FATTY ACIDS OF DEPOT LIPIDS IN MIGRATING LAPLAND LONGSPURS

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INTRODUCTION

Fatty acid composition of depot lipids often reflects that of the diet (Johnson and West, 1973; Moss and Lough, 1968; Walker, 1964; West and Meng, 1968b; West and Coady, 1974). If diets differ with geographic locality, then fatty acid composition might be indicative of geographic origin. During migration some birds feed extensively to accumulate fat for the next migratory flight which transports them great distances from the area in which they last fed and accumulated the deposits. Fatty acid composition of birds known to have migrated over a certain route can be compared with that of individuals that migrated over a different route to arrive at the same locality. If differences exist, then we can hypothesize that a group of collected birds may be separated as to their migratory routes on the basis of fatty acid composition.

Lapland Longspurs (*Calcarius lapponicus*) use at least three principal routes migrating to Alaska (West et al., 1968). This migratory pattern can be used to test the hypothesis stated above.

MATERIALS AND METHODS

From 4–13 May 1967, we collected 29 longspurs from the many flocks moving along the Alaska highway (AH) between miles 667 and 1300 (about Watson Lake, Yukon Territory to Tok, Alaska). From 25–27 April 1968, we collected 13 longspurs between miles 717 and 1200 AH (about Teslin, Y.T. to Beaver Creek, Y.T.) from the first wave of spring migrants that we were certain had come through the mountain passes from the coast or along the mountain trenches of British Columbia to Yukon Territory (routes 1 and 2 of Fig. 1 in West et al., 1968). No birds were seen southeast of Watson Lake (mile 635 AH) towards the prairies.

The large flocks of prairie birds, which increased the Watson Lake population from 200 to 1,500 birds on our census route, did not arrive there until 30 April, three days after our collection of early migrants. A sample of six longspurs from the known prairie population was taken from 6–9 May 1968, in the Watson Lake area (mile 633 AH), well east of the usual early influx point of mountain birds (which appear early on the Cassiar Road, west of Watson Lake).

On 13 May and 2 June 1970, Simon Paneak collected 10 and 9 longspurs, respectively, at Anaktuvuk Pass in the Brooks Range of northern Alaska. From his observation, the first group was composed of migrants; the second represented breeding birds.

Birds were frozen intact immediately after collecting and kept frozen until analyzed. Each individual was weighed and measured. The gizzard and esophageal contents were removed, and the carcass cut into pieces for freeze drying. After the birds were dry, each was crumbled into a

TABLE 1.

Principal fatty acids (% by wt.) and the double-bond index (DBI) of the total lipids of Lapland Longspurs migrating over known routes through Yukon Territory.

Fatty acid[1]	Coastal route 25–27 Apr. (n = 13; x̄ ± 1 SD)		Prairie route 6–9 May (n = 6; x̄ ± 1 SD)
14:0	1.20 ± 0.33		0.99 ± 0.36
16:0	24.62 ± 1.35	**	19.94 ± 2.08
16:1	5.47 ± 1.49		4.98 ± 1.01
18:0	7.16 ± 1.19		6.22 ± 1.36
18:1	43.96 ± 2.48	*	35.44 ± 5.86
18:2	13.53 ± 1.91	***	26.17 ± 3.62
20:1	1.94 ± 0.39		3.71 ± 2.05
20:4	0.93 ± 0.28		0.86 ± 0.43
22:6	tr		tr
DBI	0.834 ± 0.02	***	1.022 ± 0.067

[1] Number carbons in fatty acid chain followed by the number of double-bonds. * Significant at $P < 0.05$; ** significant at $P < 0.01$; *** significant at $P < 0.001$.

Soxhlet thimble and extracted with petroleum ether (30–60°C BP) for about 8 hr. An aliquot of the total ether extractable lipids was saponified, the fatty acids recovered in petroleum ether, and methylated with BF_3-methanol. The fatty acid methyl esters (FAME) were chromatographed on a ⅛ in × 8 ft column containing 20% diethyleneglycolsuccinate on 60–80 mesh chromosorb W. Peaks were identified utilizing known standards and accepted plotting techniques (Ackman, 1963, 1969). Quantification was accomplished by measuring peak height times peak width/2. The double-bond index (DBI) was calculated (Richardson et al., 1961), thus providing a measure of the relative degree of unsaturation of the fatty acid mixture.

RESULTS AND DISCUSSION

Twenty-two different fatty acids ranging from 12- to 22-carbon chain lengths with from 0 to 6 double-bonds were identified from the lipids of most individuals. Of these, nine made up over 95% of all fatty acids: myristic (14:0), palmitic (16:0), palmitoleic (16:1), stearic (18:0), oleic (18:1), linoleic (18:2), eicosenoic (20:1), arachadonic (20:4), and docosahexaenoic (22:6). Two groups of birds were initially compared, the known coastal/mountain group with the known prairie group (Table 1). Three fatty acids (16:0, 18:1 and 18:2) and the DBI showed significant differences in percentage. Two of these (18:2 and DBI) were significantly different at the $P < 0.001$ level and were used to distinguish individuals from the mixed flock of 29 birds taken in 1967.

The mean linoleic acid value for the coastal birds was 13.53% + 2 SD = 17.35, whereas the mean for prairie birds was 26.17% − 2 SD =

TABLE 2.

Principal fatty acids (% by wt.) and the double-bond index (DBI) of totals lipids of a sample of migrating Lapland Longspurs separated into two groups on the basis of fatty acid composition (see text).

Fatty acid[1]	"Coastal Route" 4–13 May (n = 15; $\bar{x} \pm 1$ SD)		"Prairie Route" 4–13 May (n = 8; $\bar{x} \pm 1$ SD)
14:0	1.07 ± 0.34		1.24 ± 0.83
16:0	25.76 ± 2.04	*	18.85 ± 4.09
16:1	6.05 ± 1.90	*	4.32 ± 1.46
18:0	7.56 ± 1.27	**	6.13 ± 0.83
18:1	39.38 ± 3.86	**	34.20 ± 3.03
18:2	14.08 ± 2.73	***	23.86 ± 5.04
20:1	4.28 ± 2.43		5.80 ± 2.80
20:4	0.91 ± 0.51		1.61 ± 2.11
22:6	tr		tr
DBI	0.821 ± 0.004	**	1.074 ± 0.175

[1] Number carbons in fatty acid chain followed by the number of double-bonds. * Significant at $P < 0.05$; ** significant at $P < 0.01$; *** significant at $P < 0.001$.

18.93. Because these two values do not overlap, we can assume (with 95% accuracy) that birds with a linoleic acid percentage less than 17.35% are coastal, and those over 18.93% are of prairie origin. Those with intermediate values are in doubt. The same situation applies to DBI, where the coastal birds may be those with a DBI of 0.890 or less ($\bar{x}$ + 2 SD) and those with DBI of 0.888 or greater are prairie birds. Only those birds with a DBI of 0.889 are in doubt.

Separating the 29 birds collected in 1967 according to the above criteria yielded two groups, one of 15 with a mean linoleic acid value of 14.08% and a DBI of 0.821 and a second group of 8 with a mean linoleic acid value of 23.86% and a DBI of 1.074 (Table 2). The remaining six birds did not meet both criteria, i.e., were separated by either one or the other parameters (linoleic acid or DBI) but not by both. A comparison of the two newly designated groups showed that five fatty acids and the DBI are significantly different. Therefore, 23 out of 29 (79%) individuals from the mixed flock could be identified as to probable migratory route.

The birds collected at Anaktuvuk Pass in May and June differed from each other significantly in three acids (18:0, 20:4, and 22:6) and in the DBI (Table 3). Because of the larger amounts of 20:4 and 22:6 acids in the Anaktuvuk birds, the DBI was much higher than in the coastal or prairie populations. If we believe fatty acid composition of depot lipid is reflective of diet, two explanations are possible for the difference between the Anaktuvuk Pass birds and coastal/prairie migrants: (1) the birds coming to Anaktuvuk Pass migrated there from the north having

TABLE 3.

Principal fatty acids (% by wt.) and the double-bond index (DBI) of total lipids of Lapland Longspurs collected at Anaktuvuk Pass.

Fatty acid[1]	Anaktuvuk Pass 13 May (n = 10; $\bar{x} \pm 1$ SD)		Anaktuvuk Pass 2 June (n = 9; $\bar{x} \pm 1$ SD)
14:0	1.69 ± 0.62		1.61 ± 0.41
16:0	21.19 ± 4.42		18.08 ± 2.09
16:1	5.82 ± 0.80		4.48 ± 1.73
18:0	7.42 ± 1.06	***	12.13 ± 2.63
18:1	30.68 ± 3.47		25.61 ± 6.85
18:2	18.71 ± 3.03		16.85 ± 3.81
20:1	7.13 ± 2.15		6.02 ± 1.73
20:4	1.80 ± 0.68	**	3.77 ± 1.34
22:6	2.42 ± 1.55	*	5.05 ± 2.75
DBI	1.106 ± 0.164	*	1.322 ± 0.185

[1] Number carbons in fatty acid chain followed by the number of double-bonds. * Significant at $P < 0.05$; ** significant at $P < 0.01$; *** significant at $P < 0.001$.

come either from Siberia across the Bering Straits, up the Noatak River Valley to the Colville and thence south along the Anaktuvuk River Valley, to Anaktuvuk Pass, or from the east out of the Mackenzie River valley, west along the coast and south into the mountains (considered unlikely by Irving, 1961), or (2) the birds did come through interior Alaska but in stopping to feed there, the fatty acid composition of their migratory fat was reconstituted from the new diet.

Simon Paneak, skillful observer of birds at Anaktuvuk Pass, has written to Laurence Irving and to me that the longspurs he sees arriving at Anaktuvuk Pass do in fact appear from the north. No other sightings are known of birds to the north, east, or west of Anaktuvuk in early May to corroborate this observation. On the other hand, Irving (1961) states that portions of the large flocks of longspurs observed in interior Alaska in spring migrate northward through the passes in the Brooks Range.

If we assume that the Anaktuvuk birds arrived from interior Alaska, then we can legitimately make fatty acid comparisons between them and the coastal and prairie populations. Several fatty acids in the May sample at Anaktuvuk show no change or an averaging of coastal and prairie values (16:0, 16:1, 18:0 and 18:2). Oleic acid decreases in the May birds and continues to fall in the June sample. The proportion of 14:0, 20:1, 20:4, and 22:6 increases in the May sample. Oleic acid has been suggested as the fatty acid accumulated for migratory depot stores (Walker, 1964; West and Peyton, 1972) in many species, but not in arctic nomads and short-distance migrants (Common Redpolls, *Carduelis flammea,* West and Meng, 1968a; Willow Ptarmigan, *Lagopus lagopus,* West and Meng, 1968b) which accumulate linoleic acid. From the proportion of fatty acids analyzed in the May sample, it is not clear from which route the birds had come. If they did come through the interior, their feeding en route and the gradual diminution of migratory fat stores as they arrived on the breeding ground might have contributed to the different fatty acid pattern seen.

From May to June at Anaktuvuk Pass, three significant increases are noted in fatty acid percent (18:0, 20:4 and 22:6); the increase in DBI is due to the increases in 20:4 and 22:6. The decreases in 16:0 and 18:1 are not significant. The June sample represents the fatty acid constitution of birds at the initiation of nesting (Irving, 1960). Factors other than diet, such as temperature and physiological state, influence fatty acid composition of tissue lipids in birds (West and Meng, 1968a) and small mammals (Williams and Platner, 1967; West and Coady, 1974), and, therefore, it cannot be stated that the fatty acid composition of birds in June is a result of dietary influence. We are, however, reasonably sure that the differences observed in migrants are the result of dietary differences in that all birds should have been in a similar physiological state (migratory) and subjected to similar environmental factors (e.g., temperature and photoperiod), and, thus, their fatty acid composition resulted from diets obtained in different geographic regions.

Results obtained from fatty acid analyses of Tree Sparrows (*Spizella arborea*) migrating through Yukon Territory also indicated the potential for movement over several different routes to the points of collection (West and Peyton, 1972). *Calidris* sandpipers moving through the Copper-Bering River Delta system in the Gulf of Alaska also showed differences that we interpreted as resulting from differences in dietary history (Senner et al., 1978). Therefore, this phenomenon is probably of a general nature in birds migrating to Alaska.

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LITERATURE CITED

ACKMAN, R. G. 1963. Structural correlation of unsaturated fatty acid esters through graphical comparison of gas-liquid chromatographic retention times on a polyester substrate. *J. Amer. Oil Chem. Soc.*, **40:** 558–564.

———. 1969. Gas liquid chromatography of fatty acids and esters. *In* Methods in Enzymology, J. M. Lowenstein (ed.), Vol. XIV, Lipids, p. 329–381. New York, Academic Press.

IRVING, L. 1960. Birds of Anaktuvuk Pass, Kobuk and Old Crow: A Study in Arctic Adaptation. *U.S. Natl. Mus. Bull.* 217.

———. 1961. The migration of Lapland Longspurs to Alaska. *Auk,* **78:** 327–342.

JOHNSON, S. R., AND G. C. WEST. 1973. Fat content, fatty acid composition and estimates of energy metabolism of Adélie Penguins (*Pygoscelis adeliae*) during the early breeding season fast. *Comp. Biochem. Physiol.*, **45B:** 709–719.

MOSS, R., AND A. L. LOUGH. 1968. Fatty acid composition and depot fats in some game birds (Tetraonidae). *Comp. Biochem. Physiol.*, **25:** 559–562.

RICHARDSON, T., A. L. TAPPEL, AND E. H. GRUGER, JR. 1961. Essential fatty acids of mitochondria. *Archs. Biochem. Biophys.*, **94:** 1–6.

SENNER, S. E., G. C. WEST, AND D. W. NORTON. 1978. Nutritional significance of Copper Bering River intertidal system to spring-migrating shorebirds breeding in western Alaska. Final Report to NOAA/OCSEAP & DOE. 63 p., mimeo.

WALKER, A. T. 1964. Major fatty acids in migratory bird fat. *Physiol. Zool.*, **37:** 57–64.

WEST, G. C., AND M. S. MENG. 1968a. The effect of diet and captivity on the fatty acid composition of redpoll (*Acanthis flammea*) depot fats. *Comp. Biochem. Physiol.*, **25:** 535–540.

WEST, G. C., AND M. S. MENG. 1968b. Seasonal changes in body weight and fat and in the relation of fatty acid composition to diet in the Willow Ptarmigan. *Wilson Bull.*, **80:** 426–441.

WEST, G. C., L. J. PEYTON, AND L. IRVING. 1968. Analysis of spring migration of Lapland Longspurs to Alaska. *Auk*, **85:** 639–653.

WEST, G. C., AND L. J. PEYTON. 1972. The spring migration of the Tree Sparrow through southern Yukon Territory. *Bird-Banding*, **43:** 241–256.

WEST, G. C., AND J. W. COADY. 1974. Fatty acid composition of tissue lipids of captive and wild brown lemmings. *Comp. Biochem. Physiol.*, **47B:** 353–368.

WILLIAMS, D. D., AND W. S. PLATNER. 1967. Cold induced changes in fatty acids of the rat and hamster. *Amer. J. Physiol.*, **212:** 167–172.

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