forestry. SAF is approved by the commission on Recognition of Postsecondary Accreditation, and it's successor organization, as the specialized accrediting agency of forestry in the United States.

The SALRM program joins 47 other accredited four–year programs in the U.S. which lead to professional degrees in forestry. It is the only four–year forestry program in Alaska that is accredited by SAF.

"This is a great tribute to the quality of education available at UAF and to our hard working and dedicated faculty, staff, and students," said Dr. John D. Fox, Jr., head of the Department of Forest Sciences. "Our goal is to continue serving Alaskans by producing competent and well–rounded, professional resource managers. Being accredited by SAF tells prospective students and employers that our program met the society's rigorous national standards and provides an external, independent, and objective assessment of our academic program on a regular basis."

Resource managers gather info

by Dr. Dave Verbyla
Professor of Geographic Information Systems

Natural resource managers in Alaska have a unique prob lem. They are asked to manage areas that are remote and huge by "outside" standards. Unfortunately, in Alaska many published map sources are 30 to 50 years old and unlikely to be updated. Fortunately, technologies such as Global Positioning Systems (GPS), Geographic Information Systems (GIS) and Image Processing are providing new tools for landscape–level management and planning. These technologies are making it possible to gather information in a timely manner and allow resource managers to make informed decisions.

SALRM has a modern GIS Teaching Lab that provides students with hands–on experience with these new technologies. In addition, many NRM students are already applying what they have learned through internships with the Division of Forestry, Department of Natural Resources.

SALRM offers four NRM courses in this area: NRM 338 Introduction to GIS, NRM 341 GIS Analysis, NRM 438 GIS Programming, and NRM 641 Remote Sensing Applications in Natural Resources Management. Some courses are taught at night to accommodate working professionals. SALRM also offers workshops in GIS, GPS, and Image Processing every January.

What is GIS (Geographical Information Systems)?

A GIS is a computer system that stores, analyzes, and displays information as layers or themes. Themes can be represented by points (research plots, wells, lightning strikes, campsites, etc.), lines (streams, logging roads, mushing trails, pipelines, etc.), polygons (timber stands, wildfires, crop areas, ownership parcels, etc.), or grids (elevation data, oil spill data, radiation data, etc.).

Each theme is linked to a spreadsheet database that contains non–locational information about the theme. The spreadsheet information can contain numeric values, dates, text, or any other type of information the user has about the theme. Typically the spreadsheet information is entered by keyboard or imported from existing databases when the theme is developed. A theme can contain thousands of points, lines, polygons, or grid cells and the associated attribute tahle may have hundreds of columns of information.

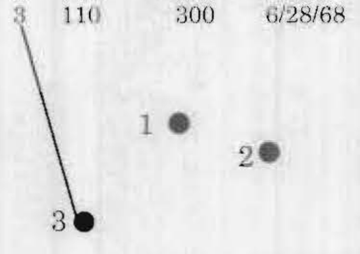
The GIS allows resource managers to ask spatial questions such as: Where are all the sawtimber spruce stands on slopes of less than 15 % within a mile of a road or river that are over 40 acres in area? Is there a

Attributes are defined in a spreadsheet and labeled on the map using an ID number.

Point Attributes

well theme (points)

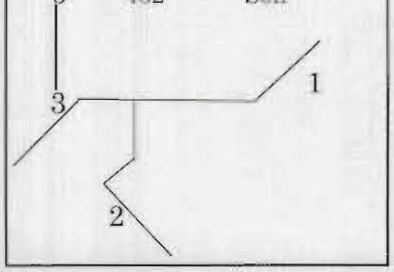
ID	Depth Drilled	GPM	Date
1	250	330	7/15/83
2	330	290	8/2/89
3	110	300	6/28/68



Line Attributes

road theme (lines)

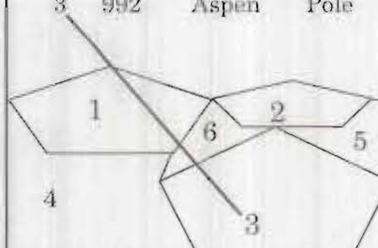
ID	Length	Surface
1	1,239	Paved
2	986	Gravel
3	432	Soil



Polygon Attributes

forest theme (polygons)

ID	Area	Type	Size
1	505	Spruce	Saw
2	512	Spruce	Pole
3	992	Aspen	Pole



Attributes from a spreadsheet can be used to create a grid like the one below depicting the spread of an oil spill over a period of time.

Oil Spill Grid

4	4	4	4		
4	4	4	4	4	
4	4	4	4	4	4
4	4	4	4	4	4
4	4	4	4	4	4
	4	4	4	4	4
	3	3	3	4	4
	3	3	3	4	4
	3	3	3	4	
	2	2	3	4	
	1	2	3	4	

Grid Attributes

Day	Area	Spread
1	100	0
2	300	200
3	1200	800
4	3300	2100

relationship between bark beetle infestations and stand age, elevation and slope direction? Where is the nearest gravel deposit that is within 100 meters of a road system? Where are suitable sites for locating a landfill given environmental constraints? If there is a fire at this location, what is the best route to get to the fire along a road network?

What is GPS (Global Positioning Systems)?

GPS is a constellation of NAVSTAR satellites that transmit precise timing signals to computerized GPS receivers. By receiving the timing signal from at least four satellites and calculating where the signals meet, a GPS receiver can estimate your location anywhere on the globe. Surveyors use special GPS techniques to estimate locations within an inch accuracy! GPS is used in many resource management applications such as precision agriculture, navigation in remote areas, mapping of new mines or logging roads, wildlife telemetry, and locating permanent inventory plots. At SALRM, students taking the Introduction to GIS course get hands–on experience using GPS at the Bonanza Creek Experimental Forest.

What is Image Processing?

Image Processing uses computer–based tools to improve the information that you can derive from digital images. In NRM 341, students learn image processing tools to inventory clearcut harvest units from scanned aerial photographs and for vegetation mapping in Alaska. In NRM 438, students develop a program for creating 3–D perspective views of Alaska from a grid of elevation values.

See if you can correctly match the following images: A) Seward Peninsula viewed from the west. B) Denali National Park viewed from the south. C) Juneau viewed from the south east.

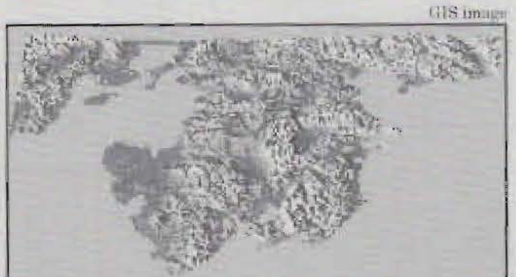
GIS image

1 ←

2 →

GIS image

3 →



GIS image

For answers see page 18

Using GIS to solve problems for Alaska

Natural Resource Management students are using the geographical information system to help State of Alaska resource management agencies. While learning what GIS is and how to use it, students are completing internships, senior thesis, master and Ph.D. projects that are applicable to Alaska. These students contact agencies like the Bureau of Land Management and Alaska State Parks Service to learn about projects that require GIS work. Occasionally students will receive funding from these agencies to complete their projects. Some of our students have also been hired by these agencies after graduation.

Student maps commercial spruce stands

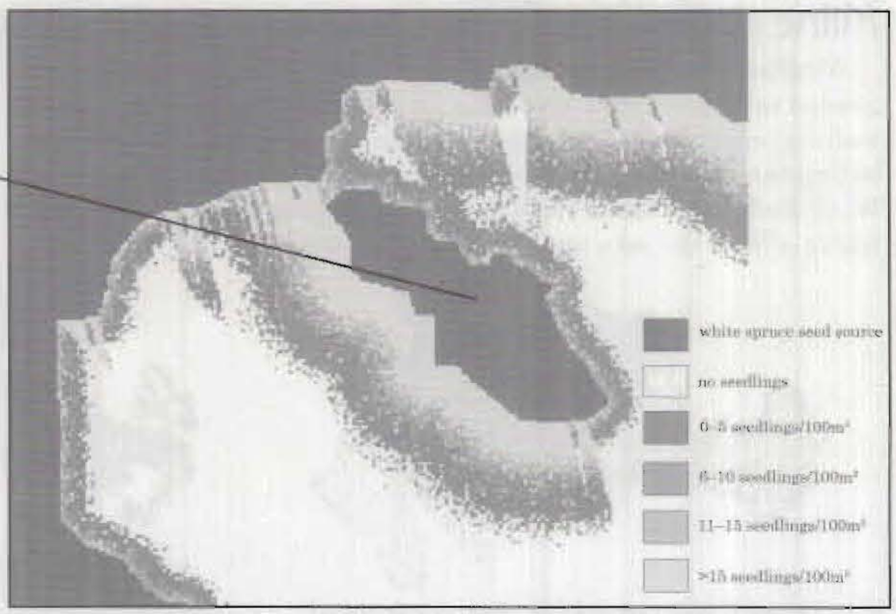
As part of his masters thesis, **Tim Hammond** analyzed the potential for using satellite data to map forest types within the Tanana Valley State Forest. Hammond found that although it was virtually impossible to separate aspen versus birch stands from satellite data, the data have potential for separating commercial versus noncommercial spruce sawlog stands. Such information is valuable for planning potential harvest units across the landscape.

Test area within the Tanana Valley State Forest (GIS image).

Rupp produces computer models of spruce regeneration

A good spruce seed year is relatively rare. Even when a good seed year does occur, conditions must be optimal for good seedling establishment. As part of his Ph.D. research on white spruce, **Scott Rupp** is using a GIS to develop a model for understanding and predicting factors that control spruce seedling establishment across the landscape.

Aerial photo of Rosie Creek burn.

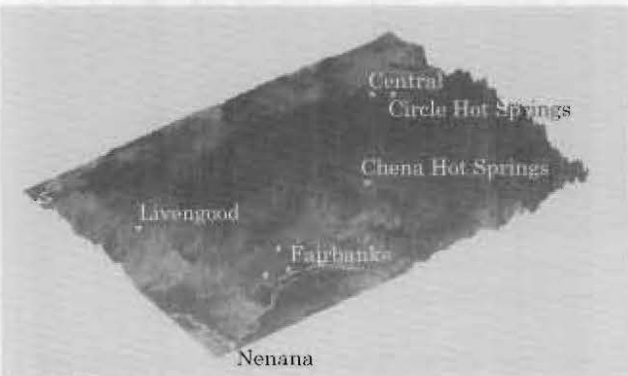


White spruce spruce seedling establishment pattern for the 1987 cohort at Bonanza Creek Experimental Forest (GIS image).

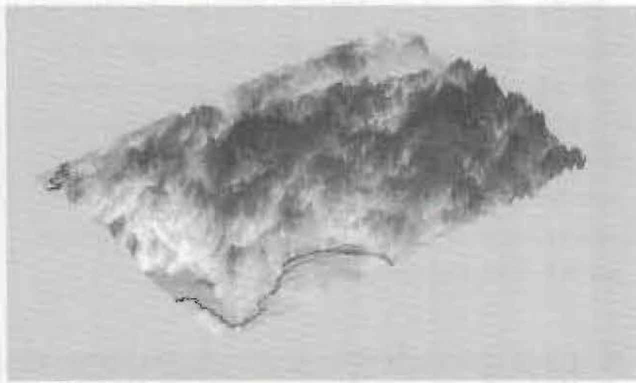
Student maps the growing seasons for Alaska

In Alaska, the growing season for plants is very important. Caribou movements are related to spring greenup across the landscape. Timber production is related to growing season length. With global climate change, the transition from forest to tundra will be related to growing season length. In the past, estimating growing season across the landscape has been almost impossible because there are relatively few weather stations in Alaska and they are located mainly along river floodplains or along the coast. Instead of using weather station data, **Heather Goldman** is using daily satellite data received at UAF for her M.S. thesis research to estimate the growing season for all of arctic and subarctic Alaska. The data will be obtained from AVHRR (Advanced Very High Resolution Radiometer) on board NOAA satellites. For each one kilometer grid cell, Goldman will estimate the growing season as the period from spring greenup to fall senescence. She will use data from weather stations and other satellites to validate her estimates.

Goldman is an awardee in the 1997 Center for Global Change student research grant competition. She received $3,520 which will be her graduate stipend for the summer months. In the fall, Goldman will continue working on her project with a stipend awarded to Dr. Verbyla from the UAF Natural Resources Fund.



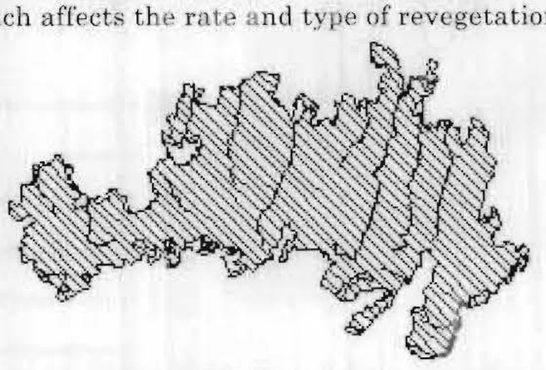
This image depicts early May landscape greenness derived from the weather satellite data. The darker color means less green. The only light colors present are along the Tanana River floodplain. (GIS image)



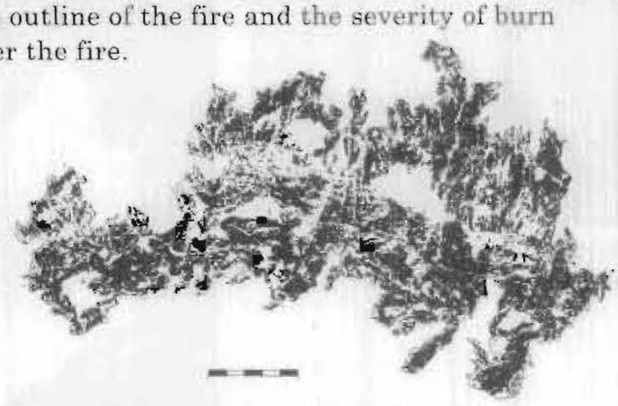
Late May landscape greenness derived from the weather satellite data is shown in this image. Notice the only dark areas left are in the higher elevations of the White Mountains. (GIS image)

Milne compares GPS maps with satellite images of wildfire burns

Wildfire is a dominant disturbance factor in the subarctic landscape. A cost–effective method is needed to map wildfire areas and to inventory burn severity classes. **Dave Milne** is comparing two techniques for inventory of large burns as his senior thesis project. Milne is comparing GPS–based helicopter mapping with image processing of satellite imagery for mapping a large wildfire within Wood Buffalo National Park. Milne is mapping the outline of the fire and the severity of burn which affects the rate and type of revegetation after the fire.



This image is a wildfire burn that was mapped using GPS information gathered while flying over the burned area in a helicopter.



This classified satellite image shows the same wildfire burn. (GIS image)

Computers help inventory caribou habitat

In the White Mountains between Fairbanks and the Yukon River, lichen growing in open spruce stands are an important caribou winter habitat. As an NRM Senior Thesis Project, **Chris Janak**, in cooperation with the Bureau of Land Management, is attempting to develop a computer–based method for efficiently mapping this critical habitat over millions of acres. Janak is using image processing techniques with satellite imagery to develop this method on a test area near Eagle Summit.

This is a satellite image from near Eagle Summit. The Birch Creek drainage is included in this area. (GIS image)

This classified image shows important spruce–lichen stands that may be critical winter caribou habitat. (GIS image)

Satellite images may help detect wildfires

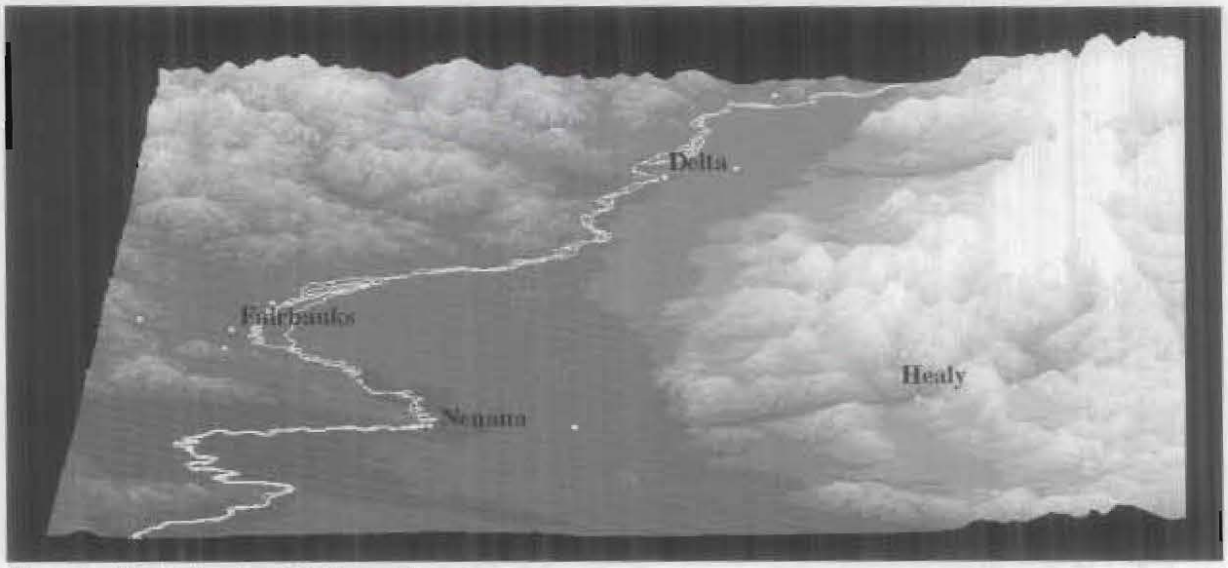
In a typical year, there are hundreds of wildfires burning in Alaska. Many of these fires occur in remote locations and are not reported for days. As part of his M.S. thesis research, **Steve Boles** is developing a method to detect wildfires using updated satellite images received daily at the University.

Satellite image from August 1996.

The same image with active wildfires highlighted in white. (GIS image)

Combining satellites images and radar can map wetlands

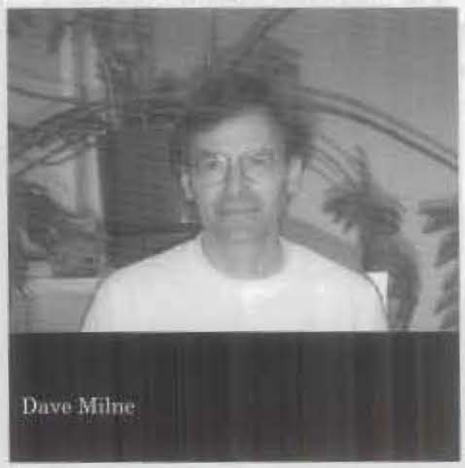
UAF receives radar images every day. Radar is great because it can see through clouds and map ice, snow, glaciers and open water. However, can radar be used for mapping wetland vegetation types? **Andrew Balser** completed his M.S. research by comparing radar versus optical satellite data for mapping wetlands. He found that radar was not as accurate as optical satellite data, but it did improve accuracy when he combined radar with optical satellite data. Balser's study focused on the Tanana Flats region southwest of Fairbanks.



Tanana Flats Basin (GIS image).

Featured students involved with GIS projects include:

T. Scott Rupp



Dave Milne

Chris Janak

Steve Boles

25 years in perspective

Arctic tundra revegetation

by Jay D. McKendrick, Ph. D.
Professor of Agronomy

Why study tundra revegetation in the Arctic for the long–term? The obvious answer is because it relates to Alaska's economic well–being. We must know that we can repair and restore tundra damaged or destroyed during exploration for and production of oil. Without this knowledge, Alaska's oil future is in jeopardy.

Opposition to developing oil, gas, coal, and other mineral resources in any region is strong. The opposition is especially intense for the tundra wetlands of Alaska's North Slope. The arguments against development focus on perceptions that if tundra vegetation is either damaged or destroyed, it cannot return and there would be irretrievable losses of wildlife habitat. After studying tundra revegetation and recovery for more than a quarter century, I am convinced that such fears are unwarranted. I do realize, though, that without proof, it is difficult to allay the concerns of those who have not witnessed tundra recovery from a natural annihilation, an oil spill, or complete removal by bulldozing. Acquiring the proof requires time. It cannot be simulated in a laboratory or hurried in the field.

There is more to answering the question of 'why' than assuaging the worries of those opposed to resource development. The purpose of tundra revegetation has evolved over the past 25 years. As the objectives changed, the field practices changed accordingly. With solving each new problem, our understanding of the tundra ecosystem has increased.

Because the Agricultural & Forestry Experiment Station is a research organization mandated to solving problems associated with developing and using land resources in Alaska, it was well within our stewardship to address this issue involving soils and plants. In 1972 we began a three–year contract with the oil industry to research tundra revegetation. Over time, it evolved into a long–term research project with support from multiple sources.

The original objective was to protect tundra soils from eroding. Dr. Wm. W. Mitchell sought suitable plant species while I addressed soil problems. During the initial phase, Dr. Mitchell identified three grass species ('Alyeska' polargrass, 'Tundra' glaucous bluegrass, and 'Arctared' red fescue) which were indigenous to Alaska, adapted to the Arctic, and could be grown commercially for seed on farms outside the Arctic. We discovered that phosphorus–followed by potassium and nitrogen–was the most limiting soil nutrient. Seeding these grasses and fertilizing to assure rapid seedling establishment was, and still is, possibly the best means to protect against soil erosion on well–drained to intermediately drained habitats.

Among many other unknowns when we began studying tundra revegetation were the kinds of damages and disturbances that would occur with oil and gas production in this region. We could only speculate based on evidence from exploration sites. The industry has modified exploration and production technology to avoid and/or minimize impacts. Consequently the anticipated need for revegetating large areas of tundra damaged by bulldozing, major oil spills, or other significant damage has not occurred in Alaska. Soil erosion has proven an insignificant risk except in natural sand deposits of the Sagavanirktok River Delta. Hence, revegetation challenges have mostly been areas with saline soil, gravel fill, and impounded water.

As it became apparent that tundra revegetation was possible and soil erosion was not a major risk, restoring wildlife habitat took prominence. Whether or not climax tundra is the most productive habit for wildlife, currently it is the most likely choice. Therefore, it has become increasingly important to direct tundra revegetation toward restoring the natural complex of plant species.

Establishing dense stands of the recommended grasses and heavy applications of phosphorus and potassium fertilizers slow the return of natural tundra. Grasses established 25 years ago in plots well fertilized are still flourishing. There is little evidence that they might soon relinquish their territories to the natural diversity of plants that would ordinarily occupy such sites. Furthermore, where seeded grasses initially failed to establish in unfertilized plots, now there is a natural complex of tundra plants, resembling the adjacent undisturbed tundra. This is exactly opposite of what we expected after completing the initial 3-year project.

Over the years, Agricultural & Forestry Experiment Station researchers continued responding to requests from either the industry or the industry combined with a government agency to research the various vegetation and soil problems arising from oil exploration and production in Alaska's Arctic. Many of these problems would not have been chosen for research if industry had not targeted them for us, even if funding had been available from some other source. Equally important is the fact that these problems have revealed interesting and useful information that might have remained undiscovered without the industry–directed focus.

Each research and consulting project that has taken us to the Arctic has extended our observing and data collecting on the original research test plots, yielding an insightful record through time. We observed the tundra's unassisted natural change and vegetative recovery on rehabilitation sites. The discoveries in this applied research have been gratifying and useful,

One consistent fact has been the importance of retaining soil to promote and improve revegetation projects. If a suitable soil exists on a disturbed site, seeded or naturally invading vegetation will invariably become established. If the soil surface has been deformed due to blading or vehicular traffic, the site should be tilled and reshaped to match the natural contour, even if it means killing remaining vegetation. This practice will eventually yield a more aesthetically pleasing landscape than if timidity reins and the soil is left rutted and rough. If soil is absent, such as on gravel fill sites, then the recovery process becomes lengthy. Adding even small quantities of silt loam and organic matter to the surface of gravel fill is effective in accelerating plant establishment.

Observing the natural recovery of tundra plant species reveals the process as protracted and, in so being, assures maximum species diversity on these sites. We learned from observing drained lake basins. These habitats consist of sediments eroded from the margins of the lake by wind–driven waves before the lake drained. As the mixture of mineral and organic matter was carried throughout the basin and deposited, a smooth surface formed. After the lake drained, various plants begin establishing on the barren soil. These species are usually members of the climax tundra adjacent to the lake. Since seed production is inconsistent from year to year in the Arctic, depending on suitable weather (warmer than normal temperatures during the growing season favor seed production), the initial stand consists of widely scattered seedlings. These dispersed individuals expand their territories over time, gradually increasing the plant cover in the basin. New seedlings establish over the years as more seed is carried to the site. Vagaries in weather among years favor some species one year and other species other years. Since colonization extends over several decades, there is ample opportunity for all species to invade the basin. Furthermore, even though the young seedlings are succulent and very palatable to grazers (geese and caribou), they escape heavy grazing because they are dispersed. The slow recolonization approach seems to be ideal in this environment.

Establishing thick stands of certain grass species quickly on barren sites is opposite to the way nature encourages plant species diversity in tundra communities. Where dense stands of aggressive grasses have established, there is little space for other plants to invade. If we create dense populations of tender new grass shoots, these attract grazers which stress the stands by removing leaves and trampling seedlings. However, we have established dense stands of *Puccinellia arctica* seedlings and they have not delayed re–invasion by indigenous plants nor attracted grazers. We conclude this grass is either a weak competitor, short–lived, and/or unpalatable to grazers.

Puccinellia langeana, a close relative of *P. arctica*, also occurs in the region and often colonizes various disturbed habitats in arctic oil fields. Recently, we have included *P. langeana* in experiments on salt–damages soil and are testing it in actual applications. It is too soon to judge if this species will be a desirable revegetation grass. Unlike *P. arctica*, *P. langeana* is palatable to grazers and tests growing *P. langeana* outside the Arctic to produce seed have been disappointing. In contrast, *P. arctica*, grows well in seed production fields in the Matanuska Valley.

Since establishing a dense stand of grass does not encourage return of the natural tundra, we have re–examined the question of seed application and the species of grass seeded. Specifications for revegetation have crept upwards over the years for reasons unknown. Currently, some specifications require 1,450 live seed per square foot (45 lb/a). This is a quantity recommended to rapidly establish turf but it is inappropriate for wildland revegetation. We tested applications of 25, 50, and 100 seed per square foot for *P. langeana* and found after three growing seasons in a salt–damaged soil the canopy cover was 27, 45, and 75% , respectively. These applications translate to 0.5, 1.2 and 2.4 pounds per acre. The resulting stands are open and receptive to invasion of other plant species.

For several years, we measured the quantity of seed that seasonal employees could gather from natural stands of *P. langeana* in the Prudhoe Bay Oil Field. We determined that a crew of four people could collect enough seed in two days to apply one pound of seed per acre to 12 acres of land. That suggests it is economically and biologically feasible to hand harvest *P. langeana* (if tests show that species is usable) for practical revegetation projects in the Alaska Arctic. *P. langeana* is also well–suited to survive on gravel fill and dry, dust fall–out areas along roads in this region. Since there is relatively little demand for revegetation, and the risk of soil erosion is low, this approach of hand–collecting seed in the Arctic is one alternative for tundra revegetation.

It is important for the industry and agencies to recognize that establishing a dense cover of grass (usually 60%) within three years is not necessary, as long soil erosion risk is low. By doing so, the long–term consequences are very likely an undesirable vegetation diversity, texture, color, and plant height. Instead, revegetation success should rely on criteria that indicate a strong positive trend toward a functional tundra climax forming. Among the possible indicators are: 1) natural plant species seedling establishing 2) increasing numbers of plant species colonizing, 3) strong vigor and reproduction (sexual and vegetative) of established plants, 4) accumulating standing dead in approximately three to four growing seasons, 5) accumulating biological litter on the soil surface after three to four growing seasons, and 6) initiating a moss layer at the soil surface.

All too often, the focus for rating revegetation throughout Alaska has been on vascular plants. But this should not be, if the habitat conditions dictate formation of a histic (thick surface organic layer) soil horizon. Histic horizons in the Arctic contain high amounts of organic matter, and consist mostly of moss tissues, which inherently decompose slowly. A revegetation monitoring procedure for arctic tundra should recognize and value moss cover. As we learn more about moss species and their respective roles in tundra plant succession, the species of mosses present on a site can probably be used to gauge the recovery progress.

The national emphasis is currently to protect and restore wetlands. This emphasis has found its way to Alaska through federal mandates. However, if there is genuine concern for protecting and rehabilitating susceptible environments in the Arctic, the efforts should focus on dry habitats. It is the dry sites which are most susceptible to long–term damages from spills and the most difficult to revegetate. Plant recolonization of barren sites is consistently completed most quickly in wet habitats. It may require more than twice as long on medium and dry habitats. Effects from an oil spill in a saturated sedge meadow in 1985 disappeared entirely within 10 years. In contrast, applying one cm of crude oil to a drained, *Dryas*–dominated habitat has prevented recovery of plant life for more than the 20 years. Wet borrow pits created when the first roads were built in the Prudhoe Bay Oil Field were recolonized within 15–20 years while dry, sandy, naturally drained lake basins in the NPR–A (the National Petroleum Reserve in Alaska) have remained barren for more than 40 years, and show little sign that recovery will ever occur.

During the 25 year period of these observations, personnel turnover has been a significant factor. At this time, only two from the group involved in the original tundra revegetation project are still employed at the University of Alaska, Peter C. Scorup and myself. All of the original industry and agency people have either retired or been transferred to other assignments. Some have passed away. As I contemplated my eventual retirement from the University's Agricultural & Forestry Experiment Station, I realized that if it were possible to extend the monitoring of our experiments for another quarter century and beyond, perhaps even more discoveries of how to restore tundra habitat would result. This prompted a USDA–University of Alaska–sponsored project to permanently stake plot corners, photopoints, etc. in the field and record their locations using Global Positioning Satellite (GPS) technology. This information, including documenting what was done in these various tests as well as photo records, should prove valuable for a long–term perspective. The documentation and location project includes exploration sites in the NPR–A (U.S. Government exploration), research tests at Prudhoe Bay, and wherever possible, industry exploration sites across the North Slope.

Acknowledging the help of many

Monitoring tundra recovery since 1972 has been possible only because those of us involved were employed at the Agricultural and Forestry Experiment Station. Industry, government, and private consulting firms are in no position to undertake such a task. Indeed, current university promotion and tenure criteria make it difficult, owing to the need for faculty to gain 'international recognition' within a set time frame in order to be retained and promoted. The tundra vegetation changes too slowly for that. We have been able to accomplish this through a combination of short–term contract research projects, consulting contracts, and continued funding by the State of Alaska Legislature for organized research at UAF in combination with matching federal formula funding (USDA Cooperative State Research, Education, and Extension Service). In some instances university research and private consulting firms compete for the same dollars. Because of its long–term nature and the uncertainty of outcome, this is the high–risk type of research that is best done by a Land–Grant university. It is important for those in responsible leadership positions at a Land–Grant university to direct and encourage research that serves the high–priority needs of the various states. Clearly, in Alaska, the need to support resource development, in particular oil and gas, should be a high priority for this Land–Grant University.

It is impossible to recall everyone that was involved with our tundra revegetation projects over the years, but the following is an attempt to recognize the organizations and people who contributed. For those omitted, please realize it was unintentional.

Industry

Alyeska Pipeline Service Co.	ARCO Alaska, Inc.	BP Exploration (Alaska), Inc.
Conoco, Inc.	Husky Oil NPRA Operations, Inc.	LGL Alaska, Inc.
PSA, Inc.		

Agencies

Bureau of Land Management	U.S. Army Corps of Engineers	USDA Cooperative State Research Education and Extension Service
U.S. Fish and Wildlife Service	U.S. Geological Survey	
The National Science Foundation		

AFES employees

Peg Banks	Milton Barzee (deceased)	Dave Charon	Eric Fiscus
Warren E. Fiscus	Bill Folkstad	DariGene Hann	Janice Hill
Nancy Hull	Kenneth K. Klunder	Shane Lamb	Thomas Loynachan
Allen K. Mansfield	Patrick V. Maye	G.A. Mitchell	Wm. W. Mitchell
Julia K. Moor	Palmer laboratory technicians	Pete Scorup	Gwendo–Lynn Turner
Anna Vascott	Jeffry Werner	Frank Wooding (deceased)	

Consulting firm and Industry personnel

Tom Barnes	Deb Beaubien	Anne Brown	Chris Brown
Tess Carr	Bryan F. Collver	JoAnn Day	Linda Perry Dwight
Bob Elder	Harold Engle	Tom Fink	Frank Fisher
Mark Fraker	Bradley Gerkin	Michelle Gilders	Neil Hermon
Rod Hoffman	Shelly Jones	Mike Joyce	Katie Kennedy
Jill Knapp	Carol Klein	Sean Leonard	Kirk Loman
Steve Lombard	David Lowe	Shannon McDade	Scott McKendrick
Steve McKendrick	Daniel McKendrick	David McKendrick	Rory Mayra
Jennifer Parnell	Jay Poss	Brent Rock	Conee Rock
Bob Rodregues	Scott Ronzio	Robin Sener	Diane Shaw
Phillip D.J. Smith	John Sweet	Steve Taylor	Joe Touchstone
Declan Troy	Joe C. Truett		

Agency employees

Max Brewer	David Densmore	Lloyd Fanter	Don Meares
Pam Miller	Barbara A. Reiley	John Schindler	Jerald Stroebele

Other individuals

Steve Archer	Neil Dennis	Jerran T. Flinders	Maynard Fosberg
Judy Scorup	Lee A. Sharp (deceased)	John Swanson	

Remote satellite spectral analysis in Bosnia i Hercegovina

by Dara Fell, NRM M.S. candidate
Harry Bader, Associate Professor of Natural Resources Law

In 1995, the School of Agriculture and Land Resources Management began an intensive natural resource inventory and damage assessment in Bosnia prior to the NATO/United States troop deployment. The project was initiated at the request of the United Nations and funded by grants from the Soros and Banyan Foundations. In 1996, project support was assumed by the NATO/IFOR (implementation force) Command in Bosnia.

Bosnia is one of the former Yugoslavian states which, along with Croatia, Slovenia, and Macedonia seceded from the federation in the early 1990s. Soon after declaring independence in 1992, civil war broke out in Bosnia i Hercegovina. After years of fighting, ethnic cleansing and establishing many mini-states and ethnic governments, a single government took power after nationwide and local elections were held as negotiated during the Peace Accords in Dayton, Ohio.

The University of Alaska Fairbanks project, carried out by the School of Agriculture and Land Resources Management, is designed to help implement the Dayton Accords. To do this researchers will provide information critical to the repatriation of refugees, economic reconstruction, and prosecution of war criminals.

Project goals include a comprehensive and detailed assessment of forest stand volume, health, availability and damage; infrastructure damage; watershed assessment; and agricultural lands identification using Landsat satellite spectral data. During the project we will also analyze spatial and temporal patterns of village destruction for possible use in prosecuting war crimes by the International Criminal Tribunal for the former Yugoslavia in The Hague, Netherlands.

This information will contribute to international decisions concerning (1) the repatriation and settlement of refugees in an economically viable and environmentally sustainable manner, (2) establishing priorities for reconstruction aid, (3) environmental reclamation, and (4) evidence in legal proceedings.

The focus is on timber resources due to the singular importance this resource has in the future of Bosnia. Softwoods are milled into lumber to be used in rebuilding destroyed communities. Hardwoods are used as both the primary source of energy in rural areas and for generating hard currency as exports to Germany, Austria, Slovenia, and Croatia.

Timber information, combined with data about infrastructure damage to roads, bridges, dams, homes, and industrial facilities, will be used to target those areas in this war-scarred nation that can best support the return of almost 2 million displaced people. The information will also be used to target the most cost effective areas for international aid investment, such as de-mining activity to restore agricultural and range land.

A SALRM team deployed to Bosnia in October 1995 and surveyed 5,000 kilometers (3,107 miles) of Muslim and Croat areas, taking 199 reference points to be used in classifying ground cover types. To accomplish this task, the team used a United Nations Protection Forces (UNPROFOR) military armored Land Rover with an attached GPS unit.

During September 1996, the team returned to Bosnia and completed a validation survey by sampling 104 sites in Serb-controlled territory. The 1996 survey was made possible because of NATO escorts and support services donated by the United States.

A number of Landsat images for the years 1989, 1992, 1993, 1994, and 1996 will be used. These spectral scenes will be corrected for the curvature of the Earth and the elliptical orbit of the satellite. Data will be radiometrically rectified. Surface change to villages, fields, forests, and roads will be detected using image ratioing, regression analysis, and vector change techniques.

Our preliminary results indicate massive deforestation throughout the nation. We expect this will jeopardize watershed stability, agricultural productivity, energy production, and result in lost economic potential. Most deforestation is limited to tracts less than 900 hectares (2,224 acres), and is strongly correlated to battlefront lines and villages suffering from ethnic cleansing.

We will submit three separate reports to the international community. First, a report identifying optimum areas for refugee settlement will be delivered to the United Nations High Commission for Refugees. A second report will be submitted to the Bildt Commission of the European Community and targets economic aid priorities. The third report will be given to war crimes prosecutors in The Hague to use in identifying patterns of village destruction indicative of genocide rather than tactical or strategic operations.

Due to a series of refugee crises in central Africa and in northern Kurdistan, support from the U.S. Department of Defense–Program for Humanitarian Assistance was indefinitely delayed. Project progress is temporarily halted because these funds were critical for completing the assessment. SALRM has initiated a foundation search for the final $179,000 necessary to complete all phases of the project. Upon receipt of those funds, we estimate the project will be finished within 180 days.

Assessing Bosnia forest damage using remote satellite sensing

by Dara Fell, NRM M.S. candidate

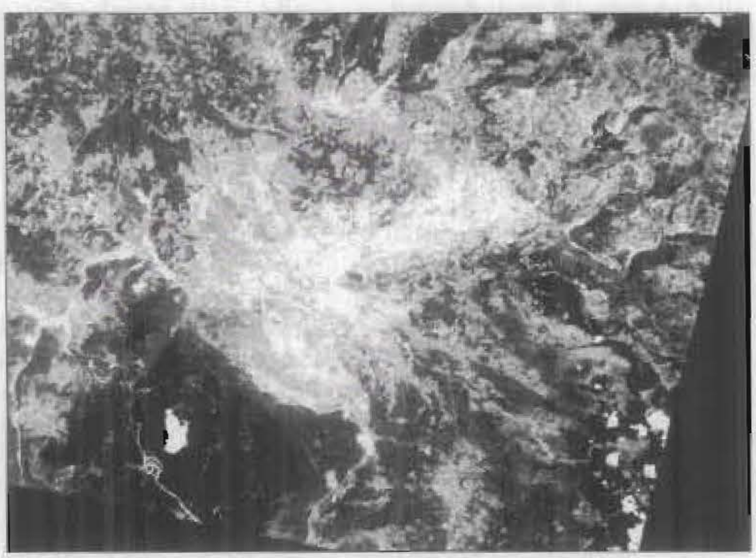
The Department of Forest Sciences, with the support of Soros Foundation, Banyan Foundation, NATO, and the United States Protection Forces (UNPROFOR), initiated an intensive forest damage assessment of Bosnia to provide information for the economic reconstruction. This project is part of a larger endeavor designed to assist efforts in repatriating refugees, establishing priorities for reconstruction aid, reclaiming the environment and prosecuting war criminals.

The objectives of the deforestation assessment are to identify the distribution and size of localized deforestation in Bosnia and to identify remaining stands of commercial timber that could be used in post conflict reconstruction activity.

The deforestation assessment project was undertaken to fulfill obligations for the successful completion of my masters of science degree in resources management. My committee, chaired by Dr. Dave Verbyla, represented the disciplines of remote sensing, forestry, geography and international policy.

The first phase of this project was to identify areas of deforestation. To accomplish this task, satellite images of Bosnia were obtained and corrected for distortion and color. Sample polygons were created using ground based photography, and cover classes were generated. Two satellite images were selected representing distinct dates. Image selection was based on a variety of criteria, including but not limited to: cloud cover, haze intensity, and time of year. Finally, images from July 15, 1987 and July 18, 1994 were chosen.

These images were corrected both for the curvature of the Earth and the elliptical orbit of the satellite. This process involved using of 100 control points, roads, bridges, rivers, and airstrips, selected from NATO aerial strike maps and easily locatable on the red band of the image. Then the color was corrected, inherent variations in spectral band quality due to sensor calibrations and atmospheric conditions must be corrected



This is a satellite image of Sarajevo, Bosnia from prewar 1987. White areas are urban deforested land in and around the city. (GIS image)

Answers from page 8. A=3, B=1, C=2

through color rectification. To rectify the color, spectral value extremes were found and matched for both images.

All 30 million pixels found in an image must be correlated to a land cover classification. This is accomplished using sample polygons derived from ground truthing photographs taken by a SALRM team in 1995 and 1996. Over 300 points were created on the ground within homogenous cover groups, photographed, described, and exact locations recorded by GPS equipment.

From this information, we created six cover classes were created. These classes are: coniferous forest, deciduous forest, water, vegetated agriculture, nonvegetated agriculture, and urban. After completing image classification, a comparison between the two images was made to determine the extent and nature of deforestation.

The distribution and size of deforested areas corresponds to the location of villages and front line conflict areas. Large contiguous blocks were rather rare. Indeed, only six areas of greater than 1000 hectares (2471 acres) each were found, representing only 2.8% of deforested lands. Blocks of deforestation ranging in area between 500 and 999 hectares (1,235.5 and 2,468.5 acres) accounted for 3.9% of total deforestation. Deforested blocks ranging in size from 1 to 499 hectares (2.471 to 1,233 acres) covered 17,000 hectares (42,007 acres) for 21% of total deforested lands. Blocks involving less than 1 hectare 2.471 acres) accounted for 59,300 hectares (146,530 acres) or 72% of the total.

The wide distribution, and relative small size of deforested plots represents a series of management problems. Damaged trees represent a source for disease infestation. Indeed, studies have shown that war–related damage in forested areas representing just 5 % of total forest cover, resulted in the spread of disease that eventually killed 20 % of all trees. Thus, reclamation efforts to restore forest health are an utmost priority, due to the singular importance of timber for providing energy, construction material, and hard currency exports.

This is the satellite image of Sarajevo in 1994. Notice the image appears lighter overall and the areas of deforested white are larger. (GIS image)

GIS Winner

Graduate student, **Dara Fell**, recently won first place in a Geographic Information Systems project contest. The contest was sponsored by the Alaska ARC/INFO users group and the Environmental Systems Research Institute. Fells project was entitled, Assessing Deforestation in Bosnia, Using Remote Sensing and GIS. She received her awards, $700 and a free software license at an awards ceremony February 14 in Anchorage.

Project contestants were required to complete a GIS project using a form of spatial analysis, such as map displays and calculations, to resolve a problem or answer a research question. The contest was open to all full–time Alaskan students studying GIS. Judges considered originality, layout and design, use of analytical tools, practicality and usefulness, and ability to solve the stated problem.

The contest was held in conjunction with the 32nd Alaska Surveying and Mapping Conference highlighting high latitude technology.

Restoring spruce beetle–impacted forests in Alaska

by Edmond C. Packee, Ph. D., Certified Forester, Certified Professional Soil Scientist

Since 1986 the spruce beetle (*Dendroctonus rufipennis*), the most destructive forest insect in Alaska, has infested nearly 3,000,000 acres of Alaska forests. Figure 1 shows the beetle–infested number of acres in a given year. Within a stand, spruce mortality, exclusive of seedlings and saplings, can exceed 95 percent. Major infestations cover tens of thousands of adjoining acres of white spruce (*Picea glauca*) or the hybrid (*Picea* X *lutzii*) on the west side of Cook Inlet, Kalgin Island, the Kenai Peninsula, the Anchorage Bowl, the Matanuska River Valley, and the lower Copper River drainage (north of the Chugach Range). Smaller outbreaks involving Sitka spruce (*Picea sitchensis*) are found in Southeast Alaska: Glacier Bay National Park, Admiralty Island, Haines, Skagway, Taku Inlet, Stikine River, and Dall Island.

The three spruce species are a common thread connecting Alaska's forests: white and black spruce primarily of the non–coastal forest and Sitka spruce of the coastal forest. Where ranges overlap, especially on the Kenai Peninsula and around Cook Inlet, white spruce and Sitka spruce hybridize. The hybrid, called Lutz spruce, is not a separate species. Although white and black spruce ranges overlap and the two are commonly found in the same forest stand, they rarely, if ever, hybridize. Black and Sitka spruce do not hybridize.

The spruce beetle, a killer of spruce trees, is a North American beetle that is at home in any forest containing any spruce species. The beetle is found from the Atlantic Ocean to the Bering Sea and from the far north to the southern Rockies. Spruce beetle outbreaks have occurred in Newfoundland, the Canadian Maritime provinces, Maine, Colorado, Wyoming, Montana, Alberta, British Columbia, the Yukon Territory, and Alaska.

The spruce beetle is endemic in spruce forests. It has been present in Alaska for centuries. White spruce is thought to be least resistant to the beetle, black spruce most resistant with Sitka spruce being intermediate. Susceptibility of Lutz spruce equals that of white spruce. The beetle is usually present in small numbers. Typically, its attacks are so light that trees survive; however, it does kill an occasional tree or stand. Woodpeckers, especially the northern three–toed woodpecker (*Picoides tridactylus*), largely keep the beetle in check.

The spruce beetle, a bark beetle, mines through the cambium under the bark of the tree. The cambium contains the tree's conducting tissues. Beetle galleries block moisture and nutrient flow between roots and the tree's top. Larvae do not mine into the wood.

No worldwide record exists of a spruce beetle epidemic as large as that currently in Alaska. Other bark beetles (*Dendroctonus* spp.) attack other conifers. Although these other infestations may be widespread, the impact is usually less severe because other conifer species occur in the stands or nearby. Only in non–coastal Alaska and the western Yukon forests are spruce nearly the sole conifer tree species. Elsewhere, more conifer species, greater topographic variability and associated environmental conditions, different disturbance regimes, and more intense silviculture (human intervention) make conifer forests more resilient.

What causes an endemic population of spruce beetles to explode and reach epidemic proportions? British Columbian expert Hodgkinson[1] lists four primary factors leading to spruce beetle outbreaks:

- Favorable Habitat: shaded, fresh spruce windthrow, large diameter slash, abandoned logs;
- Favorable Weather: heavy early snow, no unusual "cold snaps" before December, mild sunny springs;
- Spruce Under Stress: tomentosus root disease, mechanical damage to or breakage of the bole;
- Overmature Spruce Forests: more than 141 years old.

The first two result in more beetles; the latter two lower the spruce tree's resistance. If beetle numbers increase and host trees are susceptible, an outbreak will occur. These factors exist in Alaska today. Lack of tree species diversity further increases stand susceptibility.

Despite the presence of these factors, managers and others appear to embrace too quickly single factors over which they have no control when explaining Alaska's devastating epidemic. Using limited Fairbanks data, climatic warming was speculated to be the cause of the Kenai Peninsula outbreak; this, despite major regional climatic differences between Fairbanks and the more maritime Kenai Peninsula. No valid correlation exists; no cause and effect relationship has been demonstrated. Despite lack of scientific evidence, a March 1997 Alaska Division of Forestry memorandum states "Current science suggests climatic warming could be a major cause of the beetle's spread. If warm summers continue, beetle populations will be high."[2] Later in the same paragraph is the statement, "...where climatic conditions are favorable and contiguous mature spruce forests exist, outbreaks will strike periodically."

Hodgkinson[1] reviewed early efforts[3] that ranked central Rocky Mountain Engelmann spruce (*Picea engelmannii*) stands' susceptibility to the beetle. Then, using British Columbia data and experience, he developed a science–based stand hazard rating system for white spruce using five variables and sets of values for each:

Stand Hazard = (Ecologic Zone + Site Quality + % Spruce + Stand Age + DBH).

Values for each variable are: Ecologic Zone (1.50); Site Quality (Good = 1.66, Medium = 0.88, Low = 0.36); % Spruce in Stand (80 to 100 =1.33, 20 to 79 = 1.21, <20 = 0.59); Stand Age (>1.21 = 1.78, 101 to 120 = 1.10, <100 = 0.12); DBH (diameter breast high) (>12 inches = 1.00, <12 inches = 0.50). Stands with high hazard ratings and within one or two miles of a spruce beetle outbreak area have a high risk of being attacked. Hodgkinson's hazard rating system strongly suggests that many Alaskan spruce stands are at risk.

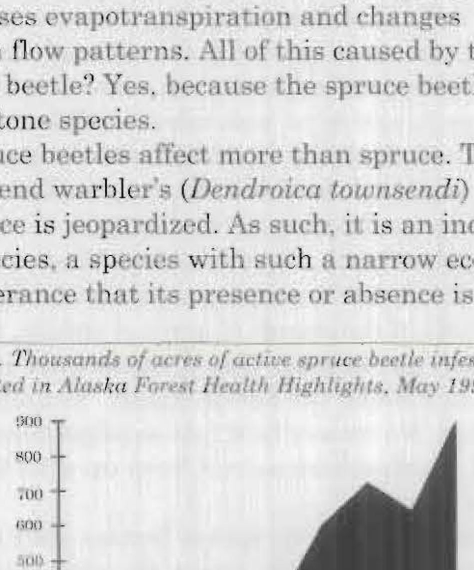
The spruce beetle is a keystone species, a species that has a central role on which the integrity of the ecosystem depends.[4] The eminent ecologist, E. O. Wilson speaks of elephants, rhinoceros, and other big herbivores as keystone species in Africa's savannas and woodlands because "[w]hen allowed to reach natural high densities, they control the entire structure of these habitats."[5]

Although much smaller in stature than elephants or rhinoceros, spruce beetles "[w]hen allowed to reach natural high densities, ... control the entire structure of [their] habitats." Thus the spruce beetle is an agent of change. In large numbers, especially unnaturally high numbers, the beetle negatively impacts the integrity of mature spruce–dominated ecosystems. In large numbers, spruce beetles kill 90% or more of the mature spruce in a stand and devastate large areas. The resulting change to the ecosystem is dramatic! The once verdant spruce forest becomes a ghost forest no longer able to support live–spruce–dependent organisms.

Where few or no spruce of a generation remain, a temporary and possibly permanent decline in the genetic diversity of spruce and species dependent upon mature spruce may occur. Loss of conifer habitat for vertebrates, non–vertebrates, plants, and other organisms impacts the food chain and ecosystem processes. Death of the spruce canopy allows more sunshine to reach the forest floor. Increased light encourages grasses and shrubs to grow more vigorously and take over the site. Increased sunshine warms the soil. Loss of living trees decreases evapotranspiration and changes stream flow patterns. All of this caused by the spruce beetle? Yes, because the spruce beetle is a keystone species.

Spruce beetles affect more than spruce. The Townsend warbler's (*Dendroica townsendi*) presence is jeopardized. As such, it is an indicator species, a species with such a narrow ecological tolerance that its presence or absence is a

Figure 1. Thousands of acres of active spruce beetle infestation as reported in Alaska Forest Health Highlights, May 1996.



good indicator of environmental conditions.[4,5] As a species sensitive to environmental change, it warns of a potential problem. An indicator species can need certain kinds of forests (species composition, age, area) or specific features within a forest. The Townsend warbler, in the non–coastal forest and possibly much of the southcentral coastal forest, requires spruce for nesting habitat. Loss of stands or even small drainages of spruce is of little consequence. But loss of extensive areas of spruce, such as that of the current beetle outbreak, means Townsend warblers will be displaced and possibly extirpated from large areas. Reed[7] identified the Townsend warbler as having restricted habitat specificity within its breeding range and ranked its extinction susceptibility as 5 on a scale of 1 to 8 (1 = highest and 8 = lowest); habitat loss was the basis for the ranking.

Other species that depend upon living spruce trees will also be displaced. Foliage, twig, branch, and bark feeding and inhabiting insects will disappear. Foliage gleaners, birds that eat foliage–feeding insects, will be displaced if the food supply disappears. Spruce seed–eating and bud–eating birds and mammals will be displaced. When the woodpeckers' bark beetle feast disappears, woodpecker numbers will crash.

The spruce beetle is an agent of change. At normal population levels, the beetle kills scattered individual trees or groups of trees within a stand, can cause mortality of scattered stands within a watershed, and even cause serious damage to scattered watersheds within a region. This kind of activity contributes to the patchwork mosaic of the forest. During the last decade or so, beetle populations have increased throughout much of southcentral Alaska to well above the forest's carrying capacity and killing hundreds of thousands of acres of spruce. Beetle numbers are so great that predators are incapable of control; the beetle simply "swamps" its enemies. No matter how fast woodpeckers breed, woodpeckers cannot keep up with the spruce beetle.

At outbreak levels, spruce beetles alter species composition of the forest: the spruce component is lost, the forest cover type is converted to an earlier successional stage, understory plants are no longer kept in check by the shade of the spruce and become strong competitors for and controllers of growing space. The lack of viable spruce seed reduces chances of prompt, natural spruce regeneration to low or non–existent. Lack of regeneration can last for a considerable period—50 to more than 150 years is not out of the question.

Simply, the direct impacts on a site of a spruce beetle outbreak are sudden and long–term defoliation and tree mortality. These are the two principal impacts of the beetle to the ecosystem. Although these impacts are not unique to spruce beetles, they must be addressed. To look for impacts only associated with or caused by spruce beetles ignores the obvious—the beetle is merely the agent of change. Once attention is focused less on the beetle and more on defoliation and tree mortality, the literature is found to be rich with information.

Duration and intensity of defoliation and tree mortality on living and non–living ecosystem components depend upon species composition, tree characteristics, biotic relationships, environmental characteristics, and area involved. Impacts to a pure white spruce stand will differ from those to a mixed stand of paper birch (*Betula papyrifera*) and white spruce. However, impacts specific to spruce will be the same, e.g., loss of Townsend warbler nesting habitat.

Individual tree characteristics define stand characteristics. With respect to the beetle, what percent of the spruce trees in the stand are at risk? How many trees are already heavily attacked or dead? How many trees are likely to remain alive once the beetle leaves? Other agents of change and tree species present must be addressed in a similar manner. Dimensions of the live crown, length and width as well as branch characteristics, are important for retaining precipitation and providing habitat. Lengths of bole with dead branches and their height above ground address the "fuel ladder" concern. Foliar biomass quantity and quality affect the amount of habitat or food available for organisms.

Stand characteristics must then be coupled with environmental considerations. These include percent of watershed or region impacted, landscape location (riparian, midslope, tree line), aspect and slope, prevailing and storm wind directions, soil organic horizon and surface mineral attributes, tree rooting depth, and understory species composition and coverage. These enter into any prescription for ecosystem restoration. Percent and pattern (mosaic versus large blocks of contiguous stands) of infested acres totally or partially defoliated affect the intensity and duration of impacts. Equally important is location of the sites to be treated relative to high–value sites.

Defoliation and tree mortality impacts include: changes to community structure and ecosystem functions and processes; changes to hydrology; decreases in timber values—both monetary and aesthetic; wildlife and fish habitat alterations that benefit some species and harm others; decreased recreational opportunities with increased liabilities; aesthetic degradation; and changes to fire hazard. The changes are neither straightforward nor simplistic. Two questions beg; What kind of replacement forest does society desire? Does society even want a forest?

The beetle changes structure within the ecosystem. Spruce provides certain structures utilized for habitat by many organisms: horizontal to drooping branches, rough bark surface, small–needled, evergreen foliage. Branch structure and foliage define the crown's architecture, something akin to a tent: a top, an interior relatively free of foliage, and an outer surface of foliage. Each is used differently by various organisms. The Townsend warbler depends upon the foliage area for nesting and insect gleaning early in the breeding season; the boreal chickadee (*Parus hudsonicus*) uses, along with other tree species, the bole for nesting (cavities) and branches and foliage for gleaning. Certain lichens are totally dependent upon live spruce. In Scandinavia, some lichens are listed as endangered because of the loss of specific types of tree crown structure due to timber harvest. In Alaska, the spruce beetle is the "harvester." Loss of live spruce structures negatively impact certain lichens, insect grazers, and foliage gleaners.

Defoliation and tree mortality change ecosystem processes. Loss of crown structure and foliage means less snow and rain retention and decreased evapotranspiration by trees. More moisture reaching the ground and less evapotranspiration increase soil moisture. Increased soil moisture can cause water tables to rise (paludification) and increase runoff to streams. Raised water tables can stress some species and improve the competitive ability of others. Changed snow deposition and melt patterns can increase spring runoff. Increased runoff changes streamflow and often causes higher flood levels. Reduced shade can increase water temperatures and cause earlier spring runoff. Increased streamflow can modify channel characteristics and processes including erosion and sedimentation.

Loss of foliage permits more sunlight to reach the ground resulting in warmer and drier soil surface horizons in summer. Warmer temperatures increase rates of biological and chemical activities. Organic matter decay rates increase. Litter dries out earlier. Numbers of shade–requiring organisms decrease; some may disappear. Lack of shade during the cold season coupled with light fall snow cover can cause soils to freeze deeper resulting in increased runoff (flashing) in the warming rays of the spring sun.

Dead and dying trees provide sudden inputs of needles and fine branches to the forest floor. This sudden addition of litter, tens of tons per acre, over a few years is followed by a long period of no additional similar material. The sudden supply and then dearth of litterfall, also, affects soil chemistry and biological processes. Biological processes are altered due to changes in the food supply available to organisms, especially microorganisms, that inhabit soil organic horizons. Changes in raw material (tree litter), processes, and process rates impact nutrient cycling.

Dead roots lose their strength and soon are unable to support the standing dead tree. Hence, dead spruce remain standing for only a short time; once all have fallen, there is little more large woody conifer debris available to the forest floor or streams. This can have a major impact on terrestrial and aquatic organisms as well as in–stream processes. Dead roots also lose their power to bind the soil and protect against erosion—a particular concern in the riparian zone.

By killing spruce, a late successional species, the spruce beetle sets plant succession back to an earlier stage. Spruce forests differ from hardwood forests which differ greatly from grass and herb communities (earlier successional stages). Where fire is suppressed, a different, possibly abnormal successional pathway may develop. Franklin[8] states that early successional stages are usually well represented in North American temperate forests and that "old–

growth" forests should be preserved or recreated. Similarly, in Alaska, late seral stands ofspruce are vital to maintaining ecosystem biodiversity.

Why should Alaskans care about the spruce beetle infestation? Alaska is committed to sustained yield of its replenishable natural resources. Of major concern to many is the beetle's economic impacts due to sudden defoliation and death of spruce. Non–commodity, or value concerns, such as things that "touch one's soul," are of equal concern.

Spruce mortality impacts drastically the timber resource. Dead trees do not contribute to sustained yield; they detract from it. Excessive numbers of dead trees are a liability to sustained yield. Arguments against prompt salvage because such cutting is not sustainable are folly. Dead spruce trees have limited use; the ability to use dead spruce for certain high, value–added products including veneer and lumber decreases rapidly. Once dried, except for a few specialty markets, the dollar value is one–fifth to one–tenth that of green timber. This means less stumpage paid to the landowner and less product value to the logger. Dead trees do not produce seeds for regeneration. Because of the low value of dead trees, the economics of forest regeneration is greatly impaired. Low timber values, means timber cannot be used to subsidize other forest management activities including enhancing wildlife habitat, recreation, aesthetics, and managing riparian zones. Dead trees are a liability, not an asset!

Spruce mortality impacts wildlife and fish by altering babitats, especially cover and food. Some dead trees provide essential wildlife (woodpeckers and cavity nesters) habitat. Live trees provide an abundance of food necessary to support healthy populations of many animals. Dead trees provide limited species and quantities of food organisms. Successional changes favor certain species over others; early successional stages benefit sparrows and most close–to–the–ground nesting warblers but not woodpeckers, chickadees, or Townsend warblers. Birds and mammals that depend heavily upon spruce seed no longer have a food supply. Loss of spruce means loss of hiding and thermal cover for many animals. Loss of spruce means loss of spruce brooms caused by the rust fungus (*Chrysomyxa arctostaphyli*) which many ecologists contend are important for winter survival of northern flying squirrels (*Glaucomys sabrinus*). Some ecologists further contend that the flying squirrel is essential for successful dispersal of truffle (fungus) spores.[9] Truffles form mycorrhizae on green plant roots and are important for nutrient uptake.

Loss of spruce impacts recreation and aesthetics. Most people, including tourists and homeowners, prefer living, green forests. Dead trees negatively impact real estate value. Dead trees provide an abundance of falling debris and can topple without warning. Thus, dead trees are a liability for property owners. A particular liability exists for recreation entrepreneurs who must maintain safe conditions for clientele through additional trail and site maintenance.

Dead trees contribute to the fire hazard. Fuel type conditions change from cool forest understories to open, herb and grass dominated understories. Fire control procedures and time of fire season change. Fuel loadings change; for a considerable period of time there is more cured, fine fuel in the dead overstory. Then it falls to the ground; after a few years, larger material begins to fall. Coupled with cured herbaceous vegetation, fire has a chance to run from one slash accumulation to the next where it burns hot. Impacts can last for a few years to a century or more depending upon ecological processes and rates. Fire hazard concern increases as witnessed by the clearing of firebreaks at Cooper Landing at costs in excess of $1,000 per acre[2] and planned for the Anchorage area between Chugach State Park and the "hillside."

Can Alaskans afford to lose Northern Forest ecosystem benefits as we know them today? Should Alaskans be concerned with leaving a legacy of healthy forests that provide many options in terms of commodities and values for future generations? Is there a need to restore the spruce forest ecosystems impacted by the spruce beetle in Alaska? The answers are obvious.

Ecosystem restoration is the practice of reestablishing the historic plant and animal communities of an area or region and the renewal of ecosystem structures, processes, and functions essential for maintaining the desired communities into the future. The desired condition need not be natural or original. The effort alters sites with an objective to reestablish conditions or opportunities that permit, over time, conditions to sustain a certain species and genetic richness.

At minimum, society should restore spruce beetle impacted ecosystems to a condition similar to that prior to the current outbreak. The Townsend warbler, an indicator species, suggests this condition must include dense stands of late successional spruce. Recreating such stands requires prompt action to ensure availability of adequate quantities of spruce seed and to begin reforestation. An umbrella organization of federal, state, and private landowners is essential to coordinate activities and to make prompt, responsible decisions. There is no single solution for all impacted ecosystems and stands, for all property owners, or management units. Biological realities must be accepted. Public process must accommodate prompt action and maintain the productivity and biodiversity of the region. Process cannot be allowed to obfuscate responsible actions. No action is a willful decision and often irresponsible.

In ecosystem restoration, silvicultural concerns involve adequate regeneration and stand treatments that help maintain existing spruce stands of various ages, densities, and structures. Special silvicultural treatments may be essential to maintain critical habitats or stand conditions for some wildlife species or human uses. Pruning and single tree thinning of larger trees may be essential around communities and in campgrounds to reduce individual tree stress, create a less desirable habitat for the spruce beetle, and reduce fire hazard.

Activities in the riparian zone must consider the unique structure, processes, and functions found there. Future loss of large woody debris inputs must be addressed. Establishing high density, mixed plantings of cottonwood (*Populus balsamifera* var. *trichocarpa*) and spruce is a high priority. Fast growing cottonwoods should make large woody replacement debris available within 30 to 40 years of planting; these trees can then be felled deliberately into streams. Later, spruce will complement the cottonwood. Stream bank stabilization must be pursued actively and includes regenerating understory species and placement of land and in–water structures. Riparian zone activity is a professional effort, not simply an agency responsibility, and must involve professionals from various disciplines.

Regenerating spruce is critical to restoration. Where possible, natural regeneration should be encouraged. This may mean site preparation to create good seedbed conditions for seed germination. The object is to secure spruce, not hardwoods. If planting is required, seedlots must be the most appropriate for the site. Use of non–native species has no role in ecosystem restoration. Although it may be argued that exotics can increase local biodiversity, they detract from the integrity of natural ecosystems.

Collecting local spruce seed is critical because seed–producing trees are rapidly dying. Efforts must include collecting light cone crops from all lands regardless of ownership, felling trees to maximize cone harvest, and paying premium prices for cones and seed. This is an emergency because the beetle affects a tree's vigor and ability to produce viable seed. Identification of collections and tracking their use is a must because, once exhausted, there may be no future replacement seed.

Silvicultural options exist for restoring beetle–impacted stands. Prescriptions depend upon site specific conditions and objectives and include: do nothing; salvage and do nothing; do nothing and plant; salvage and seed; burn only; salvage and plant; burn and plant; salvage, burn, and plant; fell, burn, and plant; and salvage, site preparation, and plant.

Within each option, variations for achieving specific results exist.

Within the riparian zone, adapt treatments to meet current and future needs associated with zone goals and concerns. Some adaptations include:

- Minimize salvage impacts: no heavy equipment in zone; fell trees to "lead" so as to minimize streambank disturbance.
- Do not cut trees needed for future large woody debris inputs.
- Plant trees close together to replace lost spruce; include cottonwoods if moose browsing is not a problem.
- Plant shrub species such as devils club (*Oplopanax horridus*).
- Place proper channel "devices" to protect streambanks from erosion.
- Fence streambanks, where necessary, to keep people out.
- Plan future felling of trees to provide large woody debris.

Safety related hazard abatement is reality. Abatement requires removing dead, dying, and hazard trees. Slash must be removed, burned, or chipped. Prune live trees to reduce the quality of the environment for beetles and to reduce fire hazard. Along roads and trails and in recreation sites treat the travel influence zone to reduce liability and preserve what is alive. Plant spruce, but encourage mixed stands. Around homes and buildings, remove spruce from within the fire defensible space zone and plant or encourage hardwood species within the zone.

Prompt harvest of dead and dying trees is essential. To suggest that little can be done to prevent or control periodic beetle outbreaks and not engage in prompt harvest of infested timber[2] ignores reality—large scale epidemics are preventable. Within the boundaries of an existing, large epidemic, little can be done to stop high hazard stands from being overcome by beetles; but impacts can be reduced and smaller trees made less attractive to beetles. An objective in promptly harvesting at–risk stands is to capture value for the landowner, private or public, so that conifer regeneration costs are covered.

Within boundaries of regional and watershed level beetle infestations, log high hazard stands by removing spruce only and leaving the hardwoods or clear–cut all species. Uniform seed tree cuts or diameter limit cuts generally do not work with spruce! Clumps of small trees with seed–producing trees suggest a patch–seed tree approach. Protect clumps or patches of thrifty young spruce, seedlings and saplings, wherever possible.

Good resource managers strive to prevent spread of the beetle from outbreak areas by identifying stands at risk and taking action. Preemptive actions to control beetles are far less costly than ecosystem restoration. Hawley and Hawe[10] in their 1912 classic, *Forestry in New England*, describe the use of sanitation and salvage cutting to help stop the spread of the beetle. Alberta uses three strategies to control spruce beetle outbreaks: pheromone–baited trap trees, felled trap trees, and salvage logging; British Columbia, uses timely salvage, sanitation, and host depletion strategies.[11] Hodgkinson[1] explains "Proper spruce utilization can significantly reduce the amount of both infested host material and uninfested potential breeding material...Effective utilization or 'good housekeeping' requires that: stumps be cut as low as possible; tree–length logging or a 10 cm (4 inch) top utilization be used and all tops be scattered on the block or piled and burnt; if permitted, all long butts should be piled and burned on suitable landings or elsewhere before the beetles emerge; prompt removal of edge windthrow, and decked and spilled loads before they are attacked."

Where bark beetles have severely impacted spruce forests on a regional basis, ecosystem restoration is essential. Where beetle outbreaks are small in size, prompt action can control their spread. Bark beetles are "controlled" and timber values salvaged elsewhere in North America with salvage income paying for regeneration. Alaska needs this kind of prompt action to avoid high cost ecosystem restoration. Public involvement, although essential, cannot be managed in such a way that essential, prompt actions are delayed. Very few beetles attend public meetings.

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Rejuvenating the land:

Converting mined lands to thriving ecological communities

by Dr. Dot Helm
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What happens to mined lands after mining is completed? In the case of coal mines, these lands are regraded to the approximate original contour of the site and revegetated by natural and/or artificial means to meet standards suitable for a pre–designated post–mining land use, such as wildlife habitat. In the case of non–coal mines, the sites need to be prepared so natural revegetation can occur. Sites may also need to be seeded and fertilized.

The techniques used are as varied as the goals and time frames. Three main objectives are usually present: (1) control erosion and stabilize the site, (2) achieve post–mining land use to meet regulatory requirements, and (3) maintain good public relations.

The Agricultural and Forestry Experiment Station (AFES) became involved in revegetation in 1969 in conjunction with oil–related development. AFES has since become an innovator in recognizing the biological properties of soils and reconstructing self–sustaining plant communities on coal mined sites which must meet more stringent regulations than other development industries.

Initial studies by the AFES focused on collecting native plant seeds and selecting the varieties most promising for forage and conservation purposes. Some of the most successful grass species for general soil conservation in Alaska were developed at the AFES: Arctared red fescue (*Festuca rubra*) was released in 1978 and Norcoast Bering hairgrass (*Deschampsia beringensis*) and Nortran tufted hairgrass (*Deschampsia caespitosa*) in the mid 1980s. Norcoast and Nortran can be green, vigorous plants after seven years growth on low nutrient soils with one fertilization. This contrasts to introduced species that decline as the initial fertilizer is depleted during and beyond the third year. These two hairgrass cultivars may also provide a biological control for less desirable plant species, such as bluejoint reedgrass (*Calamagrostis canadensis*), that compete with


AFES photo
Dr. Dot Helm photographing a revegetation plot area.

woody plant colonizers. Woody colonizers are critical to native plant community development.

In the late 1980s mined land revegetation research at the AFES made the transition to ecological approaches in establishing native plant communities more readily and reducing maintenance. Observing natural successional communities on disturbed lands such as floodplains, deglaciated areas, and abandoned mined lands are helping us understand natural processes that can be mimicked during revegetation.

Current strategies include creating microtopography, using growth media available on the site and suitable for the desired plant species, and using plant materials from the site.

Revegetation can depend heavily on natural colonization; it can be accomplished by intense site preparation, seedings, transplantings, and other operations; or it can use combinations of both. Natural colonization could be the most effective and cost efficient means of establishing native vegetation on disturbed sites. However, other processes may be needed to control erosion in the first few years and establish successional communities compatible with the desired land use in 5 to 10 years. Species, especially grasses, are frequently seeded to establish ground cover in the short term, but these may interfere with long term goals. Strategies used in mined land revegetation are usually a balancing act of short term needs and long term goals that may vary even from one part of a mine to another.

revegetation—a balancing act of short term needs and long term goals

Planning revegetation starts with an inventory of soils and vegetation prior to mining. We identify resources available, determine how on–site resources can be used to maximum benefit, and determine where additional amendments such as seed and fertilizer may be needed.

Post–mining environments are different from pre–mining environments. Although vegetation and soils assessments prior to mining determine what plant species and soils were present, the ecological requirements of the plants and the post–mining goals must be considered in conjunction with differences in the post–mining environment. Prior to mining, the plants may be growing in sheltered, shady sites on well–developed soils with established microbial communities. After mining, the environment may be windy and sunny. Soils have been drastically disturbed, and stockpiled soils may have different properties from the original materials, especially with respect to biological properties.

Some soils resources may be particularly beneficial to achieve revegetation goals. Even though low in extractable nutrients, certain soil materials can retain nutrients longer than others, thus reducing the need for multiple fertilizations. Soil properties that can assist succession include physical properties such as particle size distribution (texture), chemical properties such as extractable and total nutrients, and biological properties such as soil microorganisms and buried plant propagule (seed, rhizome) banks.

Finer textured soils can hold more nutrients but are more easily eroded than coarse textured soils. Surface soils may have organic nutrient pools that slowly release nutrients through weathering and decomposition, but is not sufficiently available immediately. These nutrient pools are made available to plants by mycorrhizal symbioses. Mycorrhizal fungi help the plant absorb nutrients and moisture from the soil, and the plant provides the fungi with carbon as an energy source. The mycorrhizal fungi present in soil depends on the plant species and successional stage of the vegetation. Other microorganisms present in soils may be essential for decomposition, nutrient cycling, and other ecosystem processes needed to establish functional ecological communities.

Natural succession can be facilitated by amendments such as plant materials (seed or cuttings of various plant species), fertilizer, and inoculum for symbiotic microorganisms. In harsher sites, grasses can help control erosion, add organic matter to the growth media, and provide surface roughness that helps reduce the impact of wind. Timing of seeding (fall versus spring) can produce more vigorous plant growth on some sites for some species. Seed and cuttings provide ground cover until natives can establish and increase surface roughness.

Plant materials can be collected from the site or, in some cases, obtained commercially. Fertilizer provides readily available nutrients to improve plant establishment. Fresh (live) soils provide microorganisms for decomposition and symbiotic relations. Commercial inoculum may not be available for cold regions so these on–site resources can be critical in establishing certain plant communities.

Extensive research was done on establishing grass species and alder (*Alnus* spp.) on overburden materials in the late 1970s and early 1980s. Vegetation and soils characteristics of revegetated sites up to 17 years old have been documented at Usibelli Coal Mine, which began revegetation trials in 1971 and actual revegetation 1972. On some of the older sites, initial grasses used for erosion control have died out and extensive woody colonization has occurred.

In some cases, the diversity of the post–mining community is similar to that of the pre–mining community. Diversity is index reflecting number of species and how evenly cover is distributed among them. Even where grasses were used heavily for short–term erosion control, woody species have extensively colonized some sites.

Because seeded grasses are likely to die or become inconspicuous within 5 to 10 years, it is desirable both for revegetation success and economics to make use of on–site resources to facilitate natural processes.

A proposed mine on the Matanuska Valley Moose Range needed to establish moose browse after mining. The plant species usually considered best for moose browse grow on floodplains where the soils have near neutral pH values (7). The soil materials proposed as a growth media had pH values near 5.2 to 5.6. We didn't know if the desired plant species would grow under these conditions. A study was implemented to evaluate seedlings and rooted cuttings of seven woody species on four growth media (three soil materials and one simulated overburden). Overburden is the geological material below the soil but above or between the coal seams or ore deposits. Materials for six of the species were collected from plants on the proposed mine site.

After eight years some of these species have produced tall shrubs and trees averaging more than 13 feet tall on some sites with no fertilization. Native colonizers grew beneath the trees, resulting in almost complete ground cover. This was without seeding or fertilizing. These sites had a particularly favorable growing environment. At other sites where the growth potential of the soil is substantially less, native colonization is almost negligible.

These trials help us understand which soil and vegetation characteristics facilitate the revegetation processes. Salvaging soils require special handling and add substantial cost up front, so it is critical to know if there is any benefit to using soil. AFES trials on various sites identify where it is appropriate to salvage soil for mined land revegetation.

In this same study, grasses were needed to control erosion but concerns were raised about seeded grasses and bluejoint reedgrass competing with the desired woody plants. Bluejoint negatively impacts forest regeneration in Southcentral and Interior Alaska. Seven grass varieties and several mixes were tested to determine which grasses might be best for erosion control and competition with the undesirable colonizers but still be usable where moose browse production was the primary concern.

Other studies have looked at increasing the mycorrhizal inoculum on woody plants at active and abandoned mined sites. Natural colonization on an abandoned placer mine along the Steese Highway was documented prior to reclamation. Followup studies on seeded grass species, timing of seeding and fertilizing, and timing and elevation above water for planting rooted and unrooted cuttings were conducted. Although placer miners can depend completely on natural colonization for their revegetation, some are using grasses in the short term for erosion control and appearance. This increases the surface roughness which could result in increased native seed deposition on the site. One placer miner near Wiseman is evaluating grass species and fertilizers to control erosion, improve natural colonization, and compatibility with neighboring land uses. We are evaluating natural colonization on different slopes, in areas with or without fertilization, and with or without seedings. AFES personnel have also been involved with testing sewage sludge as an amendment on a Fairbanks mine.

Each study adds to our knowledge on revegetating mined sites. Results help miners achieve better revegetation and environmental regulators to better understand tbe impacts of the various options. Now we can harvest our under ground natural resources and enjoy the rejuvenated land left behind.

ACKNOWLEDGMENTS

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Tundra plant succession and vascular plant species diversity

by Dr. Jay D. McKendrick, Robert C. Wilkinson, and Dr. Robert G. B. Senner

One intriguing aspect of plant ecology is plant succession. The process has been described as an orderly, and thereby predictable, sequence of plant communities beginning with pioneering colonizers on barren sites and terminating with the relatively stable endpoint identified as climax. The classical work was developed largely by Clements (1916) for the Nebraska prairies and was driven by economics. Deteriorating prairie pastures and rangelands were a problem so discovering the plant successional sequence of the mixed prairie was immediately useful to livestockmen, landowners, and lending institutions. The prairie was periodically stressed with drought and damaged by excessive hay harvesting and livestock grazing. By knowing the plant successional sequence, one could more accurately determine either the degree of damage or recovery stage for a given piece of land. The Soil Conservation Service later refined and quantified criteria for judging rangelands based on the presence and prominence of plants that were either *decreasers*, *increasers*, or *invaders* (Dyksterhuis 1949). Decreasers were species of the climax community rating high in their palatability for grazing livestock. Increasers were members of the climax community or a subclimax stands and were less attractive to grazers than the decreasers. Invaders were species of plants that were not part of the climax community and could only occupy a given site after the climax community was severely weakened or entirely destroyed. These invaders were often the 'weeds' of croplands and unpalatable to grazers.


photo by Dr. Jay McKendrick

Robert C. Wilkinson examines a robust Carex clump that is colonizing on gravel fill exploratory wellsite, Sagavanirktok River Delta, east of Prudhoe Bay.

The outcome of those early plant ecological studies was more than solutions to managing deteriorated prairie; it expanded acceptance of a captivating field of science based on the interrelationship between living organisms and their environment. Understanding plant succession is as useful and interesting today as it was during its discovery. The application of plant ecology varies with the management objective. Plant succession is the process agronomists and weed scientists wish to prevent, as they strive to maintain competition–free fields for crop production. However, the climax vegetation of the prairie is what stockmen needed to feed their animals, so their goal was to promote plant succession.

Principles of plant succession are used on wildlands to manage timber and wildlife habitats, design revegetation programs, and evaluate condition and trend for disturbed sites. Understanding plant ecology, particularly plant succession, and knowing the respective roles of various species give depth of appreciation to nature observers and increases the perception of what they see. This understanding and appreciation must be acquired for each ecosystem, due to climatic and species variations.

Seral plant communities are usually more productive in terms of biomass, and nutrients cycle faster through them than through climax communities. Eugene P. Odum (1959), a prominent ecologist at the University of Georgia stated:

It is rather amazing that in a great many instances, organisms which man most desires to perpetuate are members of early seral rather than of late seral or climax stages. Thus, most game birds, many fresh–water game fish, and many of the most valuable timber trees thrive best in what are, actually, temporary communities.

We agree with that observation for Alaska and add that in the Arctic, the diversity and often the beauty of flowering plant species is much greater in seral tundra communities than in undisturbed climax communities.

Recently, we examined vascular plant species on severely altered habitats at exploratory drilling sites and adjacent undisturbed tundra in the region between the Sagavanirktok and Canning river drainages. The accompanying graph illustrates a greater diversity of plant species on disturbed sites. Besides a difference in numbers of plant species, there was also a greater abundance of flowering forbs in the seral stands, making those sites more interesting to wildflower enthusiasts.

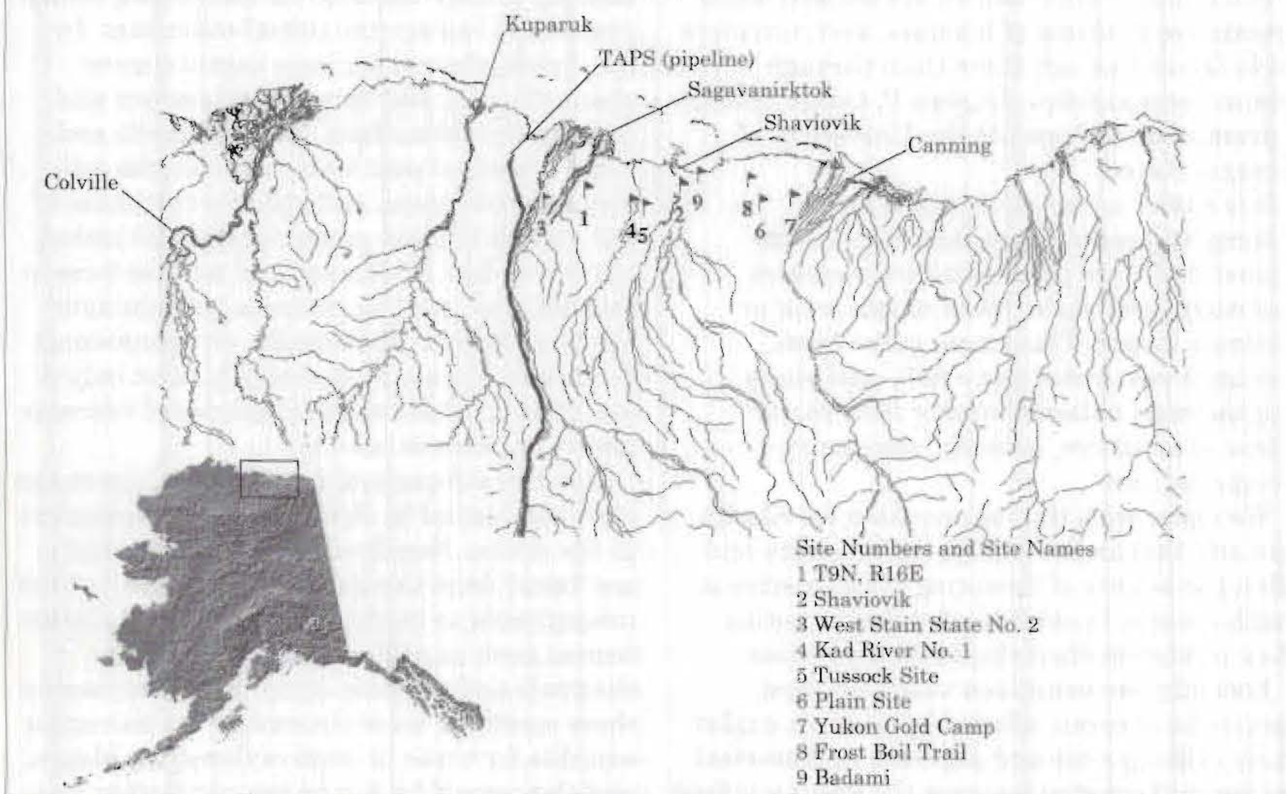
The science of plant ecology explains that seral communities modify the environment, making it more suitable for successors, which eventually replace the initial colonizers. In the Arctic, these colonizers capture snow, shade the soil, add litter to the surface and roots to the subsurface. Mosses invade and build a layer of peat that insulates the soil, elevates moistness, and reduces thickness of the annual thaw to approximately 20 inches (50 cm) or less. Ice lenses and wedges form in the soil, and polygon patterns predominate the land surface. Eventually, environmental conditions change so drastically, that only a few, if any, of the original species of vascular plants are able to survive.

It is the influence of mosses that is perhaps most influential in changing the environment in the Arctic. Nearly all the colonizing forbs are forced from the habitat, which has become inhospitable to them. Without natural disturbances such as soil erosion along stream channels and periodic draining of lake basins, there would be no environment in this region suitable for these attractive flowering plants, and they would be forced into extinction by a lack of habitat. Their very existence depends on the continual destruction of climax communities. Although disturbance of the arctic tundra is not advocated as a land management objective, there are positive results to

Photos by Dr. Jay McKendrick

Eriphorum colonizes shelf in partially drained lake, east of Prudhoe Bay (above). Northern tansy (Descurainia sophioides) grows in the long–term gravel vegetation project in the botanical garden plots at Prudhoe Bay (right).

Vascular plant species observed at several disturbed and undisturbed sites between Sagavanirktok and Canning rivers, North Slope Alaska, 1993.



such activities, because "nature abhors a void". And nature often heals the voids in tundra with flowers.

If a pictorial wildflower guide were prepared for the Arctic, it is most likely that the majority of illustrations would originate from photographs of plants found on sites disturbed either by nature or man. Surely appreciation of nature varies among people, but for some aficionados of the arctic wildflowers, it is the denizens of seral communities that provide the most enchantment.

Acknowledgment

Travel to these sites was provided by BP Exploration (Alaska), Inc. Map is courtesy of Dr. Dave Verbyla, SALRM.

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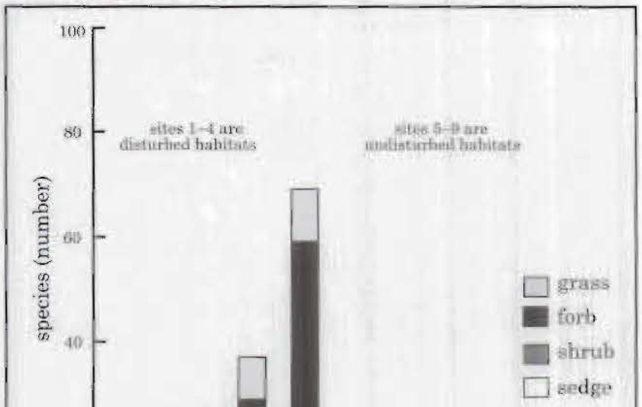
Vascular plant species recorded during the summer of 1993 between Sagavanirktok and Canning rivers.



Bioremediation of petroleum-contaminated soil using fish bonemeal in cold climates

by *Dr. James L. Walworth, Associate Professor of Soil Science, SALRM*
Dr. Craig R. Woolard, Assistant Professor, School of Engineering, UAA
Kent C. Harris, Former Graduate Research Assistant, School of Engineering, UAA

In 1995, the National Marine Fisheries Service estimated that over 55% of the 9.9 billion pounds of fish commercially harvested in the United States came from Alaskan waters. Approximately 18.5% of this catch ends up as processing by–products, consisting largely of fish heads, bones, and viscera. In the past, these wastes were disposed of, but with increasing environmental and economic constraints placed on the fishing industry, new uses of fish processing by–products are being developed. Solid fish wastes are dried, ground, and sieved, and the fine particles are used as protein supplements in animal feeds. The course material, bonemeal, contains large quantities of bone fragments and is less suitable for feeds. However, fish honemeals are rich in nitrogen and phosphorus and have been successfully used as agricultural fertilizers.

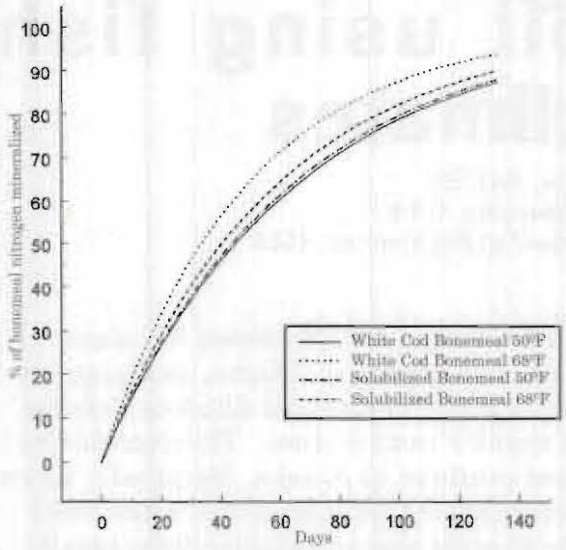
A joint research program at the University of Alaska Fairbanks and the University of Alaska Anchorage has been designed to study the potential of Alaskan fish bonemeals for fertilizing petroleum–contaminated soils to enhance bioremediation. Bioremediation is a generic term for technologies that rely on microorganisms to consume petroleum or other organic soil contaminants. The University of Alaska research is using fish bonemeal to supply nitrogen and phosphorus to soil bacteria and fungi responsible for degrading the soil petroleum at contaminated sites.

Thousands of sites throughout the state of Alaska have been contaminated by improper disposal of waste materials, accidental spills, and the failure of storage and transportation facilities. The Alaska Department of Environmental Conservation lists over 2,000 contaminated sites in its database, eight Superfund sites are scheduled for major remediation efforts in Alaska, and approximately 120 formerly used Alaskan defense sites require remediation. These problems are not confined to Alaska. Nationally there are over 300,000 contaminated sites that range in scale and complexity from small underground storage tanks to Superfund sites. The magnitude of contaminated soils overseas has yet to be fully documented (especially in the countries of the former Soviet Union).

Bioremediation is one type of technology that can be used to remediate many of these contaminated soils. At their most basic level all bioremediation technologies (e.g., land farming, biopiles, bioventing, slurry reactors, etc.) rely on the ability of microorganisms to utilize organic chemical contaminants (such as petroleum hydrocarbons) as a food source (or substrate) for growth. Soil microbes capable of degrading petroleum contaminants are likely present in virtually all petroleum–contaminated soils. Under optimal conditions, these microbes can convert the soil contaminants to carbon dioxide, water, and cell mass, thereby remediating the site. Various nutrients, such as nitrogen and phosphorus, are required for microbes to grow and degrade site contaminants. At many contaminated sites the natural concentrations of nitrogen and phosphorus are not sufficient for effective microbial remediation and fertilizers must be applied. Typically, nutrients are applied as inorganic salts of ammonium, nitrate, and phosphate.

Water–soluble inorganic fertilizers originally developed for agricultural use can be problematic when used in bioremediation systems. At highly contaminated sites, for example, large quantities of nitrogen are

Figure 1. Nitrogen mineralization from two fish bonemeal products added to soil at two temperatures.



required to ensure that nutrient limitations do not occur. If high concentrations of nitrogen are added in a single application, the salt content of the soil system can be dramatically increased, especially in course–grained soils with low moisture contents. The resulting decrease in soil water potential can inhibit microbial contaminant degradation, and, in effect, create a situation analogous to "burning" a lawn by over–fertilization. Salt–induced microbial inhibition can be avoided by multiple applications of small quantities of inorganic fertilizers, which increase costs, particularly at remote sites where transportation and fuel are extraordinarily expensive. Alternatively, slow–release fertilizers which release small amounts of nutrients over an extended period of time can be used.

Slow–release nutrient sources manufactured by coating nitrogen fertilizers with selectively permeable membranes to control the rate of diffusion of nutrients into the soil have been successfully used in bioremediation. Organic materials such as fish bonemeals that gradually release nutrients as they decompose can also be used as slow–release fertilizers and have received some attention as potential fertilizers for bioremediation.

Although Alaskan fish bonemeals contain between 5 and 9% nitrogen and from 4 to 10% phosphorus, the bulk these nutrients are not in a form that can be directly used by bioremediation microbes. Approximately 6% of the phosphorus and only about 0.5% of the nitrogen in the bonemeals we tested were immediately available for biological consumption. Before it can be used, bound nitrogen must be mineralized, or converted from organic (proteins, amino acids, etc.) to inorganic (nitrate and ammonium) forms. Phosphorus contained in bone fragments must be dissolved in the soil solution. As a result of these processes, bonemeal nutrients are released to plants and soil microbes slowly, preventing salt buildup which can inhibit microbial activity, and delaying formation of nitrate (a potential drinking water contaminant). Fish bonemeal also contains a large amount of carbon (10 to 25%) which provides a substrate source for the soil microbial population.

The rate at which bonemeal releases nitrogen, the nitrogen mineralization rate, is a key engineering design parameter because it quantifies the rate at which readily usable nitrogen is provided to microorganisms degrading organic contaminants such as petroleum hydrocarbons. Nitrogen mineralization is a biological process, and the responsible microorganisms are affected by soil conditions such as soil acidity and temperature. On the other hand, soil phosphorus dynamics are largely mediated by inorganic chemical reactions. Dissolution of phosphorus–containing bone minerals (bone apatite) and formation of insoluble precipitates (mainly calcium phosphates) govern phosphorus concentrations in

Figure 2. Oxygen consumed by petroleum biodegradation in soil fertilized with fish bonemeal, diammonium phosphate (DAP), or in unfertilized soil.

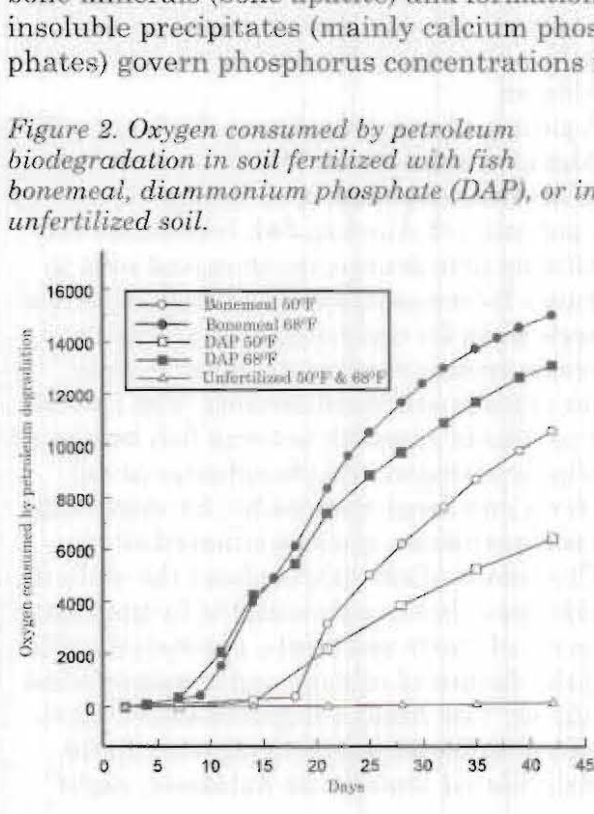


Table 1. Reduction of extractable petroleum (% of the original 20,000 mg/kg lost) in soil fertilized with diammonium phosphate (DAP), white cod bonemeal, or in unfertilized soil incubated at 50° or 68°F.

Time	Temperature = 50°F			Temperature = 68°F		
(weeks)	DAP	Bonemeal	Unfertilized	DAP	Bonemeal	Unfertilized
3	61%	69%	43%	74%	85%	19%
6	89%	91%	56%	92%	92%	78%

soils fertilized with fish bonemeal. Although these phosphorus reactions are non–biological, they are also affected by soil acidity and temperature. Laboratory experiments were designed to measure bonemeal nitrogen mineralization rates and phosphorus dynamics in soil with acidity levels ranging from pH 5.5 to 7.5 and at two temperatures (50°F and 68°F) to provide this critical design information. We tested two fish processing by–products, white cod bonemeal and a liquid material produced by solubilizing fish bonemeal in phosphoric acid.

Results from our studies indicate that the bioavailability of bonemeal phosphorus is not significantly affected by soil acidity or temperature (within the ranges tested). Nitrogen release from bonemeal is dependent on soil temperature, and is only minimally affected by soil acidity. Within 10 weeks, most of the organic bonemeal nitrogen was mineralized in soils incubated at 68°F, whereas equivalent mineralization at 50°F required 12 to 14 weeks (Figure 1). Nitrogen from white cod bonemeal mineralized slightly faster than that from solubilized bonemeal. Although nitrogen mineralization is slower in cool than in warmer soils, microbial petroleum breakdown is affected similarly and nitrogen release from fish bonemeals compares favorably with the rate at which nitrogen is consumed by microbes during bioremediation. Because petroleum degradation rates and nitrogen mineralization rates are similar, it can be assumed that bonemeals will provide enough available nitrogen for the desired growth and reproduction of microbes.

Additional experiments were conducted to compare the effectiveness of white cod bonemeal and inorganic fertilizer for bioremediation of soil contaminated with diesel fuel. Nitrogen and phosphorus were added, either as the commercially available inorganic fertilizer diammonium phosphate or in the form of fish bonemeal. Activity of soil microbes degrading diesel fuel was measured by monitoring consumption of oxygen and production of carbon dioxide. Oxygen consumption was minimal in soil containing neither diesel fuel or bonemeal, because there was not sufficient substrate to sustain a high level of microbial activity. In diesel–contaminated soils where no nutrients were provided, there was also minimal oxygen consumption, indicating that the soil was nutrient limited. 'Net' oxygen consumption (the difference between oxygen consumption by contaminated soil versus clean soil, either amended with diammonium phosphate, bonemeal, or without nutrient addition) indicates the consumption of oxygen resulting only from microbial consumption of diesel fuel. Regardless of incubation temperature, net oxygen consumption was somewhat greater in soils fertilized with fish bonemeal than in soils fertilized with diammonium phosphate. Net oxygen consumption in unfertilized soil was minimal.

We also monitored extractable soil petroleum levels. Soil petroleum becomes less extractable over time as it becomes bound to soil constituents, so the petroleum levels shown in Table 1 decreased even in the unfertilized soils where microbial petroleum degradation was minimal. This reduction represents a change in availability rather than total amount of petroleum hydrocarbons in the soil. However, residual soil petroleum hydrocarbon levels decreased more where fish bonemeal or diammonium phosphate were used. Addition of diammonium phosphate resulted in a 73% decrease of petroleum contamination during the first 3 weeks of incubation, whereas there was an 85% decrease when bonemeal was the nutrient source. After 6 weeks of incubation there were very small differences between soils treated with bonemeal and diammonium phosphate, but both treatments had much greater soil petroleum reduction than unfertilized soils.

The results of this laboratory research show that Alaskan fish bonemeal is a practical option as a bioremediation nutrient source. White cod bonemeal and solubilized bonemeal released nitrogen and phosphorus at rates sufficient to supply soil microbes responsible for bioremediation. Bioremediation of petroleum–contaminated soil occurred at least as rapidly in soil fertilized with white cod bonemeal as in soil amended with inorganic fertilizer. Bonemeal is a locally–produced nutrient source that can be used in relatively high concentrations, without inducing salt buildup that can occur with inorganic fertilizers.

With their effectiveness demonstrated in the laboratory, bonemeals are now being tested on a pilot scale cleanup. Fish bonemeal has been applied to soil contaminated by a leaky heating oil underground storage tank where bonemeal performance is again being compared to diammonium phosphate. The potential use of fish bonemeal in bioremediation is demonstrated by the number of sites with contaminated soils. In general, bonemeals may be suitable for any application where organic waste breakdown requires addition of nitrogen and phosphorus. These include composting facilities that utilize municipal wastes, and wood and food processing wastes.

Acknowledgments

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1996 Alaska women in agriculture

Three women, Mrs. Hamilton of Palmer, Mrs. Gail Mayo of Fairbanks, and Mrs. Abby Ala of the Kenai Peninsula were named 1996 Alaska Women in Agricultural and honored at the Agricultural Symposium on November 15th, 1996. Presenting their awards were Dr. Fredric Husby, School of Agriculture and Land Resources Management dean and Bob Franklin, Alaska Farm Bureau president.

Mrs. Hamilton's 31 year history with farming in Alaska includes being secretary for Hamilton Farms, an active dairy farmer, business coordinator for the Alaska Dairy Cooperative, director for the Farm and Home Administration, and director for the Commercial Fisheries and Agriculture Bank.

Mrs. Hamilton receives her award from Dr. Fred Husby.

Mrs. Mayo is presented her certificate by Dr. Husby.

For the last 20 years, Mrs. Gail Mayo, along with her husband Larry, has operated Happy Gap Farm and Tanana Wools. She is active in the Alaska Sheep and Wool Assoc., Alaska Soil and Water Conservation District, Friends of Creamer's Field, Alaska Bird Observatory, and the Tanana Valley Fair livestock committee. Mayo actively supports Future Farmers of America and 4–H.

Dr. Husby presents Mrs. Ala with her award.

A certified seed grower at the age of 12, Mrs. Abby Ala has always been a staunch supporter of greenhouses and farming in Alaska. At Ridgeway Farms she incorporates a polyculture greenhouse with permaculture farming. Mrs. Ala has served her community as a 4–H leader, volunteer in various civic organizations, and through memberships in the Kenai Peninsula Combined Training and Dressage Assoc., Kenai Soil and Water Conservation District, Farm Service agencies, and the Sheep and Wool Growers Association.

Characteristics of permafrost soils along a latitudinal transect in arctic Alaska

by Dr. Chien-Lu Ping
Professor of Soil Sciences

Organic carbon contents in arctic tundra soils have been grossly underestimated with 1.4 to 2.5 times the amounts previously estimated. Nearly 50% of the total carbon is stored in the upper permafrost layer which is likely subjected to thawing upon global warming. The arctic tundra is expected to change from a carbon sink to a source of global warming gases and the carbon stored in the upper permafrost would certainly double the release of global warming gases.

Characterizing the morphological, chemical, and physical properties of permafrost–affected soils and the study of soil organic matter dynamics are key. With this realization, we began a study to characterize arctic soils. Seventy soil pits representing different ecosystems in the arctic ranging from NE Russia, Alaska, and NW Canada were excavated to 3 feet wide and at least 3 feet deep unless the permafrost table was deeper than 3 feet or excavation was limited by bedrock. Soil profiles were described and sampled according to the *Soil Survey Manual*. Special attention was paid to the cryogenic (caused by freeze and thaw) structures, ice content, and depth of permafrost tables. Soil samples were analyzed according to the USDA National Soil Survey Laboratory procedures.

Soils on the costal plain with wet, nonacidic tundra vegetation are poorly to very poorly drained. Soil occurring on low–centered polygons or waterways have 6 to 10 inches of organic material and on flat or high–centered polygons have deep (more than 16 inches) organic layers over fluvial deposits. These soils have alkaline reactions due to carbonates deposited on the soil surface. Ice wedges are common to these soils. Soil textures are peat and muck in the organic layers and sandy or course loamy in the mineral substratum.

There are two major soil groups on the glaciated foothills south of the coastal plain. Moist, nonacidic tundra soils are formed in calcareous loess over glacial till along the northern edge of the foothills. The soil reactions range from nearly neutral to slightly

Dr. Chien-Lu Ping digging a soil pit.

alkaline. The pH values decrease with depth, indicative of recent deposition processes. Moist, acidic tundra soils are formed in loess over glacial till, extend from south of the nonacidic tundra zone to the footslopes of the Brooks Range. They have acidic to strongly acidic reactions as a result of increased leaching. The base saturation in most horizons is generally less than 40%.

The nonacidic tundra soils are found on low hummocks with frost boils (breaks in the organic layer where mineral soil is pushed up by frost heaving). This suggests a more exposed landscape position. These soils are highly cryoturbated (disturbances caused by frost action). They have warped and discontinuous horizons, frost–churned organic matter into the lower horizons, and a second concentration of organic matter in the upper permafrost layer. These features attest the cryogenic environment.

The acidic tundra soils are found south of the nonacidic tundra soils on landscape dominated by well–developed tussocks and with only occasional frost boils. Ice wedges and strongly developed fine ice lenses in subsoils are common to both kinds of soils. The surface organic layer consists of partially to well decomposed organic matter. The subsoils are loamy or silty and are generally gleyed or strongly mottled. This suggests a fluctuating water table caused by the rise and fall of permafrost due to annual climatic variations. The upper permafrost layers have mucky silty loam texture and well developed ataxitic structures (ice–rich).

Soils along the water tracts and drainage ways are very poorly drained, and inundated during most of the growing season. The submerged organic layer is dominantly muck overlying a strongly gleyed mineral subsoil. A gleyed soil is a sticky, bluish–grey soil formed under the influence of excessive moisture. Soils formed in depressions and valley bottoms are dominantly organic with peat and muck layers exceeding more than 1.5 ft. Due to their landscape positions, these soils are stratified with thin layers of mineral soils.

Soils on the sparsely vegetated upland and alpine tundra do not have permafrost within 6 ft. of the surface. The seasonal freeze–thaw cycle has resulted in strongly developed granular and platy structures in the subsoils. The organic matter accumulation rate is very low. These soils generally have a redder hue due to well–drained conditions. Soils along major river channels also lack permafrost within 6 ft. These soils are coarse–textured and excessively drained. Under shrubby vegetation cover, humus accumulation has produced a dark surface horizon.

In summary, the salient characteristics of the soil formation process include cryogensis, organic matter accumulation, and reduction–oxidation (anaerobic–aerobic). Cryogensis results in patterned ground, causing microrelief and soil drainage differentiation, ice wedges, ice lenses, atazitic structures, and distorted horizons. Due to the cold climates and slow decomposition rate, organic matter accumulates on the soil surface and is incorporated into lower profiles because of cryoturbation. A large portion of the soil carbon is sequestered in the permafrost due to cryoturbation and could be released upon climatic warming. In addition, the upper permafrost layers contain more than 70% water by volume. This excessive amount of water will be released once the permafrost thaws. As a result, there will be more thermokarst lakes and wetlands formed in the arctic slope.

Shain is new reindeer researcher

Welcome!

Dr. Drew Shain joined the Department of Plant, Animal, and Soil Science in January as an Assistant Professor of Animal Science specializing in reindeer.

He comes to us from the University of Nebraska where he earned his Ph.D. in Animal Science–Ruminant Nutrition in 1996. Dr. Shain received his master and bachelor degrees from the University of Wyoming in 1986 and 1983.

Shain's current research interests pertain to the development of and progress toward increasing reindeer production in free ranging and reindeer farming systems. Specific areas of interest include: 1) nutrient availability focusing on mineral, metabolizable, and degradable protein utilization, 2) factors controlling growth and methods of improving the efficiency of growth, 3) utilization of forages in reindeer diets, and 4) factors controlling the reproductive efficiency and survivability of reindeer in free–ranging and game farming systems.

Wetlands could hold the answer

by Jan Hanscom

photo by Ron Kovalik

Dave Maddux inspects wetland plants growing in the Fairbanks area.

Dave Maddux came to Alaska during those years when so many came with 'black gold fever' driven with dreams of making a fortune on the pipeline. Instead he ended up working for a local geological engineering firm and then as a driller. Dave was very good at his job but in his words "It is hard physical labor that was fine when I was younger but..." Now Dave has "swamp fever."

After he decided to find a less physical job, Dave found he needed to continue his education. With that in mind he investigated what UAF had to offer in his areas of interest which included biology, chemistry and zoology. Dave decided an applied education would better meet his needs. This naturally led him to the School of Agriculture and Land Resources Management where he earned his B.S. in '94. Right away he discovered a B.S. didn't allow him to start working at the level he wanted and Dave started thinking of a masters project. His M.S. project grew in scale to become a Ph.D. project with tremendous possibilities to help solve a major problem in rural and urban Alaska alike, sewage treatment.

Dave says he has always loved swamps. As a child, when he went on a walk in the woods, if a wetland was in the way it was a bonus for him. He loved to go right through the middle of the swamp looking for turtles, frogs and anything else that moved. His interest in wetlands and constructed wetlands was re–awakened while taking a class on the ecology of rivers and streams, to the point of building a small wetland at his home.

Dave started his graduate project with a small test in the greenhouse using six native Alaskan plants to test uptake of heavy metals. The plants in this experiment are now being analyzed and preliminary results indicate our plants are just as good at cleaning up Alaskan water as they are in the lower 48. These miracle plants are common swamp plants like cattails, duckweed, reeds, bulrush, and burreed. Alaska does not necessarily have the same species used in wetlands constructed in other locations but we

photo by Yvonne Neiman

Maddux is amazed at how tall wetland plants grow even in the greenhouse.

have many of the same genera of plants. Dave plans on testing them to make sure they are as efficient as their warmer climate relatives. If they are, you can go down to the local swamp, dig a few up, and put in your own sewage treatment wetland.

In the near future, Dave will construct a wetland near the Agriculture and Forestry Experiment Stations' swine sewage lagoon. He will collect data to determine how quickly plants spread to fill an area and therefore how tightly plantings should be done. Various amounts of sewage effluent will be run through this wetland to determine the most efficient area needed to clean the desired amount of sewage and still output clean safe water.

Think what this would mean to the villages of Alaska. They could construct a wetland with an area based on the number of people in the village and the length of the growing season for the plants in their wetland. Then, during the summer months when the plants are actively growing, they will empty their sewage lagoon through the wetland and end up with clean water. There will be no high tech sewage treatment plant to maintain. The villagers will need to maintain a fence around the wetland to keep animals and children from inadvertently getting in. No longer will disease carrying raw sewage be dumped into the local river, lake or tundra.

Presently, most villages have a sewage lagoon for primary treatment of their waste. During primary treatment, large solids sink to the bottom and liquid with suspended solids is left. The lagoon will still be the primary treatment facility.

Some of the concerns expressed about this plan are 1) the growing season is too short to treat all the waste produced, 2) since decomposition rates are slower in our cold temperatures, the system would clog up with dead plant material and 3) it will smell and attract insects. To Dave, the answers to these questions seem very straight forward. For Alaska, the wetland design would be based on the amount of time the wetland will work and will need to be large enough to handle the effluent stored in the lagoon. The decomposition rate may need to be calculated on a site by site basis. Each area would have to monitor their own wetland and determine how long it takes before maintenance of the wetland was required. The sewage cleaning wetland should have little smell and is not expected to attract insects.

Since Maddux has gotten the swamp bug, he goes around town just looking for places his plants might make a difference. In the spring there are many unsightly drainage ditches just crying out for a little help. Now if he can just convince the Department of Transportation or local businesses that this is a better landscaping tool than a grass ditch, Dave will be in business.

Maddux doesn't see the same thing we see when he drives around urban areas. He sees the possibilities those drainage ditches possess. They could be thriving wetland communities instead of garbage collecting, muddy, weedy trenches.

Faculty, students, and alumni in the news

High School Science Symposium

Dr. Pat Holloway worked with two students this semester on experiments related to plants for the high school science symposium. Holloway says they both worked hard and she learned some interesting things as well.

Collin Lichtenberger, a student from Lathrop High School, investigated the effects of Vitamin B_1 on root growth in seedlings. It was believed that drenching seedlings in a vitamin B_1 solution increases transplant survival by increasing root growth. Lichtenberger was told by an Ortho Chemical representative that it was all a hoax. He completed his experiment and discovered that, in the marigold seedlings he tested, there was no effect on roots but there was an increase in the number of flower buds.

Sara Johns, West Valley High School student, wanted to learn about differences in seed germination and growth of pasque flowers originating from different latitudes. Using the Internet, Dr. Holloway helped her track down pasque flower seeds from Nebraska to Alaska. She grew seedlings in a wide range of temperatures and found significant differences in germination rates in seeds from different latitudes. Johns will continue her experiment and set up permanent field plots this summer to look at adaptations of plants from a latitude gradient to subarctic conditions

NRM graduate recognized

Eric Yeager was recently recognized for his work helping the Borealis Kiwanis Club in planning the new Borealis–LeFevre cabin in the White Mountain National Recreation Area. Yeager, 1990 NRM graduate, is an outdoor recreation planner for BLM.

SAF Chair–elect

Dr. Glenn Juday, Associate Professor of Forest Ecology, is the chair–elect of the national Forest Ecology Working Group of the Society of American Foresters. His responsibilities will include serving as policy advisor to the national organization, edit the working group newsletter, and organizing technical sessions for the 1997 and 1998 national meetings of the Society. Dr. Juday has been on the UAF faculty since 1981 teaching in the Forest Sciences Department and conducting research with the Agricultural and Forestry Experiment Station. He previously served on assignment with the USDA Forest Service, Pacific Northwest Research Station, and has worked contractually or on projects with most of the state and federal land management agencies in Alaska.

1996–97 Outstanding Students

SALRM has chosen the 1996–97 Outstanding Students. Each year three students, one from each department, are chosen to receive this award. This year's recipients are **Cheryl Wickstrom**, Department of Plant, Animal and Soil Sciences, **Samantha Lown**, Department of Forest Sciences, and **Rochelle Pigors** from the Department of Resources Management.

Rochelle Pigors has been on the Chancellor's list since her first semester at UAF with a 3.98 GPA. She excels across disciplines, majoring in Natural Resources Management with a minor in history. Pigors' senior thesis is a history of the Fairbanks Agricultural and Forestry Experiment Station.

Samantha Lown, from Juneau, has been on the Dean's list every semester since she enrolled in 1993. She is graduating with a resources option and a strong interest in forestry. Samantha's senior thesis is entitled "Irrigation and Radial Growth of White Spruce in Fairbanks, Alaska."

Enrolled through the Palmer degree program, Cheryl Wickstrom has worked hard and maintained a 4.0 GPA. Her unique and timely senior thesis, "Landscaping Recommendations to Reduce your Home's Risk in the Event of a Wildfire," will be published by the Division of Forestry.

Watch for it

Harry Bader, Associate Professor of Natural Resources Law, was recently interviewed by CNN's Steve Darby about his work in Bosnia. Bader is involved with a project, in cooperation with the United Nations, to use satellite spectral imagery to provide critical data on Bosnia concerning war crimes and economic reconstruction. He expects the interview to air this summer.

Alumni gets promoted

1974 NRM M.S. graduate, **Jerry Brossia**, was recently selected as the BLM authorized officer with lead federal responsibility over the Joint Pipeline Office. The JPO is a consortium of six state and five federal agencies given the task of regulating the Trans–Alaska Pipeline System and other oil and gas pipelines in Alaska.

Wetland Possibilities

Alaska's Interior has an abundance of land designated as wetlands. A Ph.D. candidate for the School of Agriculture and Land Resources Management believes these lands have an even greater purpose than using for wildlife habitat. The related story begins on page 37 (photo by Ron Kovalik).