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Pacific Northwest Laboratory Annual Report for 1978 to the DOE Assistant Secretary for Environment

Part 2 Supplement Ecological Sciences
July 1979

Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830

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B. E. Vaughan and Staff Members
of Pacific Northwest Laboratory

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Pacific Northwest Laboratory
Richland, Washington 99352

FOREWORD

In 1974 the Energy Research and Development Administration (ERDA, now Department of Energy, DOE) began funding several environmental programs that investigated the impacts of petroleum developments in northern Alaska. The program for which 1978 results are reported here began at that time as an extension of ecological studies that were conducted at Prudhoe Bay during 1971-1973. Those studies were funded by companies that formed the Gas Arctic/ Northwest Project Study Group to investigate the environmental implications of an experimental natural gas pipeline simulation in arctic tundra situations.

Various aspects of the 1978 studies were conducted under permits granted by the Atlantic Richfield Company; Sohio Petroleum Company; Alyeska Pipeline Service Company; Arctic Slope Regional Corporation; State of Alaska Departments of Fish and Game, Environmental Conservation, and Natural Resources; and U.S. Department of the Interior, Fish and Wildlife Service. The Studies were expedited by the cooperation of Alan Sargeant of the Northern Prairie Wildlife Research Center at Jamestown, North Dakota and Jim Helmericks of Colville Village, Alaska.

This program has been continuously supported by the Department of Energy Ecological Research Division through Contracts W-7405-ENG-36 at Los Alamos Scientific Laboratory (LASL) and EY-76-C-06-1830 at the Pacific Northwest Laboratory (PNL).

This is a report of progress made in research conducted in northern Alaska during Fiscal Year 1978 while the program was at LASL. On October 1, 1978 the program was transferred to PNL. While the transfer worked well from an administrative standpoint, it occurred at an inopportune time so far as reporting schedules were concerned; as a result, it was inconvenient at both LASL and PNL to fit this information in the annual report production schedule. We have, therefore, taken an alternative course to provide the sponsor and interested colleagues with this report of our 1978 results as a supplement to PNL-2850 part 2, Ecological Sciences.

Previous reports describing this program can be found in Los Alamos Scientific Laboratory Reports: Biomedical and Environmental Research Programs of the LASL Health Division for 1975, 1976, 1977. LA-6313-PR, LA-6898-PR and LA-7254-PR.

Burton E. Vaughan
Subprogram Manager
Ecological Sciences

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12.0 Alaskan Environmental Research

ALASKAN ENVIRONMENTAL RESEARCH

• Ecological Consequences of Energy Resource Developments in Northern Alaska

Studies were conducted in northern Alaska in 1978 on arctic foxes, tundra-nesting birds, small mammals, caribou, lichens, and fallout radionuclides in the lichen-caribou-Eskimo food web in an effort to increase understanding of the structure, function, and sensitivity of the tundra ecosystem and the environmental costs of energy resource developments in northern Alaska.

Based on these investigations it is apparent that local arctic resource development such as the Prudhoe Bay oil field activities have a broader geographic and ecological impact than generally realized. Long-range movements of arctic foxes and the distant migration patterns of semipalmated sandpipers documented during these ongoing studies emphasize the potential for wide-spread impact of localized development activities. Both potentially beneficial and detrimental impacts have been noted in the Prudhoe Bay area. It is probable that the artificial food sources available to arctic foxes at the Prudhoe Bay oil camps may have increased their ability to survive and successfully reproduce during natural cyclic lows of their major prey species, lemmings. However, this fostering of fox populations may exacerbate natural periodic rabies epidemics in this species. Banding studies show that many tundra-nesting birds prefer specific areas for their nesting sites, suggesting that the loss or alteration of such habitat by industrial development heightens competition among the species affected and presumably results in the loss of some individuals.

Integration and synthesis of the information developed on northern Alaskan lichens photosynthetic patterns, gas exchange rates, productivity in grazed and ungrazed areas, and sensitivity to sulfur dioxide with earlier studies on compartmentalization and cycling of worldwide fallout radionuclides have provided greater insight into the structure and function of the northern Alaska ecosystem. This is particularly valuable in explaining the radionuclide cycling phenomena in the lichen-caribou-Eskimo food chain that is of abiding interest. The range component use pattern, particularly the shifting of the caribou diet from lichens to vascular plants in the spring and summer, explains the decline of fallout ^{137}Cs concentrations in caribou flesh during that period.

• ECOLOGICAL CONSEQUENCES OF ENERGY RESOURCE DEVELOPMENTS IN NORTHERN ALASKA

Principal Investigators: W. C. Hanson and L. E. Eberhardt

Field Technicians: R. A. Garrott, D. A. Garrott, E. E. Hanson and S. G. Jones

The objective of this research is to provide an integrated program of investigation for the definition of the ecological consequences of resource developments in northern Alaska. Qualitative and quantitative results are obtained that describe environmental costs incurred by petroleum resource extraction and transportation, including interaction of industrial activities with arctic foxes (Alopex lagopus), small mammals, and tundra-nesting birds in the Prudhoe Bay field and along the Trans-Alaska pipeline and haul road; similar information from the Colville River delta for comparative purposes; baseline information on moose (Alces alces) populations, caribou (Rangifer tarandus) range quality and use, and lichen communities that are or will be impacted by resource developments; field experiments to determine lichen sensitivities to sulfur oxide concentrations likely to be encountered near pipeline pumping stations; food chain transfers of stable and radioactive elements that utilize a data base of some 19 years for comparative purposes; and evaluation of oil field development activities on rabies and other physiological phenomena in foxes. A significant fraction of the research is coordinated through university contracts that utilize academic researchers in specific areas of expertise.

During 1978 research by the authors and university subcontractors from the University of Alaska, Pennsylvania State University, and Arizona State University continued to emphasize investigations on the ecological consequences of petroleum resource development in northern Alaska. Studies were conducted this year on arctic foxes, tundra-nesting birds, small mammals, caribou, lichens, and fallout radionuclides in the lichen-caribou-Eskimo food web.

Lichen Studies

Integration and synthesis of the information developed on northern Alaskan lichens photosynthetic patterns, gas exchange rates, productivity in grazed and ungrazed areas, and sensitivity to sulfur dioxide with earlier studies on compartmentalization and cycling of worldwide fallout radionuclides (Hanson and Eberhardt, 1973) have provided greater insight into the structure and function of the northern Alaska ecosystem. This is particularly valuable in explaining the radionuclide cycling phenomena in the lichen-caribou-Eskimo food chain that is of abiding interest. The range component use pattern, particularly the shifting of the caribou diet from lichens to vascular plants in the spring and summer, explains the decline of fallout ^{137}Cs concentrations in caribou flesh during that period.

A third year of study by Arizona State University personnel produced information in two areas of interest: a) the photsynthetic response of common lichens to long-term sulfur dioxide fumigation of natural lichen communities; and b) daily photosynthetic patterns and productivity of common arctic lichens, particularly the major caribou forage lichens Cladonia stellaris (= C. alpestris) and C. rangiferina (Nash and Sommerfeld, 1978).

Sulfur dioxide fumigations were made with a 18-kg tank of SO_2 and a tubular fumigation apparatus placed in the middle of a 1-m x 4-m plot in a relatively dense Cladonia-Cetraria lichen community. Continuous fumigation was conducted during the period June 27 to August 5. A modified Shimshi porometer was used to monitor photosynthetic activity by measuring incorporation of

$^{14}CO_2$ by the growing tips on weekly basis of five lichen species: Cladonia stellaris, C. rangiferina, Cetraria nivalis, C. richardsonii, and Peltigera canina. Samples of the fumigated plot were stratified to include specimens from 0.5, 1.0 and 2.0 m distances from the fumigation apparatus. Sulfur dioxide concentrations in the atmosphere at these same distances were measured with a portable SO_2 analyzer. Nonfumigated control samples were monitored in the same manner.

Results showed that the fumigated specimens were initially photosynthetically active at rates not significantly different from the controls and then exhibited significant declines in photosynthetic activity, beginning with the fumigated samples closest to the SO_2 source. Initial response was documented at 0.5 m at 16 days exposure and the effects then developed progressively away from the fumigation source. Artifically moistened samples of both fumigated and control lichens demonstrated the potential for photosysthesis, particularly on dry days, up to 8 days after the experiment started. In the next week there was significant reduction in photosynthesis in the 0.5 m stratum and thereafter no photosynthetic activity was detectable in samples from that position although activity continued to be observed in the control samples. In summary, it appeared that SO_2 concentrations of 0.62 ± 0.31 ppm were sufficient to inactivate the species studied.

The photosynthetic study of caribou forage lichens employed the modified Shimshi porometer to obtain measurements of photosynthetic activity over 24-hr periods during five summer days. Sampling time during each 24-hr period was concentrated in the early morning hours of optimum environmental conditions for photosynthesis. Emphasis was placed on the species Cladonia stellaris and C. rangiferina, with ancillary information from Cetraria richardsonii, C. cucullata, and Dactylina arctica. Environmental parameters of air temperature, relative humidity, and solar radiation were monitored during the course of each sampling date.

Results confirmed the 1976 studies of Cetraria cucullata and the 1977 studies of physiological distribution of photosynthetic activity in lichens (Moser and Nash, 1978), revealing that most of the photosynthesis occurs in the upper few mm of the lichen thallus. This gradient was also apparent in C. richardsonii, a foliose species, where photosynthetic activity was greatest in the tertiary branching tips, with significantly less activity in the sesecondary and primary branches. Photosynthetic activity in the lower portions of the C. cucullata thalli, although significantly less than the growing tips, showed a tendency for an extended period of activity after the tips had dried and become inactive. That condition did not exist in C. richardsonii, which is a species that lies relatively flat on the top of the Cladonia-Cetraria lichen mat.

Photosynthetic patterns of all lichen species studied were very similar and were directly dependent on high atmospheric moisture content for photosynthetic activity, such as occurs during periods of rain or fog. Low levels of CO_2 accumulations observed during the hours of 2400-0200 were in response to low light intensities which consistently occur at that time of day at that latitude (68°06'). A differential photosynthetic activity period between lichens growing on north and south slopes was noted. North-facing slope samples had an earlier peak in photosynthetic activity than those from south-facing slopes but it was of shorter duration. This contrast of periodicity appeared to be strongly correlated with differences between north and south slopes in terms of relative humidity, air temperature, and solar radiation.

Samples of C. stellaris and C. rangiferina were air-dried and shipped to the University of Würzburg, West Germany, where they were analyzed for gas exchange capabilities by the infrared techniques of Lange (1969). Those results showed a clear gradient in metabolic activity (both respiration and photosynthesis) from the tips of the lichens to the base of the lichen mats. The effect was most pronounced in photosynthesis, where essentially 100% of the activity was restricted to the top half of the lichen mat (0-4 cm). In contrast, about 80% of the respiration in C. stellaris and 67% of the respiration in C. rangiferina was concentrated in the top half of the lichens. Further partitioning of the top half of the lichens into progressively smaller sections demonstrated that peak activity occurred in the tips (0-0.5 cm) for both photosynthesis and respiration. The underlying chemical-physical basis for the observed differences in photosynthetic rates is the corresponding differences in chlorophyll a and b concentrations. In terms of chlorophyll concentrations, there is a clear gradient with the highest concentrations in the top 0.5 cm and the lowest values in the bottom portion of the lichens.

The productivity study of lichens (Moser, 1977) was extended to include an evaluation of the effects of caribou grazing on lichen mats of the Anaktuvuk Pass region. During a portion of the 1967-1968 winter, a herd of about 4,000 caribou wintered at the Anaktuvuk Pass village site and severely

overgrazed lichen communities with <0.6 m of hard snow cover. To quantify the grazing effects eight years later, sampling for biomass was employed in grazed and ungrazed areas. Microclimate effects on vegetational composition was offset by sampling only on north and south slopes. Bias in site selection was reduced by criteria of slope and exposure that identified 17 slopes as candidates, of which 10 (5 north and 5 south) slopes were randomly selected for future sampling. After the snow had melted, clearly distinct grazing lines were distinguishable so that the selection of grazed and ungrazed areas involved minimal subjectivity. A total of 140 2-dm x 2-dm quadrats were sampled, 70 from each of ungrazed and grazed plots.

There were substantial differences between biomass yields from the ungrazed and grazed plots, with mean values about six times greater in ungrazed than grazed plots on south slopes and eight times greater on north slopes. In contrast, the confidence intervals clearly overlapped when north and south slopes were compared within a grazing combination, indicating no significant diffence in total lichen biomass attributable to exposure effect. The four most common species, Cladonia stellaris, C. rangiferina, C. arbuscula and C. mitis, made up about 80% of the biomass in ungrazed areas and occurred in almost equal abundance on north and south slopes when compared in grazed and ungrazed plots. In contrast, all four species showed significant reduction in biomass from ungrazed to grazed areas within a particular slope. Asahinea chrysantha was the only macrolichen that exhibited higher biomass values in grazed areas than in ungrazed areas, indicating a clear role for that species in the successional process. Sterocaulon alpinum was three times more important, on a percentage basis, in grazed areas on south slopes than in ungrazed areas. Thus this species, as a nitrogen fixer with the alga Nostoc in its cephalodia, may also have an important role in the successional sequence, a role that persists into the mature lichen mat stage where its absolute abundance is even greater.

In areas of only moderate caribou (or reindeer) grazing, recovery of lichen mats may be expected in 8-16 years because the lichens have not been grazed below the actively growing portions (Pegau, 1968). However, the Anaktuvuk Pass area represents a different situation where the caribou grazing has essentially removed the whole mat. Thus, recovery will predictably take much longer, probably on the order of 25 to 50 years.

The taxonomic study of Anaktuvuk Pass lichens has now added 228 species in 71 genera to the previously reported lichen flora (Murray 1974), making a total of 287 species in 71 genera for the area. Of these, 42 are new reports for the North Slope of Alaska and one, Aspicilia plicigera, is a new report to North America.

Caribou Range Studies

A second season of field work in the Utokok River region of northwestern Alaska was completed to determine the chronological order and degrees of use of vegetation components by the Western Arctic Caribou Herd and to determine the relative quality of their forage. This study concentrated on the core and peripheral calving grounds of the caribou and emphasized forage selection, forage intake rates, and vegetation sampling to obtain data for calculation of forage use:availability ratios.

Preliminary results (Kuropat, 1978) suggest that lichens and floral heads of cottongrass (Eriophorum vaginatum) were the primary food of the caribou during and immediately following the calving period. It is also noted that rock (Lagopus mutus) and willow (Lagopus lagopus) ptarmigan were very abundant in the area and also heavily utilized the floral heads of the cottongrass. As during the 1977 season, it was apparent that intensive use of this food resource by both animals could lead to competition between these species during this important period.

When the caribou calves were 3-4 weeks old the adult caribou shifted their diet to lupine (Lupinus arcticus) and willows (Salix glauca and S. pulchra) when the lupine floral heads emerged and willow leaf expansion occurred. Willows of several species then became the major food item of both cows and calves during the remainder of the summer season, with a variety of forbs being used in lesser amounts. Suitable samples of all observed food items were collected for chemical analysis to be completed at a later date.

Vegetation mapping and areal estimates of forage types in the calving grounds were initiated by use of Landsat and high altitude photography of the National Petroleum Reserve Alaska area made available through the U.S. Geological Survey in California.

Arctic Fox Studies

It is now apparent that the implications of the Prudhoe Bay oil field development have broader geographical and ecological impacts than generally appreciated. These impacts have both beneficial and detrimental aspects, as illustrated by the apparent

survival value to arctic foxes of the artificial food resources available at Prudhoe Bay oil camps. The increased reproduction by foxes in that region this year while their natural food resource, the lemming, remained low in population densities may be a positive result of such an impact on the system. If the fostering of fox populations exacerbates the periodic rabies epidemics that occur in circumpolar areas in general and Prudhoe Bay in particular, a negative aspect is apparent. The potential effect is of increased importance in the future if public access to the North Slope is realized. The long-range movements of foxes documented this year and the migration patterns of semipalmated sandpipers noted last year emphasize the extensive impact of the localized resource activities. The specificity of many tundra-nesting birds for certain areas for their nesting sites was demonstrated by banding studies; this suggests that the loss or alteration of such habitat by industrial development heightens competition among the species affected and presumably results in the loss of some individuals.

The second year of an intensive study of the arctic fox populations on the Colville River Delta, an undisturbed area approximately 80 km west of the Prudhoe Bay oil field activities (Figure 12.1) was conducted by a graduate student of Pennsylvania State University (Garrott and Garrott, 1978). Fox populations at both the Colville River Delta and the Prudhoe Bay area have begun recovering from the cyclic low experienced in 1977 (Hanson and Eberhardt, 1978) as measured by the percentage of fox dens with juvenile animals present (Table 12.1). Numbers of small mammals, primarily varying lemmings

TABLE 12.1. Arctic Fox Dens Examined on the Prudhoe Bay and Colville River Delta Study Sites

	Prudhoe Bay Site		Colville River Delta Site	
Year	No. of Dens Examined	Percent with Juveniles	No. of Dens Examined	Percent with Juveniles
1975	17	71	—	—
1976	20	85	30	37[a]
1977	19	21	39	5
1978	10	50	46	44

[a] Minimum percentage, based on aerial survey only with no ground check.

(Dicrostonyx groenlandicus) and brown lemmings (Lemmus sibericus) that are a major prey of arctic foxes, have apparently increased at the Colville River Delta since the 1977 population low; however, similar increases were not observed at Prudhoe Bay (Table 12.2). Why fox reproduction success increased at Prudhoe Bay from 1977 while lemming population densities appeared to remain extremely low is unclear.

Aerial census techniques for determinating the density of arctic fox families during the spring or summer on the Colville River Delta were refined. Development of reliable census techniques is important for obtaining population densities to evaluate the impact of resource development, the impact of prey species cycles on arctic fox populations, and for management decisions about this species as a fur resource. Optimum time for conducting a census appears to be in early August when the juveniles are spending a maximum amount of time

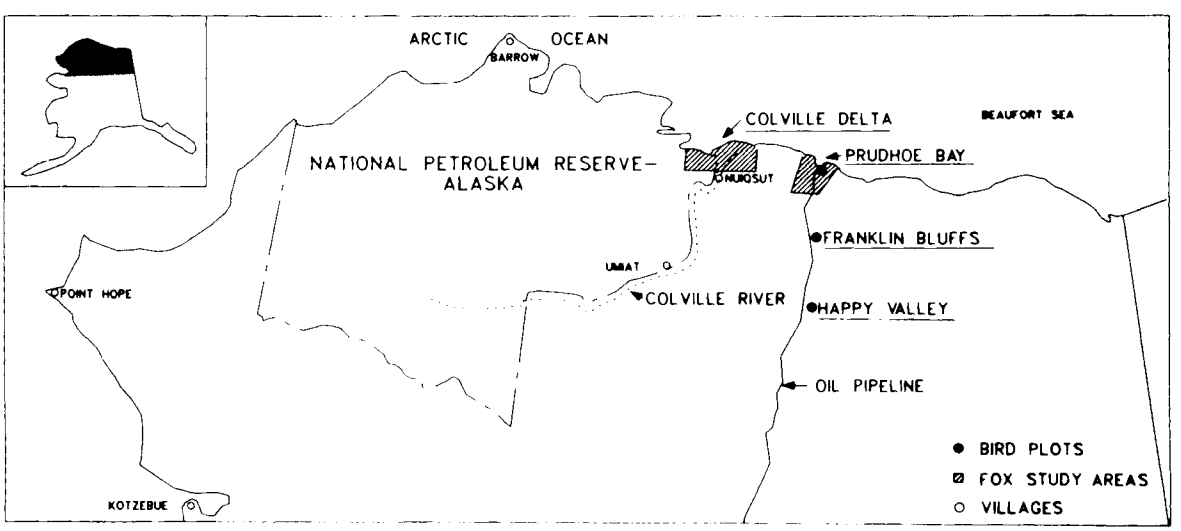


FIGURE 12.1. Study Sites in Northern Alaska

TABLE 12.2. Small Mammal Trapping Results at the Prudhoe Bay and Colville River Delta Study Sites

	Prudhoe Bay		Colville River Delta
Year	Snap Trapping[a] (No./1000 Trap Nights)	Live Trapping[b] (No./Hectare)	Snap Trapping[a] (No./1000 Trap Nights)
1975	9.1	19.2	—
1976	8.7	7.1	—
1977	1.8	0	4.7
1978	0	<1	11.3

[a]Using Pitelka (1973) trap lines.
[b]Sherman live traps on 17 individual grids of 0.116 ha each operated for about 3840 trap nights each season.

outside the den and yet not dispersing widely from the immediate vicinity. Ground checks following aerial surveys of dens on the study area revealed that 91% of the active dens were correctly identified from the air in August while only 50% were correctly identified in July. Optimum times for observing juvenile foxes were in the early morning and late evening hours on cool, breezy days with no precipitation. Optimization of the flight times was based on 600 hours of observation of juvenile fox activity at dens and monthly aerial census of the Colville River Delta region.

Forty-eight arctic fox dens in the Colville River Delta study area were examined for activity. Twenty-two (46%) were vacant, three (6%) were occupied by adults only, and twenty-three (48%) were occupied by a family group during at least part of the denning season. At least 4 of the 23 dens occupied by family groups were not utilized during the entire denning season as two family groups abandoned their natal dens in July and took up residence in previously unoccupied dens within 1.5 km of the natal dens.

Summer food habits of foxes were determined through 35 scat collections from 17 different dens and by recording den litter at 24 dens. Scat samples have yet to be analyzed; however, bird remains were the most commonly recorded prey remains, occurring at 75% of the dens, and represented a wide variety of avian families. Arctic ground squirrels (Spermophilus undulatus) were found at 50% of the dens, egg shells at 38%, caribou at 30%, and small mammals and fish at 17% of the dens.

Forty fox carcasses were collected from the Colville River Delta and Arctic Coast trappers during the 1977-78 trapping season, most of them taken during December 1977. Several indices of the relative health of the animals were measured in each fox including body weight/length ratios; relative amounts of subcutaneous heart and gut fat; organ weights; analysis of histological sections of 13 organs; stomach contents and intestinal tracts for parasites; and examination of reproductive tracts to determine reproductive history of all female foxes and other population parameters. Age structure of the fox population sample was determined by examining cementum annuli in extracted and sectioned teeth. Results suggest that the relatively poor physical condition of this sample from the Colville River Delta region may be a result of limited food supplies, as indicated by the very low small mammal population densities shown in Table 12.2. However, another possible explanation of the poor physical condition could be the physical stress on the animals that was induced by the trapping process. Foxes that were caught in leg-hold traps may have been in the traps for several days before the animal was killed by the trapper or froze to death. Such stress may have seriously affected such health indices as body length/weight ratios and amounts of various fat deposits. Future carcass collections will hopefully include animals that have been killed soon after being trapped so suitable comparisons can be made. The histological data and parasite information is probably not affected by the trapping stress and will be available in the future.

There was a balanced sex ratio in the 1977-78 population sample but the age structure was significantly different from results obtained one year earlier. Only animals one year old or less were trapped in the 1976-77 season, with 75% of the 16 animals being pups (~8-10 months old) and four were yearlings. This same ratio was present when the data were separated on the basis of sex. In contrast, the 1977-78 sample contained almost equal numbers of pups, yearlings and two-year-olds, with a few three- and four-year-old animals. When separated into sexes, however, male pups were trapped in greatest numbers and four-year old males were trapped the least. Among females, one- and two-year-old animals predominated. These differences in age structure of the trapped samples for the two years were presumably a reflection of the denning success and production in the study area during the previous summers. Although intensive work was not begun in the Colville River Delta until 1977, aerial surveys of the area indicated good production there for the 1976 denning season. This portended a large population of pups in the wintering population, which was borne out by the trapped sample. Production was very low during the 1977 summer and portended a majority of older foxes in the sample. Age structure

data for the winter of 1977-78 supports that conclusion but further indicates that a fair number of dens were successful in producing young to contribute one-third of the trapped sample.

The first year of a behavior study of the interactions of penned arctic and red foxes (Vulpes vulpes) was conducted by a Pennsylvania State University graduate student at the U.S. Fish and Wildlife Service Northern Prairie Wildlife Research Center in Jamestown, North Dakota. The purpose of this investigation (Graves and Rudzinski, 1979) is to determine the interrelationships within and between two closely related species whose ranges overlap in the region currently being impacted by northern Alaskan petroleum development. An understanding of this relationship is necessary to evaluate the potential effects of development on these species. The experimental design used comprised releasing a pair of arctic foxes into a 4-ha enclosure that contained artificial and natural dens, allowing them to acclimate for one week, and then releasing female and male red foxes on different days. When the female red fox was put into the enclosure, all three animals shared the east side but the arctic foxes usually gave up the preferred area to the invading female red fox. They avoided her or threatened her when she approached their withdrawal area too closely. Placing the male red fox into the enclosure after several days intimidated the arctic foxes to a greater degree. Chases became more frequent and the arctic foxes generally decreased their activity and avoided the red foxes by moving to less preferred areas within the pen. Several replications of the experiment with naive animals yielded similar results.

A continuing study of the comparative metabolism of arctic and red foxes was conducted at the animal facilities of the Naval Arctic Research Laboratory at Barrow, Alaska. This project involves experiments in determining energy requirements of the two species during various seasons and the determination of lower and upper critical temperatures of these animals. These are, respectively, ambient temperatures that require an animal to increase metabolism to maintain the body core temperature when subjected to low and high temperatures that exceed those limits. These phenomena are a function of the insulation and behavior of the animals, and may partially explain differences in distribution, territory size, den utilization and other parameters dependent upon differential energy requirements. The abilities of these two species to adapt to the Alaska North Slope environment, particularly the low temperatures and substantial winds, may be partially determined by these differences. The study was seriously impaired shortly after initiation by an accident in which a visiting scientist irreparably damaged the gas analyzer and a replacement instrument could not be obtained until late in 1978. Ancillary data was obtained in a feeding experiment involving five arctic foxes (3 adults and 2 6-month-old pups) and three adult red foxes that were fasted for two days, fed chicken necks ad libitum for 12 days and then fasted for two days. Records were kept of body weights and food ingestion rates before, during, and after the feeding trials. The amounts of food eaten by both species varied during the four seasons of the study. Arctic foxes averaged higher food consumption per kg body wt than the red foxes during winter, spring, and summer periods, in marked contrast to results from the fall experiment (Table 12.3). Feces samples collected throughout the experiment will be combusted in an oxygen bomb calorimeter and compared with suitable samples of food to determine the digestive efficiencies of the two fox species.

TABLE 12.3. Food Consumption per kg Body Weight by Arctic and Red Foxes During Various Seasons of the Year at Barrow, Alaska

	Amount of Food Consumed in kg/kg Body Wt.	
Season	Arctic Foxes	Red Foxes
Winter	0.90	0.86
Spring	0.87	0.59
Summer	1.14	0.96
Fall	0.52	0.85

Nine more arctic foxes were trapped, tagged and released as part of our studies during the year bringing to 202 the total number of animals marked since March 1975. Most (164) animals were marked at Prudhoe Bay, 25 at the Colville River Delta study site, and 13 at the Franklin Bluffs pipeline construction camp. Eighteen tagged animals have been recovered since the study began; eight were killed by trappers, five by vehicles, one was shot, and four died from unknown causes. The 4% ear-tag return rate from trappers during this study was considerably less than the 15% trap return rate reported during a 2.5-yr study on Banks Island, Northwest Territories (Urquhart, 1973) and the 14 and 16% rates for studies conducted in the USSR (Smirnov, 1967). The reasons for this difference are unclear but presumably related to differences in local trapping pressure. Seven long-distance movements by tagged arctic foxes have been documented thus far (Figure 12.2 and Table 12.4) and have now been reported in the open literature (Eberhardt and Hanson, 1978). Distances moved from the initial tagging locations ranged from 129 to 945 km. One

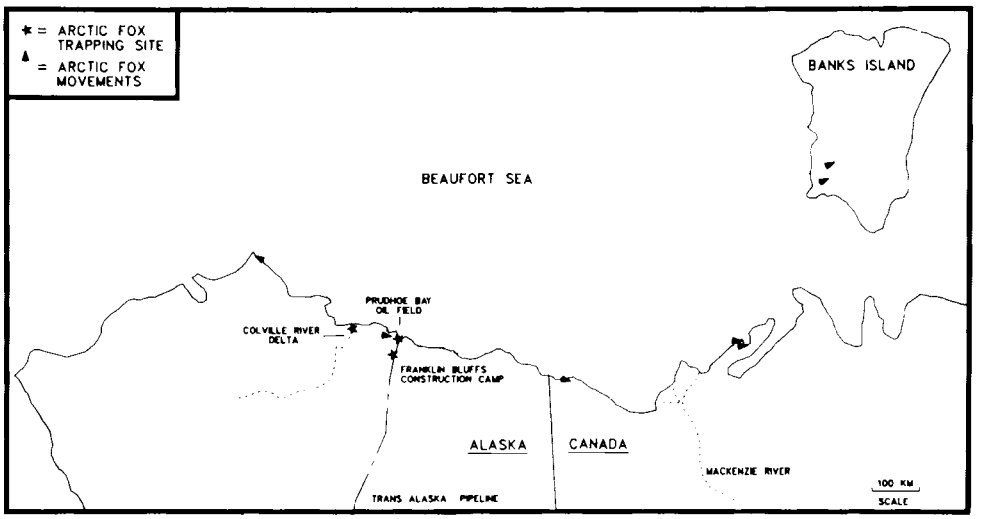


FIGURE 12.2. Long-Distance Movements of Arctic Foxes Tagged in Northern Alaska

TABLE 12.4 Long-Distance Movements Made by Arctic Foxes Tagged in Northern Alaska

Sex	Age (months)	Location, Date Tagged	Location, Date of Return	Method of Return	Distance Moved (km)	Number of Days
Male	9	Prudhoe Bay 16 March 1975	Firth River, N.W.T., May-June 1975	Observa-tion	338	35-81
Male	9	Franklin Bluffs Const. Camp. 17 March 1975	Banks Island, N.W.T., 28 March 1976	Trap	945	376
Male	9	Franklin Bluffs Const. Camp. 18 March 1975	McKinley Bay, N.W.T., 15 April 1975	Trap	676	28
Male	7	Prudhoe Bay 11 January 1977	Banks Island, N.W.T., 2 April 1977	Trap	901	81
Male	3	Colville River Delta 9 July 1976	Tuktoyaktuk Peninsula, N.W.T., March 1977	Trap	781	234-265
Female	3	Colville River Delta, 10 July 1976	Prudhoe Bay, Alaska 9 January 1977	Shot	129	183
Female	3	Prudhoe Bay 14 July 1976	Barrow, Alaska, 21 December 1976	Trap	330	160

additional long-distance movement of 2000 km by an arctic fox has been documented since the above publication. These movements are comparable to the results of small-scale arctic fox tagging studies conducted in Canada within recent years. Results of small mammal trapping indicated that lemming population densities were high to moderate in 1975 and 1976 and very low in 1977. Comparison between lemming densities, the major prey of arctic foxes as determined by a previous study funded by this program (Eberhardt, 1977), and fox movements indicates that long-distance movements were made in both high and low lemming years, which suggests that at least some movements are made irrespective of local food availability. Travel rates of foxes making the long-distance movements were estimated at <1 km/d to about 24 km/d if it is assumed that the capture dates reported by the trappers were correct; an average rate of about 24 km/d was indicated, reasonably close to the 20-27 km/d as maximum rates of travel reported in the literature.

The results demonstrate the ability of arctic foxes to make long-distance movements in relatively short periods of time. This mobility is of obvious survival value during periods of local food shortage, particularly in the Arctic where the food base is limited and cyclic in nature. Because some long-distance movements are made during apparently "good" food years, causal factors in addition to food may be involved. The significance of these long-distance movements is not fully understood, but the movements probably affect

the spread of rabies and other arctic fox diseases and may extend the impact of local arctic resource developments on arctic fox populations.

A study of interactions between arctic foxes and the small mammals and tundra-nesting birds that serve as prey items for the foxes was undertaken by a University of Alaska graduate student at the Colville River Delta (Gipson and Ellison, 1978). Plans called for construction of a 10-ha fox-proof exclosure consisting of four strands of electrified wire located near an arctic fox den and unfenced control plots of the same size and general habitat composition. Comparison of nesting bird success and small mammal populations in the exclosed plot and the unfenced plots were expected to provide a measure of the impact of arctic foxes on the prey species. This fencing technique, although successfully used elsewhere with red foxes, proved unsatisfactory at the Colville River Delta site primarily because of the logistics involved in maintaining the fence in this remote region and repeated destruction of the fence by caribou. The experience showed that in order to be effective the fence posts should be of much lighter construction, such as fiberglass, and driven into place at the end of the summer preceding erection of the fence. This would provide the necessary rigidity the following spring. Effective insulators are a necessity to make the fence operate properly and dry cell batteries are recommended for ease of transportation and maintenance.

Small Mammal Studies

Sherman live-traps were used in capture-mark-recapture studies on replicated 0.116 ha (30.5 x 38.1 m) grids at the Colville River Delta, Prudhoe Bay, and Franklin Bluffs. Thirty traps were placed at ∿8-m intervals in a 5 x 6 pattern within each grid and baited with rolled oats and peanut butter. At the Colville River Delta, the trapping was conducted on four grids within each of the control areas and exclosure area during two consecutive trapping sessions of 20 days each, yielding 4800 trap-nights of effort.

A total of four juvenile and one adult varying lemmings were captured, marked, and released during the effort; none were recaptured and a population estimate was not obtained. Other trapping conducted in the vicinity in conjunction with the arctic fox studies also indicated a very low, but recovering, small mammal population density in the Colville River Delta during the summer of 1978 (Table 12.2).

An effort of 4,080 trap-nights was made at the seventeen 0.116-ha grids located at the Prudhoe Bay Test Site (Battelle, Columbus Laboratories, 1973). Two adult lemmings, one brown and one varying were captured, marked and released. The latter was caught 7 days later in a snap-trap about 400 m from its initial point of capture. The brown lemming was recaptured during the same four-day session within the same grid but at a different location. These data indicate that the small mammal populations at Prudhoe Bay, like that at Colville River Delta, remained at a low density during 1978 but were beginning to increase from the extreme low observed during 1977.

The trapping of small mammals at Franklin Bluffs was slightly modified from previous years (Brink, 1977). Originally, the study plan was to trap the 32 grids of 0.116-ha each located within a 75-ha plot that transects both the haul road and buried pipeline for two complete sessions. However, after the first complete trapping cycle it was decided to not retrap those grids on which no animals had been captured during the first session and to substitute a new grid within that area to determine whether habitat parameters might account for the lack of animals. As a result, 23 grids were sampled during two sessions and 18 were sampled during a single session. This constitutes a trapping effort of 7680 trap-nights and yielded 141 small mammals (Table 12.5). Tundra voles (*Microtus oeconomus*) were the most numerous, constituting 63% of the animals captured; singing voles (*M. miurus*) and arctic shrews (*Sorex arcticus*) were nearly equal (16% and 13%) in captures but at only one-fourth the number of tundra voles; and varying lemmings made up 7% of the sample population. A

TABLE 12.5 Small Mammals Live-Trapped at Franklin Bluffs During the Period July 18-August 26, 1978

	Tundra Vole		Singing Vole		Varying Lemming		Arctic Shrew		Red-backed Vole		
Location	Adult	Subadult	Adult	Subadult	Adult	Subadult	Adult	Subadult	Adult	Subadult	Total
Original Grids (32)	26	41	4	8	4	5	10	0	1	0	99
New Grids (9)	7	15	4	6	0	1	9	0	0	0	42
Totals	33	56	8	14	4	6	19	0	1	0	141

red-backed vole (Clethrionomys rutilus) was captured in Grid 5B (Figure 12.3). Of the 141 animals trapped, 99 were captured in the original 32 subplots trapped in previous years and 92 survived the trapping experience. Fifty-six individuals were marked and released, of which 20 were recaptured from one to four times during the second trapping session. This yielded an overall (Table 12.6) population estimate of 67 ± 582 animals per hectare, which accounts for the great variance in the population estimate and illustrates the appreciable demand in manpower and logistics that discourages most uses of mark-recapture techniques in arctic small mammal studies except during periods of abundance (Pitelka, 1973).

Ground squirrels caused 1110 trap-nights to be lost by their disturbance of traps as they removed the cotton nesting material. Most of this activity occurred during the second trapping session and within Grids 3, 4 and 5. Six particularly bothersome ground squirrels were live-trapped and transported several kilometers away from the study site to remedy the problem.

Captures of small mammals showed fairly specific habitat preferences (Figure 12.3). Arctic shrews were strongly associated with dense sedge (Carex aquatilis) meadow habitat in Grids 7 and 8. Tundra voles were fairly abundant in all habitats that contained a dense vegetation cover, particularly in Grids 5, 6, 7 and 8. These voles construct extensive runway systems that are apparently used communally, as indicated by many different individuals being trapped at the sample locations. The runway systems were most often located along the base of polygon ridges where the physiographic and vegetative characteristics of the habitat offered greatest cover. If no such dense habitat occurred at trapping sites within a subplot, no captures were made even though extensive habitat of dense sedge and polygon ridges may have existed nearby.

Singing voles also constructed runways that were used communally, but the only captures of these animals occurred in habitats that contained at least a small portion of shrubby willow (Salix lanata) cover, such as in subplots 3B, 3D, new subplots 4E and 4F, and 5C. This vole apparently climbs into the willows to cut fresh leaves, which are then taken back to their burrows. Small piles of willow leaves were found near the burrow openings.

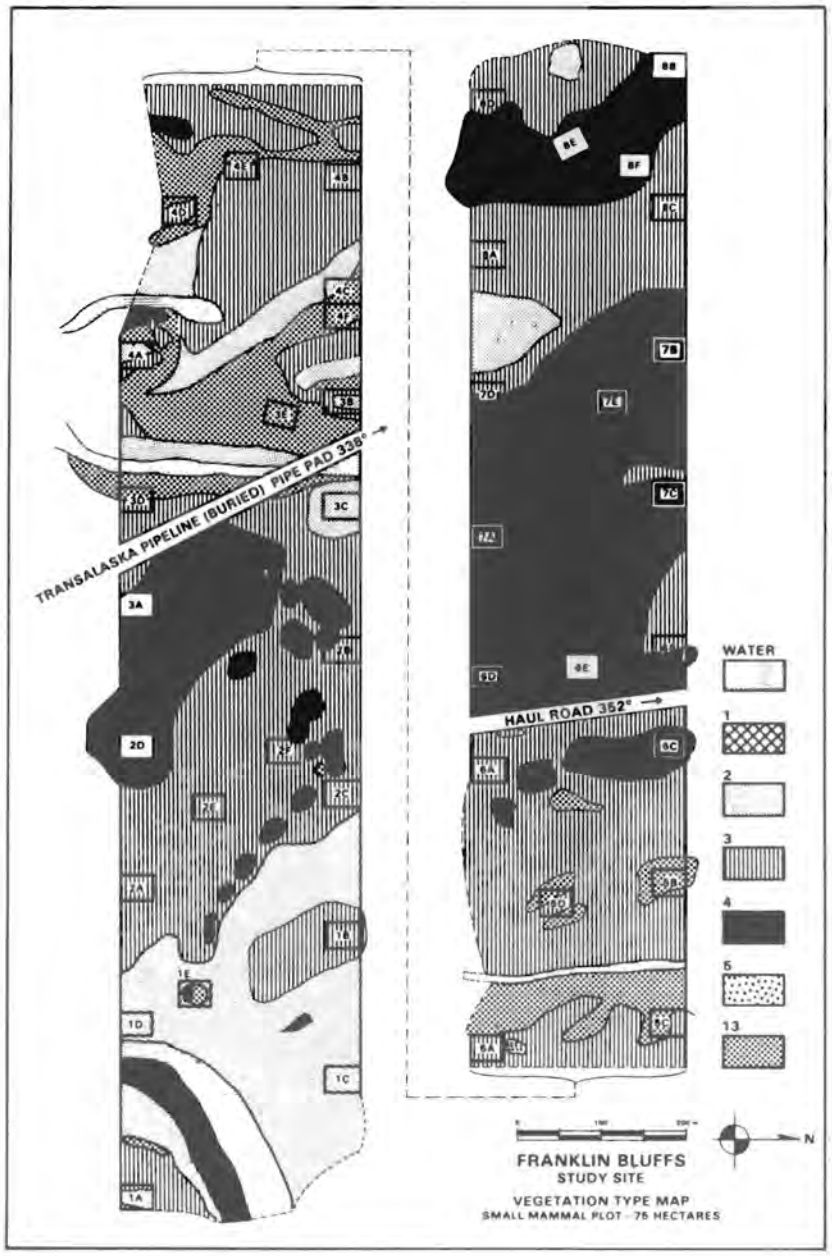
Although no population estimates were made for arctic ground squirrels it was possible to infer their habitat preferences from the patterns of trap disturbance discussed earlier. No trap disturbance occurred in those portions of Grids 6, 7, or 8 that were in wet sedge meadow habitats; traps that were disturbed were located in well-drained areas such as old river terraces and hummocks.

Tundra-Nesting Bird Studies

The studies at Prudhoe Bay and Franklin Bluffs were conducted in a manner consistent with study objectives begun in 1972 at Prudhow Bay, which were: 1) to chronicle bird species use of the sites; 2) to locate and observe all bird nests to determine habitat use and histories; 3) to trap and band both adults and young of selected bird species to determine migration routes, wintering areas, nest site tenacity and pair fidelity of adults, and other vital data; and 4) to follow movements of bird family groups in relation to oil field installations. These objectives are expected to yield data on the basic biology of the species encountered, the ecology of the arctic tundra ecosystem in the Prudhoe Bay region, and, when combined with the mammal data, to ultimately provide a realistic evaluation of the environmental cost of resouce extraction and transportation.

Detailed studies of tundra-nesting birds were conducted at the Prudhoe Bay and Franklin Bluffs study sites and ancillary information was obtained at the Colville River Delta study sites. A comparison of nesting densities of five common tundra bird species that usually occur at all three of those sites (Table 12.7) show that species diversity was greatest at the Colville River Delta. Density of total nests at that site was half that at Prudhoe Bay, where the very great density of nesting semipalmated sandpipers (Calidris pusilla) accounted for nearly 80% of the nests. The Franklin Bluffs population was somewhat more rich in species than Prudhoe Bay but had only one-sixth the density of nests of the five species.

The 1978 study season was characterized by a relatively late spring, dramatic daily fluctuations in temperature with enhanced windchill effects of the prevailing northeast wind, and a late summer with mild temperatures extending into mid-September. This weather pattern may well be characteristic of the Prudhoe Bay area which is strongly influenced by the Beaufort Sea. Daily temperatures were about -7° to -12°C in mid-May, increased as the month progressed, and the daily maximum remained above zero from June through August. Daily minimum temperature fluctuated near 0°C until late August and then began a downward trend. Brief snow storms occurred during the last week in June and the first week in August. Snow cover at both the Prudhoe Bay and Franklin Bluffs study sites was 90-95% in mid-May, decreased rapidly after May 26, and by May 30 the tundra was sufficiently clear for birds to initiate



1. *Dryas integrifolia* and crust lichens. Several other cushion dicotyledons and fruticose lichens.

2. *Dryas integrifolia* and *Cetraria* spp. Several other fruticose lichens and sedges. Few or no crustose lichens.

3. *Carex aquatilis* and/or *Eriophorum angustifolium* and *Dryas integrifolia*. Several other sedges and dwarf willows. Very few or no lichens.

4. *Carex aquatilis* and/or *Eriophorum angustifolium* and *Drepanocladus* spp., usually with *Pedicularis sudetica*. No lichens.

5. *Carex aquatilis* and *Scorpidium scorpioides*. No lichens.

13. *Salix lanata* and *Carex aquatilis*. Shrubby willows with a *Carex aquatilis* and *Dupontia fisheri* with *Saxifraga hirculus* and other dicotyledons understory.

FIGURE 12.3. Vegetation Types (Webber and Walker, 1975) of Franklin Bluffs Small Mammal Study Site

TABLE 12.6. Population Estimates for Small Mammals Live-Trapped on Franklin Bluffs Study Area, July 18-August 26, 1978

Subplot	Number of Small Mammals[a] Captured (C)	Marked (M)	Recaptured (R)	Population[b] Estimate (no./ha) n + sn
IA	5	4	2	
B	6	4	3	
C	0	0	0	
D	1	1	0	
Subtotal	12	9	5	42 ± 63
IIA	0	0	0	
B	0	0	0	
C	0	0	0	
D	0	0	0	
Subtotal	0	0	0	0
IIIA	2	1	0	
B	7	7	3	
C	0	0	0	
D	4	4	1	
Subtotal	13	12	4	72 ± 260
IVA	4	3	2	
B	0	0	0	
C	0	0	0	
D	3	2	0	
Subtotal	7	5	2	28 ± 60
VA	1	1	0	
B	7	5	1	
C	1	1	0	
D	2	1	0	
Subtotal	11	8	1	103 ± 1373
VIA	4	2	1	
B	7	4	0	
C	0	0	0	
D	3	2	1	
Subtotal	14	8	2	986 ± 687
VIIA	2	1	0	
B	21	10	3	
C	1	0	0	
D	1	1	1	
Subtotal	25	12	4	134 ± 1125
VIIIA	0	0	0	
B	10	3	2	
C	0	0	0	
D	0	0	0	
Subtotal	10	3	2	24 ± 47
Total	92	56	20	67 ± 583

[a]Numbers include only those animals marked during the first trapping session and available for recapture during second session.

[b]Modified Petersen (1896) Index, according to notation of Bailey (1951):

$$P_B = \frac{M(C+1)}{R+1}; \quad s_{P_B} = \frac{M^2 (C+1)(C-R)}{(R+1)^2 (R+2)}$$

TABLE 12.7. Nesting Densities of Five Common Tundra Bird Species at Three Northern Alaska Study Sites During the Summer of 1978

Species	Nests per 100 ha		
	Colville River Delta	Prudhoe Bay	Franklin Bluffs
Semipalmated Sandpiper	10	113	1
Pectoral Sandpiper	13	9	2
Dunlin	7	0	0
Golden Plover	7	0	7
Lapland Longspur	37	24	15
Total	74	146	25

territorial defenses and to utilize most areas for foraging. Water coverage of the tundra gradually decreased from about 20% on June 15 to 5% by August 15 except in those areas where gravel roadways or other oil field installations blocked natural drainages.

Forty-nine bird species were observed at the Prudhoe Bay Site, compared to 54 at Franklin Bluffs. Ten bird species nested within the Prudhoe Bay Site (Table 12.8), producing data for 85 nests; Franklin Bluffs had 13 species and 50 nests, some of which were beyond the boundaries of the 100-ha study area. Success was greater at Franklin Bluffs (78%) than at Prudhoe Bay (46%), reflecting greater losses to predation at the latter site (44% compared to 30% at Franklin Bluffs). Comparison of predation losses of tundra-nesting birds during various phases of the lemming cycle and relative arctic fox population at Prudhoe Bay (Table 12.9) suggests that several predators other than arctic foxes depend upon bird eggs and young as a food source. Lapland longspurs are particularly prone to such losses; they often lost their first nest to predators and several were predated when they contained nestlings. These losses to predators and the occasional devastating loss of eggs and young due to unseasonal snow storms, such as documented at both Prudhoe Bay and Franklin Bluffs last year (Hanson and Eberhardt, 1978), illustrate the appreciable mortality imposed by natural forces of the region. To this must be added the mortality incurred by losses of habitat due to industrial development of the region's resources.

Additional information concerning nest site tenacity and pair bond fidelity among 2 Lapland longspurs and 47 semipalmated sandpipers of the Prudhoe Bay population was obtained through the return of previously banded birds. Two longspurs, both adult females captured during 1975 and 1976, nested within the study area. Twenty banded semipalmated

TABLE 12.8 Numbers of Nests of Various Bird Species Observed at Prudhoe Bay and Franklin Bluffs Study Sites during the Summer of 1978

Species	Number of Nests Observed	
	Prudhoe Bay	Franklin Bluffs
Buff-breasted Sandpiper	12	10
American Golden Plover	0	7
Red Phalarope	5	0
Bar-tailed Godwit	0	3
Pectoral Sandpiper	6	2
Semipalmated Sandpiper	42	2
White-fronted Goose	1	2
Long-tailed Jaeger	0	2
Baird's Sandpiper	1	0
Stilt Sandpiper	0	1
Black-bellied Plover	0	1
Northern Phalarope	1	1
Long-billed Dowitcher	0	1
Spectacled Eider	1	0
Willow Ptarmigan	0	1
Snow Bunting	5	0
Lapland Longspur	14	23
Total	88	59

TABLE 12.9. Comparison of Predation Loss of Tundra-Nesting Birds during Years of Varying Lemming and Arctic Fox Population Densities at Prudhoe Bay

Year	Percent of Bird Nests Predated	Relative Arctic Fox Population Level	Lemming Population	
			Level	(no. per ha)
1972	37	High	Medium	14
1973	6	High	Low	2
1974	No Data			
1975	30	High	High	25
1976	49	High	High	24
1977	52	Low	Low	0
1978	44	Medium	Low	< 1

sandpipers were recaptured this year; twelve had been banded in 1977, four in 1976, two in 1975 and one each in 1973 and 1972. The bird banded in 1972 had previously been captured during each year of study except 1973, always within a 0.9 ha area and with the same mate during the past three years. Six other previously banded birds were observed at the Prudhoe Bay Site but were not trapped because they nested on the periphery of the site or their nests were predated before they could be trapped. Only one previously banded bird, an American golden plover was observed at the Franklin Bluffs site. It was unusually wary and could not be trapped to confirm the band number.

Radiation Ecology Studies

Measurements of worldwide fallout cesium-137 in Eskimo residents of Anaktuvuk Pass made during January and June (Table 12.10) confirmed the significant impact of increasing cultural change by economic and political al factors upon Eskimo people. Concentrations of ^{137}Cs were essentially unchanged from values observed during 1977 and were about one-third as much as those observed in 1975, just prior to the enforcement of caribou management laws that have restricted the harvest of that important food resouce. That food base has been replaced by processed food which the Eskimos can now afford to purchase with wages earned by employment on school construction projects that are now widespread in northern Alaska. The average adult resident of Anaktuvuk Pass received about 12 mrem of radiation exposure from the measured body burdens during 1978, compared to 10 mrem during 1977. The slight increase resulted from the consumption of fresh caribou meat from animals harvested from the spring migration in May and June. Such animals have always contained seasonal maxima of ^{137}Cs in flesh (Hanson and Palmer, 1965).

Samples of soil, lichens, caribou, and several species of carnivores were collected and returned to the laboratory for processing and radionuclide analyses.

TABLE 12.10. Concentrations (nCi per kg body wt.) of Cesium-137 in Anaktuvuk Pass, Alaska, Residents during January and June, 1978

		Cesium-137 Concentration (nCi/kg)					
		January			June		
Category	Age (yrs)	n	$\bar{x}$	s_x	n	$\bar{x}$	s_x
Adults	>21	47	0.72	0.33	40	1.22	0.66
Minors	15-20	7	0.58	0.23	7	0.54	0.25
Children	>15	7	0.32	0.13	13	0.41	0.27

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