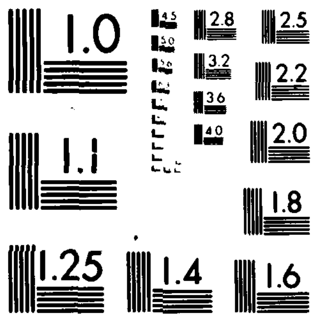
AD-A085 976 ALASKA UNIV ANCHORAGE ARCTIC ENVIRONMENTAL INFORMATI--ETC F/G 6/3
PHOTOPERIOD AND FUR LENGTHS IN THE ARCTIC FOX (ALOPEX LAGOPUS L--ETC(U)
MAY 80 L S UNDERWOOD, P REYNOLDS N00014-77-C-0234

UNCLASSIFIED NL

END
DATE
FILMED
8 80
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

ADA085976

LEVEL II

Photoperiod and Fur Lengths in the Arctic Fox (*Alopex lagopus* L.)

by

Larry S. Underwood ~~and~~ Patricia Reynolds*

12 19

* Present Address: University of Alaska, Arctic Environmental Information and Data Center, Anchorage, Alaska
and
Alaska and National Petroleum Reserve for Alaska
Bureau of Land Management, Fairbanks, Alaska

Naval Arctic Research Laboratory

Barrow, Alaska

Contract N00014-77-C-0234

11 MAY 80

Abstract

Pelage is seasonally dimorphic in the Arctic fox. During the winter, fur lengths ~~for this species~~ are nearly double similar values taken during the summer, ~~season~~. Considerable site-specific differences in fur length are noted. In general, body sites which are exposed to the environment when the ~~an Arctic~~ fox lies in a curled position show greater fur lengths in all seasons and greater seasonal variations than body sites that are more protected during rest. Well-furred sites may tend to conserve heat during periods of inactivity, and scantily furred sites may tend to dissipate heat during periods of exercise.

The growth of winter fur may compensate for the severe cold of the arctic winter. Changes in fur lengths indicate a definite pattern in spite of individual variations. During the fall, ~~months,~~ fur lengths seem to lag behind an increasing body-to-ambient temperature gradient. Both body-to-ambient temperature gradients and fur lengths peak during December through February. From March through June, gradual environmental warming is accompanied by a decrease in average fur lengths. Thus, there appears to be a ~~remarkable~~ parallel between the body-to-ambient temperature gradient and ~~the~~ fur lengths. ~~The~~ growth of fur ~~in the Arctic fox, then~~ parallels annual changes in ambient temperature and photoperiod.

Relatively little work has been done to determine the mechanism controlling molting in the Arctic fox. It may be that the onset of fall molt in the Arctic fox is indigenously controlled, while spring molt may be more related to either changes in temperature, photoperiod, or both.

Photoperiod and Fur Lengths in the Arctic Fox (*Alopex lagopus* L.)

The Arctic fox (*Alopex lagopus* L.) inhabits the entire arctic tundra region of North America and Eurasia (Figure 1), one of the most rigorous, cold-dominated environments on earth. (Bliss, et al. 1973 contains an excellent description of the arctic environment and its biota). Tolerance of extreme cold by the Arctic fox is well-documented. Scholander, et al. (1950) described the lower critical temperature of this species as "in excess of $40^{\circ}C$," and Irving and Krog (1954) stated that the Arctic fox can withstand temperatures of $-80^{\circ}C$ for one hour with no decrease in rectal temperature. Irving (1964) speculated that in winter the Arctic fox can withstand $-70^{\circ}C$ by increasing the metabolic rate by only 37 percent above resting conditions.

This paper presents the results of studies designed to more precisely define cold adaptations of the Arctic fox. Specifically, we discuss seasonal changes in the thermal quality of the fur and how growth of the fur may be timed to seasonal changes in environmental conditions.

The amount of winter fur has been observed to be greater in arctic mammals than in similar tropical species (Scholander, et al. 1950). In arctic mammals up to the size of the Arctic fox (4 kg), a direct relationship exists between the length of winter fur and body size. Larger arctic mammals all have about the same fur lengths in winter. Apparently, no comparison to summer insulation has been made.

letter on file

A

Only a few studies evaluating normal seasonal insulative changes in fur have been reported. Hart (1956) found the insulative quality of the fur of nine species of temperate and arctic mammals to be 16 percent to 51 percent higher in winter pelts, with no apparent relationship to latitude. The importance of insulation in reducing heat loss has been measured in a number of laboratory studies. White rats raised in outdoor cages develop increased insulation in response to winter cold and do not use nonshivering thermogenesis as do rats raised under laboratory conditions of continuous cold (Heroux, Depocas and Hart 1959; Hart 1960). Apparently, increased insulation retards heat loss to such an extent that metabolic adjustments are not necessary. Similarly, Davis (1963) suggested that insulative clothing inhibits other means of acclimatization to cold in man. The importance of insulation has been suggested in chronically exposed white rats (Sellers, et al. 1951), sheep (Blaxter, et al. 1959a, 1959b, and Graham, et al. 1959), and cattle (Bedwell and Wainman 1964) where removal of hair caused an increase in metabolism.

Methods

The studies reported here were conducted at the Naval Arctic Research Laboratory (NARL), Barrow, Alaska (71° 20" north latitude, 156° 39" west longitude), on the coast of the Arctic Ocean approximately 200 miles north of the Arctic Circle. Investigations were carried out in June 1969 through August 1970 and July through October 1977. Animals used in this study were from a colony of Arctic foxes maintained by the NARL's Animal Research Facility. Adult foxes were trapped locally and on the

Pribilof Islands. Juvenile foxes were born in captivity and raised by the facility. All animals were caged out of doors, where they experienced nearly ambient conditions except that wind velocities were slightly ameliorated. Velocities observed within the cages, measured with a hand-held anemometer, were consistently no more than 2.2 $m.sec^{-1}$, while those observed in exposed areas of the tundra often exceeded 12 $m.sec^{-1}$. Velocities observed in the lee of obstacles, such as pressure ridges, ice blocks, snowdrifts, and buildings, were approximately the same as those observed in the cages. It was felt that conditions in the cages approximated natural conditions since protected microenvironments are common in the tundra and the Arctic fox can avoid full exposure to winds. Maintenance, feeding, and routine health care were provided by NARL personnel. Food and water were provided ad libitum except during food-consumption experiments, the results of which are reported elsewhere (Underwood 1971).

The lengths of fur were measured on animals experiencing nearly ambient conditions. A sharpened pencil was inserted point first into the fur to the skin. The length of dense fur was marked with a thumbnail by sighting tangentially along the surface of the fur. Longer, sparsely distributed guard hairs were excluded from the measurements. The repeatability of these measurements was plus or minus one to three millimeters, depending on the body size. For these measurements, the animals were lightly anesthetized. Measurements were taken for 35 body sites (see Figures 2 & 3) each month from September 1969 through August 1970. June, July, and August measurements and December, January, and February measurements were averaged for "summer" and "winter" values. The number of individual foxes measured varied from 4 to 12 per month.

Fur lengths were also measured at 35 body sites on each member of a litter of Arctic fox pups born at the Naval Arctic Research Lab in 1977. The results of these measurements are shown in Table 1. The first set of measurements was taken in July, when the animals were approximately two and a half weeks old. The second set of measurements was taken in October. The measurements obtained in pups were compared to similar measurements taken on adults during the same months.

Rectal temperatures, measured monthly on lightly anesthetized animals experiencing nearly ambient conditions, did not vary significantly from month to month, and averaged 38.4^{o}C for the year (N=42). This figure was combined with 30-year monthly mean temperatures for the Barrow, Alaska area to compute the ambient-to-body temperature differential (Figure 4). Also, in Figure 4 fur lengths were averaged for each month for all 35 body sites and normalized as the percent of August values, when minimal fur lengths were observed.

A Duncan Multiple Comparison Test, modified for samples of unequal number, was used to analyze the differences between monthly means, where applicable. This test, which is similar to a standard t-test, minimizes the possibility that observed significant differences are due to chance (Miller and Freund 1968). Summer values for adult foxes were obtained independently by the two authors. Observed differences between the two were not statistically significant except where noted.

Results and Discussion

The pelage of the white color phase of the arctic fox is seasonally dimorphic. In winter, the animals are covered with relatively long, thick, white fur. In the majority of individuals the only nonwhite areas are the nose pad and the eyes. In summer, slate-gray fur covers the head, legs, and dorsal neck, trunk, and tail. The inner surfaces of the ear, the area around each of the eyes, and the ventrum are covered with light gray to fawn-colored fur. Although considerable individual variation in molting is observed, in general, fall molt starts in late August to late September and continues through November. White fur appears first on the head and back regions and spreads dorso-caudad to the tail and ventrum. Spring molt, which occurs in March through May, is evidenced initially as an obscure dark patch in the hip region. In the latter stages of molt the white fur is shed in large patches from the flanks, back, and legs.

In all seasons fur lengths were observed to be greater on the trunk than on the extremities, excluding the tail (Figure 2a and 2b). On the trunk, fur was longer on the anterior and shorter on the posterior region. The proximal portions of the legs had longer fur than the distal portions, except for the paw pads and posterior lower forelegs and median lower hind legs in winter.

Considerable site-specific variations in fur length exist. These variations are evident both when making topographic comparisons for a given month and seasonal comparisons for a given site. The only areas of the distal appendages that show substantial winter increases in fur length are those commonly in contact with the highly conductive snow surface, namely the foot pads and, when lying down, the posterior medial aspect of the lower leg. Those areas of the body that are still exposed when in this position (trunk and tail) possess relatively deep fur and show consistent and substantial seasonal increases, while those areas that are both not in contact with the snow surface and are protected by the rest of the body while resting (distal legs, nose, chin, ear) show less fur in all seasons and inconsequential increases in winter. Thus, site-specific variations in fur length reflect the animal's surface conditions while resting, when minimal heat loss is advantageous. Lightly furred areas are not exposed. When the activity state is other than resting, these areas are more fully exposed and could serve as effective heat dissipators.

The degree of temperature amelioration by the fur depends on the relationship between length and insulative quality of the fur. Hart (1956) and Scholander et al. (1950) found a direct relationship between fur length and insulative quality in dried pelts of several species.

Figure 3 shows a comparison of fur length measurements in winter to those of summer. In general, winter values are considerably higher than those observed in the warmer season. Considerable site-specific variations exist. Extremity sites vary from no increase in winter (chin and nose) to a near doubling in fur length. Extremity sites average 168 percent of winter values, while trunk sites average 190 percent greater in winter fur. The average for all sites is 178 percent greater lengths in winter than in summer. Thus, it appears that winter fur compensates for colder temperatures and higher winds in the winter season. In summer, shorter fur would facilitate the loss of body heat, which might be advantageous to the animal during that season.

Monthly changes in fur lengths and body (rectal)-to-ambient temperature differential are compared in Figure 4. Fur lengths were averaged for each month for all 35 body sites and normalized as the percent of August values when minimal fur lengths were observed. A definite parallelism appears to exist between the two parameters. From August to October, average fur length increased but lagged behind the increase in body-to-ambient temperature differential. In November, average fur length increased rapidly, and both parameters reached maximum values in December, January, and February and then decreased gradually through June. Thus, changes in average temperature appear to be closely correlated with changes in average fur length. Seasonal changes in other factors, such as fur density and texture, appear to be of minor significance (Hart 1956).

A comparison of average juvenile and adult measurements is indicated in Figure 4. In June, measurements of juveniles averaged only 54 percent of adults. This is not surprising when considering that the juveniles were only two and a half weeks old. However, by October the observed values for juveniles were 160 percent of adult values. There are three possible explanations for these differences. First, the differences between June and October measurements may be the result of differences in the two authors since the June measurements were taken by one author (L.S.U.) and the October measurements were taken by the other author (P.R.). However, adult values taken at the same time by the two authors showed no statistically significant differences in measurements. A second explanation is that the litter measured was an unusual litter and that the pattern of growth observed was atypical. The third explanation is that these growth differences observed are typical of Arctic fox pups, and fur growth occurs quite rapidly in late summer and not only anticipates but overcompensates for winter cold. Differentiating between these possibilities will not be possible until further field observations have been made.

Relatively little work has been done to determine the mechanisms controlling molting in the Arctic fox. It seems likely that photoperiod, ambient temperature, or both may be important. The onset of fall molting occurs in August and September, when average ambient temperatures throughout much of the North are beginning to fall, day lengths shorten, and the sun finally sets for the first time in several months. Fur lengths for adults increase gradually through the fall months, with rapid growth of fur during November and early December. This growth occurs during the first half of the dark period throughout northern Alaska. The date of fur growth appears to change in December at about the winter solstice. during this period, when day lengths are increasing and ambient temperatures are warming, fur growth appears to be inactive. Decreases in observed fur length from that time through June may be attributed to cessation of growth and wearing down of fur tips. A rapid spring molt occurs in May and June and corresponds to the region's longest days, a season of perpetual light throughout much of the Arctic.

A few anecdotal observations suggest that both endogenous and exogenous mechanisms may be at work. G. Edgar Folk (personal communication) reported that a fox taken to Iowa during the summer months underwent fall molt on schedule, suggesting endogenous controls. Sick and injured animals kept indoors at NARL under abnormal light and temperature regimes appeared to initiate spring molt earlier than animals kept out of doors. Healthy animals kept in covered cages appeared to molt later than animals experiencing natural light conditions in spring. This suggests that spring molt may be more controlled by temperature, photoperiod, or both than fall molt.

The fall molt pattern described here is similar to patterns described previously for the Arctic fox by Chesemore (1970) and Braestrup (1941). Braestrup observed that Arctic foxes native to Greenland complete their winter molt 30 days earlier than Canadian foxes. He suggested that foxes migrating from eastern Canada during years of peak population do not survive more than one season in Greenland because development of winter pelage lags about 30 days behind the onset of cold winter in Greenland but corresponds roughly to the onset of winter in the eastern Canadian Arctic. This suggests that for a given population the fall molt is synchronized to the normal seasonal temperature changes experienced by that population. Throughout continental North America the pattern of molt appears to be relatively similar and is a potential limiting factor in areas of more severe climate. Results presented in this study suggest that foxes of northern Alaska molt in a pattern parallelling seasonal changes in the environment in that region.

The primary adaptation of the Arctic fox to the severe arctic climate, then, appears to be seasonal changes in the insulative quality of the fur. These results can be compared to a study by Durrer and Hannon

(1961), who studied acclimatization in short-haired temperate dogs (beagles) to Alaska winter cold. Acclimatization in this case was accompanied by a near doubling in the amount of food consumed daily, which was attributed to increased demands in heat production. Although apparently not measured, it was assumed that no significant changes in the quality of the insulation had occurred. It is possible that for temperate and domestic species living in an environment where food is readily available year-round, adjustments in metabolic heat production in response to winter are feasible. However, for wild species such as the Arctic fox these energy-requiring adjustments might well be intolerable. If increased energy production was the primary adaptation of the Arctic fox, the season of highest energy demand would occur during the season of lowest available energy (winter). In studies reported elsewhere (Underwood 1971) it appears that the energy demands of the Arctic fox are only approximately half as much in winter as they are in summer. Thus, in winter the thermal qualities of the fur may compensate for cold, minimize energy requirement, and be a key factor in the survival of the Arctic fox.

Acknowledgements: These studies were supported by grants from the Office of Naval Research. The support of the NARL and AEIDC are gratefully acknowledged.

TABLE 1

Fur Lengths Obtained from Juvenile Arctic Foxes

Body Site	June Values			October Values		
	N	$\overline{X}$ mm	% adult	N	$\overline{X}$ mm	% adult
Chin	9	1	14	4	5	125
Nose	9	1	19	4	4	200
Ear	9	7	15	4	25	417
Paw Pad	9	6	50	4	10	67
Dorsal Paw	9	2	60	5	15	167
Medial Lower Foreleg	9	6	82	4	12	109
Lateral Lower Foreleg	9	5	43	4	10	111
Medial Upper Foreleg	9	6	45	4	33	330
Lateral Upper Foreleg	9	9	68	5	22	169
Foot Pad	8	6	39	4	27	193
Dorsal Foot	9	4	60	4	10	125
Front Lower Hindleg	9	5	75	4	14	200
Back Lower Hindleg	9	7	90	5	13	144
Lateral Upper Hindleg	9	7	53	5	14	156
Medial Upper Hindleg	9	8	80	4	46	329
Distal Tail	9	9	34	4	49	169
Medial Tail	9	10	34	6	46	135
Proximal Tail	9	13	55	4	37	119
Forehead	9	10	49	5	19	95
Cheek	9	14	49	4	33	143
Dorsal Neck	9	19	66	5	42	111
Lateral Neck	9	20	53	4	49	144
Ventral Neck	9	12	40	4	59	174
Sternum	9	12	51	4	52	196
Shoulder	8	13	63	4	34	131
Dorsal Chest	9	17	61	4	45	161
Lateral Chest	9	16	64	4	39	139
Ventral Chest	9	10	52	4	55	196
Dorsal Back	9	14	72	5	37	142
Lateral Abdomen	9	15	68	5	40	121
Ventral Abdomen	9	11	49	4	45	136
Dorsal Hip	9	13	70	5	40	149
Lateral Hip	9	13	68	5	27	108
Upper Leg	9	12	71	4	35	159
Groin	9	12	44	4	43	119
Average			54			163

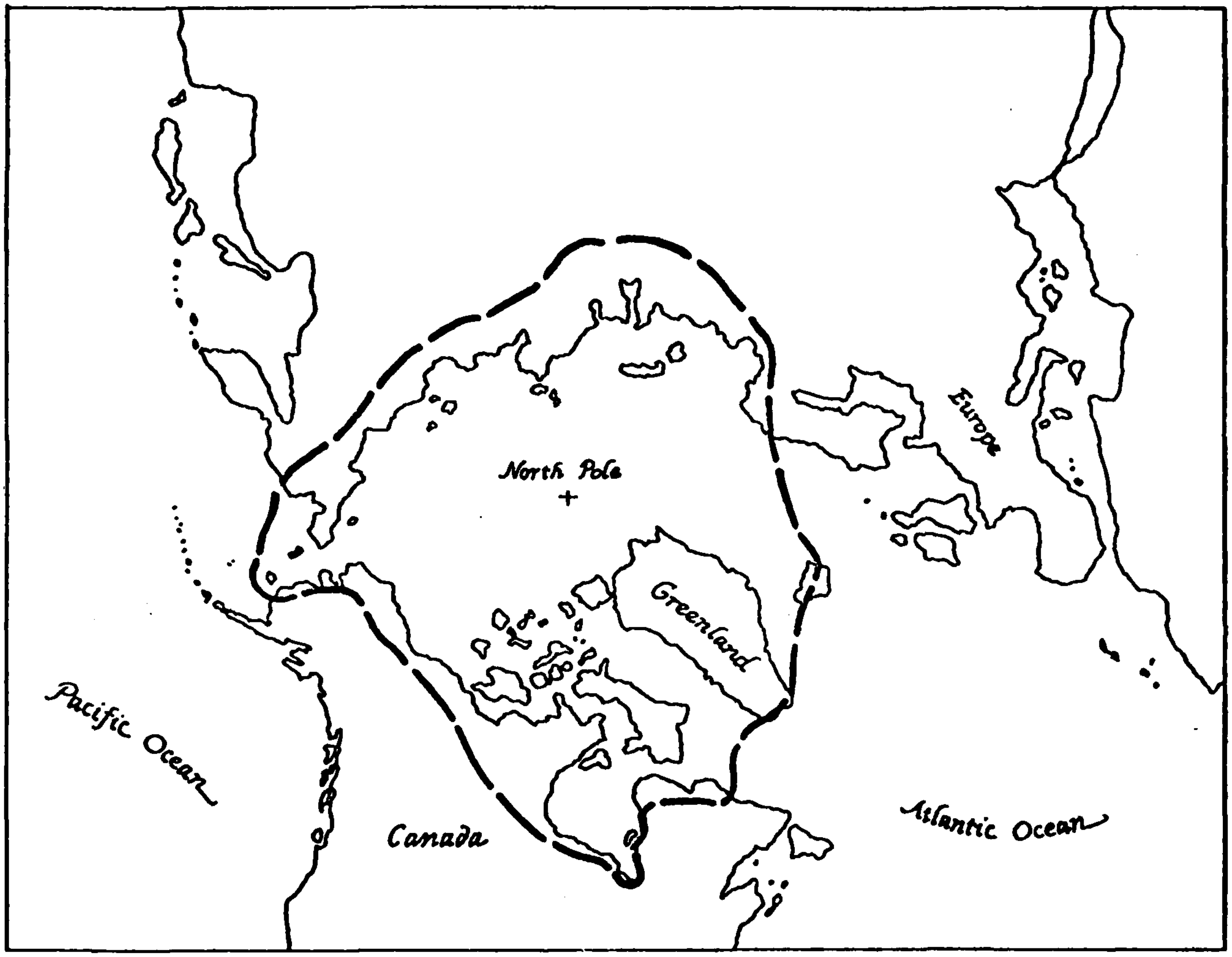
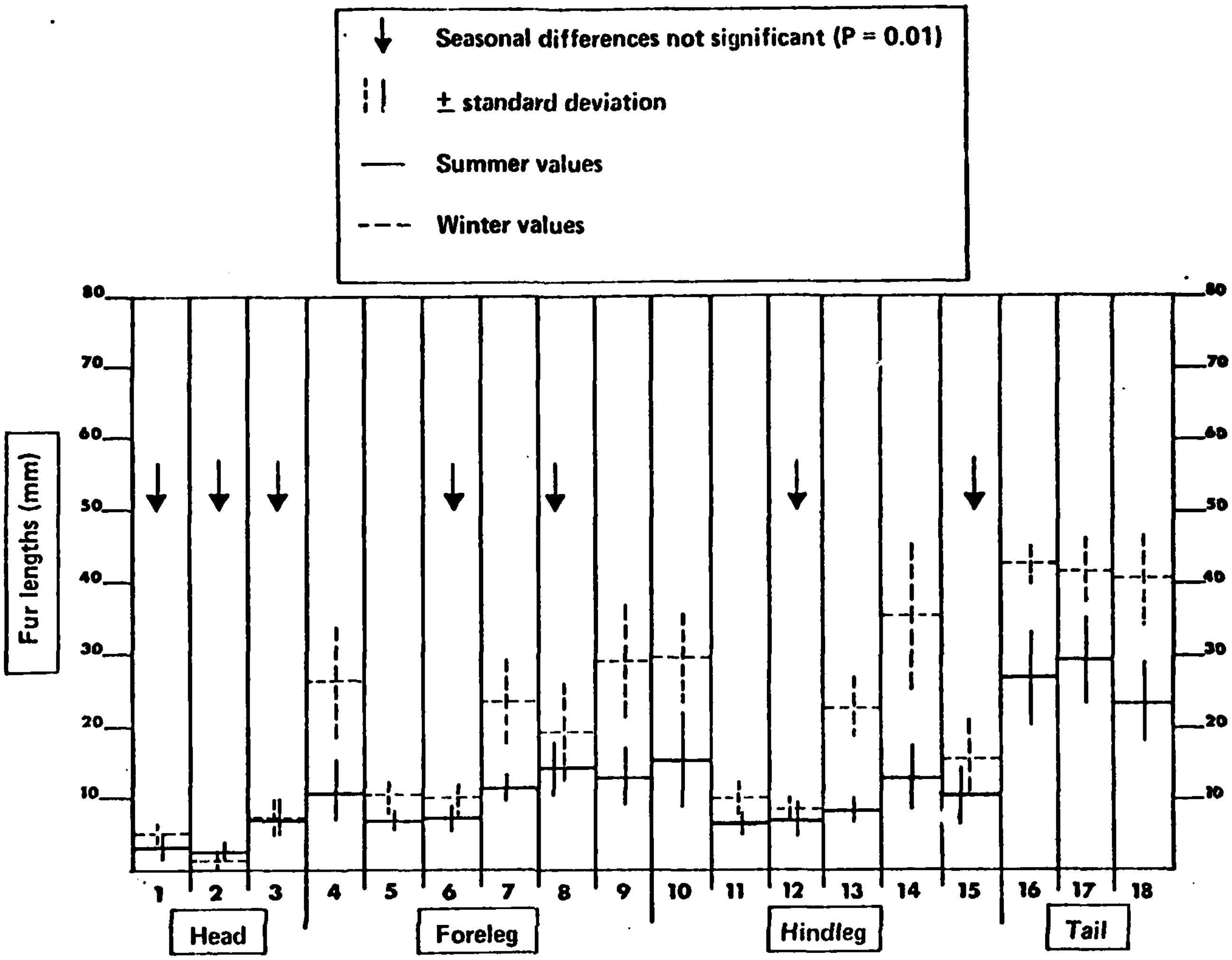
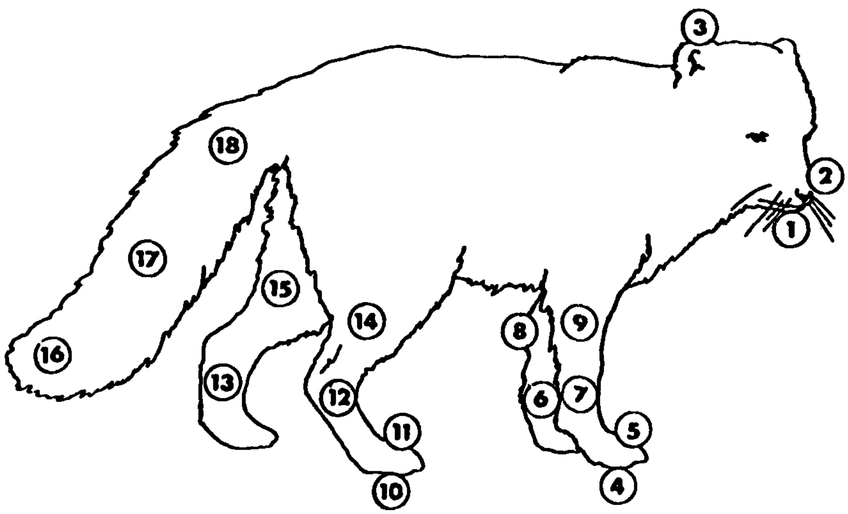


Figure 1

POLAR PROJECTION MAP SHOWING THE DISTRIBUTION OF THE ARCTIC FOX

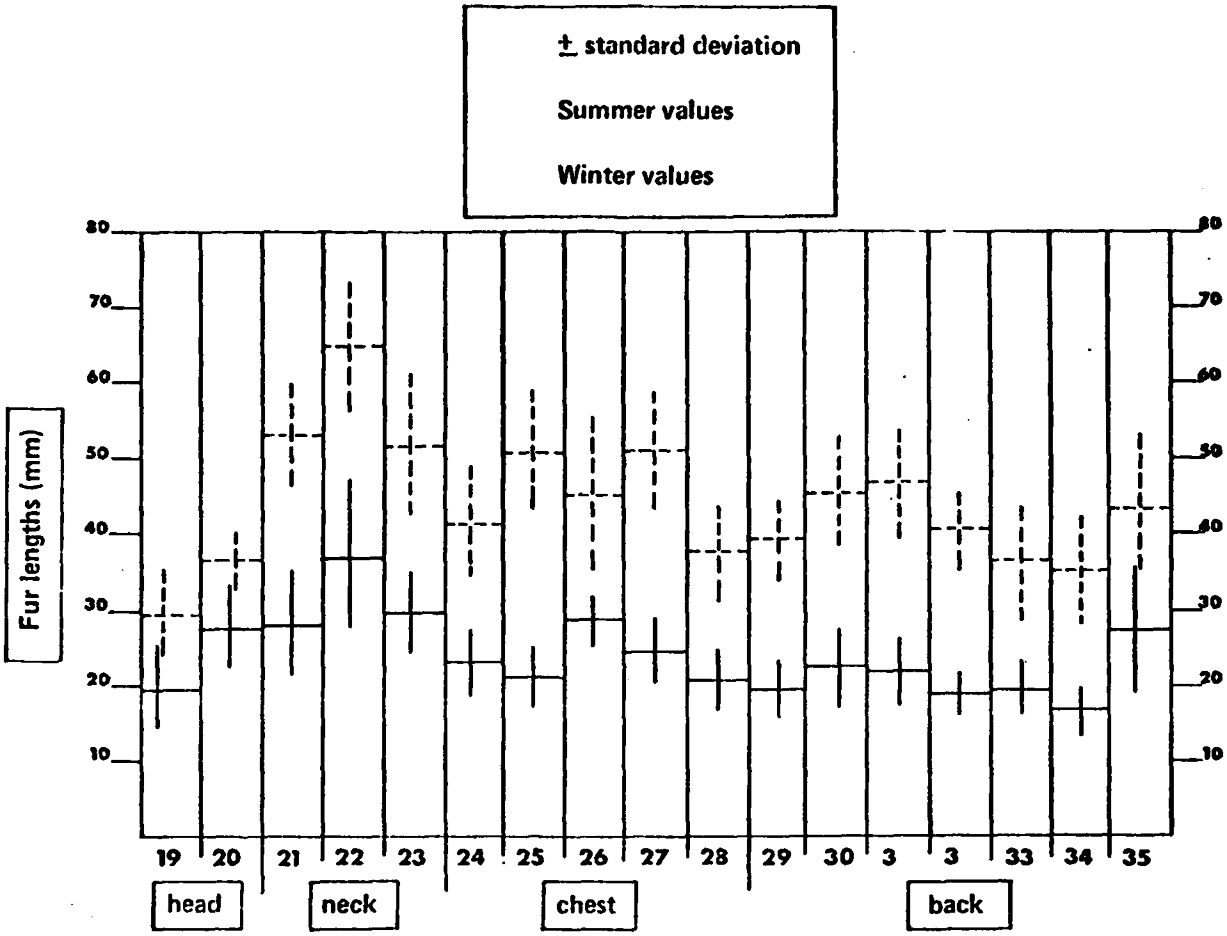


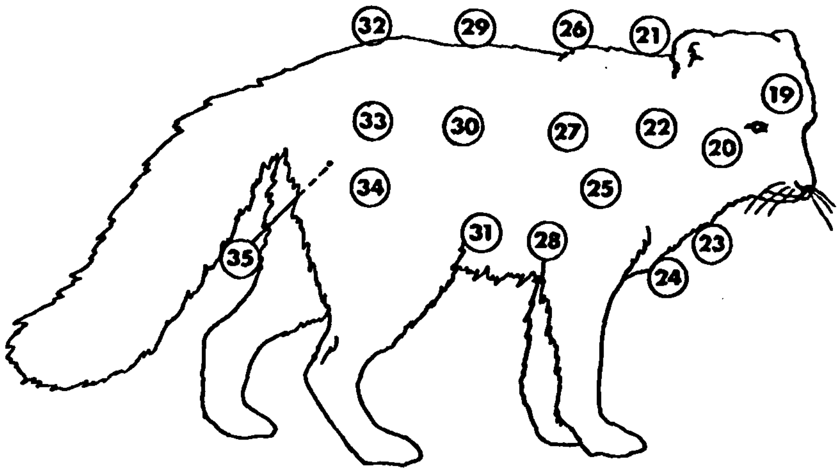


1 Chin
2 Nose
3 Ear
4 Paw pad
5 Dorsal pad
6 Medial lower foreleg
7 Lateral lower foreleg
8 Medial upper foreleg
9 Lateral upper foreleg
10 Foot pad
11 Dorsal foot
12 Front lower hindleg
13 Back lower hindleg
14 Lateral upper hindleg
15 Medial upper hindleg
16 Distal tail
17 Medial tail
18 Proximal tail

Figure 2a.

FUR LENGTH COMPARISONS - EXTREMITIES





19 Forehead
20 Cheek
21 Dorsal neck
22 Lateral neck
23 Ventral neck
24 Sternum
25 Shoulder
26 Dorsal chest
27 Lateral chest
28 Ventral chest
29 Dorsal back
30 Lateral abdomen
31 Ventral abdomen
32 Dorsal hip
33 Lateral hip
34 Groin

Figure 2b.

FUR LENGTH COMPARISON - TRUNK

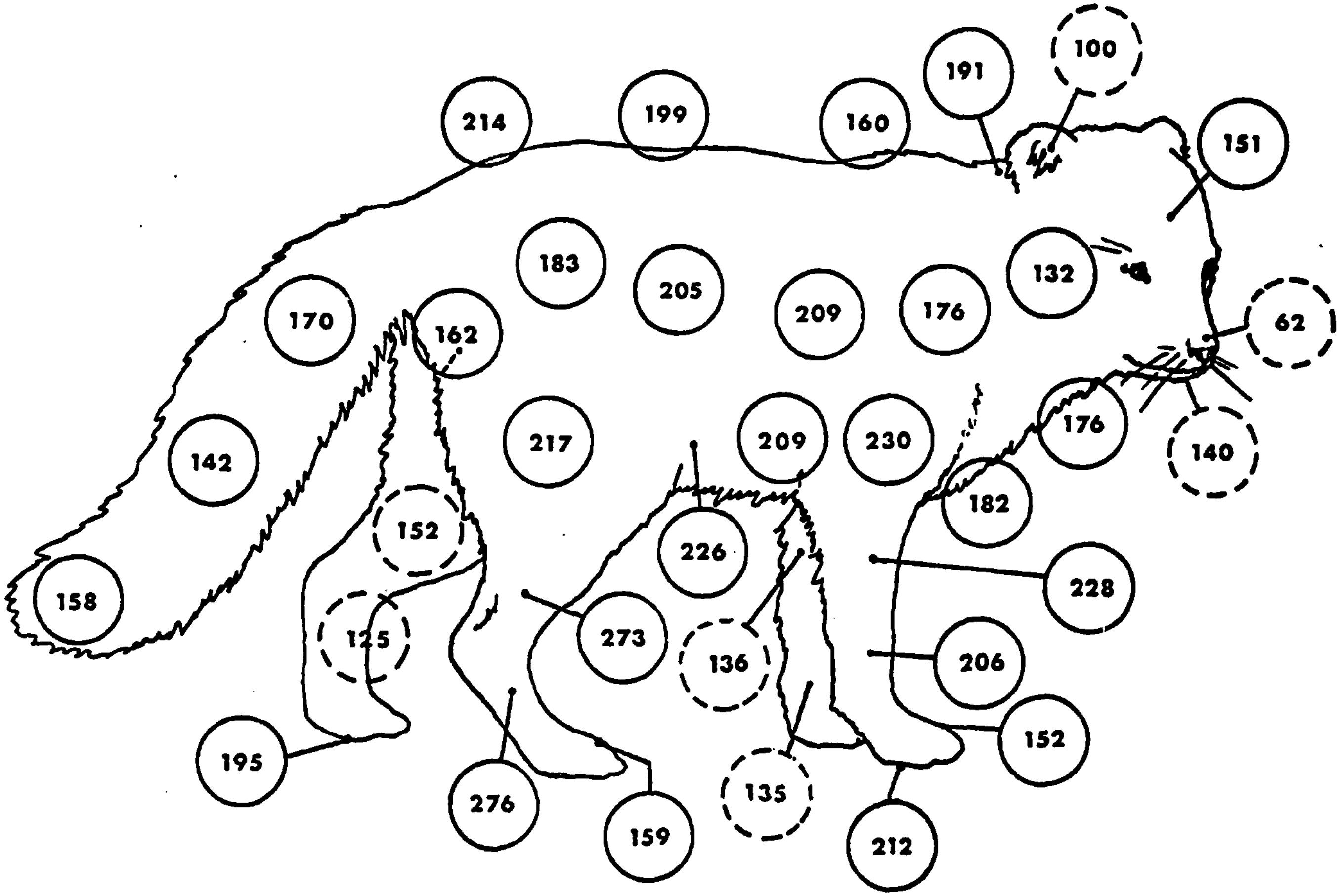


Figure 3.

WINTER FUR DEPTHS OF THE ARCTIC FOX-
PERCENT OF AUGUST

AVERAGE

All sites - 178%
Extremities- 168%
Body - 190%

◯ Statistically significant (P= 0.01)

◌ Not significant

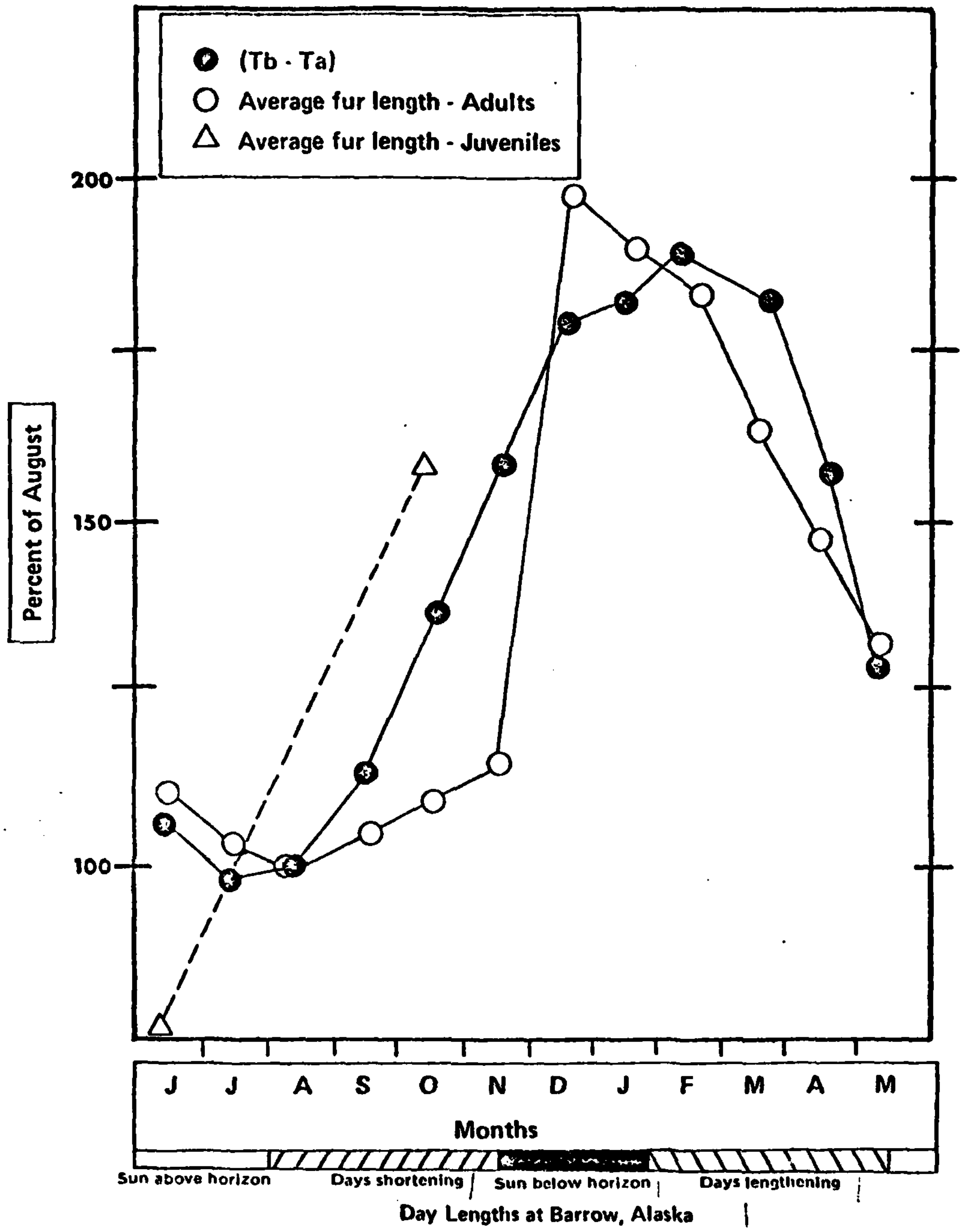


Figure 4.

CHANGES IN FUR LENGTH AND BODY - TO - AMBIENT TEMPERATURE

Adult fur lengths and (Tb—Ta) are expressed as percent of August values. Juvenile fur lengths are expressed as percent of similar values measured in adults.

REFERENCES

BEDWELL, R.L. and WAINMAN, F.W. (1964): The effect of increased air movement on the heat production and emission of steers. J. Agr. Sci. 62:207-214.

BLAXTER, K.L., GRAHAM, N. McC. and WAINMAN, F.W. (1959): Environmental temperature, energy metabolism and heat regulation in sheep III--the metabolism and thermal exchanges of sheep and fleeces. J. Agr. Sci. 52:41-49.

BLAXTER, K.L., GRAHAM, N. McC., WAINMAN, F.W. and ARMSTRONG, D.G. (1959): Environmental temperature, energy metabolism and heat regulation in sheep II--the partition of heat losses in closely clipped sheep. J. Agr. Sci. 52:25-40.

BLISS, L.C., COURTIN, G.M., PATTIE, D.L., ROEWE, R.R., WHITFIELD, D.W.A. and WIDDEN, P. (1973): Arctic ecosystems. In: Annual Review of Ecology and Systematics. R.F. Johnson (ed), Annual Review, Inc., Palo Alto, California. 359-399.

BRAESTRUP, F.W. (1941): A study of the arctic fox in Greenland--immigration, fluctuations in numbers. I. Kommission Hos. C.A. Reitzels Forlag. 97 pp.

CHESEMORE, D.L. (1970): Notes on the pelage and priming sequence of arctic foxes in northern Alaska. J. Mamm. 51:156-159.

DAVIS, T.R.A. (1963): Acclimatization to cold in man. In: Temperature, Its Measure and Control in Science and Industry. 3:443-457.

DURRER, J.L. and HANNON, S.P. (1961): Seasonal variation in the caloric intake of dogs living in an arctic environment. Tech. Rep. 61-33. Arctic Aeromedical Laboratory, Ft. Wainwright, Alaska.

GRAHAM, N. McC., WAINMAN, F.W., BLAXTER, K.L. and ARMSTRONG, D.G. (1959): Environmental temperature, energy metabolism and heat regulation in sheep I--energy metabolism in closely clipped sheep. J. Agr. Sci. 52:13-24.

HART, J.S. (1956): Seasonal changes in insulation of fur. Can. J. Zool. 34:53-57.

HART, J.S. (1960): Energy metabolism during exposure to cold. Fed. Proc. 19:15-19.

HEROUX, O., DEPOCAS, F. and HART, J.S. (1959): Comparison between seasonal and thermal acclimation in white rats I--metabolic and insulative changes. Can. J. Biochem. Physiol. 37:473-478.

IRVING, L. (1964): Temperature regulation of large arctic land mammals. Fed. Proc. 23:1198-1201.

IRVING, L. and KROG, J. (1954): Body temperature of arctic and subarctic birds and mammals. J. Appl. Physiol. 6:667-680.

MILLER, I. and FREUND, J.E. (1968): Probability and Statistics for Engineers. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 431 pp.

SCHOLANDER, P.F., WALTERS, V., HOCK, R. and IRVING, L. (1950): Body insulation of arctic and tropical mammals and birds in relation to body temperature insulation and basal metabolic rate. Biol. Bull. 99:259-271.

SELLARS, E.A., RICHMAN, S., THOMAS, N. and YEW, S.S. (1951): Acclimatization to cold in rats: metabolic rates. Am. J. Physiol. 167:651-655.

UNDERWOOD, L.S. (1971): The bioenergetics of the arctic fox (Alopex lagopus L.). Ph.D. thesis. Pennsylvania State University. 85 pp.

DATE

ILME

-8