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DUNLIN WEIGHT CHANGES IN RELATION TO FOOD HABITS AND AVAILABLE PREY

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The seasonal weight variations of the Dunlin (*Calidris alpina*) have been well documented in Europe (Evans 1964, Mascher 1966, Prater 1975, Eades and Okill 1977, Pienkowski et al. 1979, Davidson 1979), Northwest Africa (Dick and Pienkowski 1979), and North America (Holmes 1966, Page 1974, Kaiser and Gillingham 1981). Very little has been reported on lipid levels in shorebirds. To our knowledge, only Evans and Smith (1975), Mascher and Marcstrom (1976), and Davidson (1979) have published such data.

During the winter (December–March) of 1980–1981, we observed an increase in the mean total and fat free weights of a Dunlin population in western Washington. Dunlin weights at 3 other areas declined significantly during the same winter. The purpose of this paper is to examine these weight change patterns and discuss them in relation to Dunlin food habits and prey availability at each of the 4 areas studied.

STUDY AREAS AND METHODS

Three of the 4 winter Dunlin populations studied were located in Puget Sound; the fourth was located in Grays Harbor on the outer coast of Washington state (Fig. 1). Large Dunlin populations wintered at Samish Bay (ca. 10,000 birds) and Bowerman Basin (ca. 13,000 birds). The Nisqually and Kennedy Creek Delta populations characterize the smaller flocks dispersed throughout Puget Sound in winter. Approximately 2300 Dunlins wintered at each of these 2 areas.

Weights and lipids.—From collections made during November–December 1980 and early March 1981 a total of 64 and 32 Dunlins, respectively, were used in these analyses and for an analysis of organochlorine contaminants. Dunlins were collected with steel shot, placed on dry ice to stop posthumous digestion, and transferred to a freezer within several hours. They were thawed before being weighed to within 0.1 g on a triple-beam scale. Lipids were extracted with a 2:3 mixture of 70% perchloric and glacial acetic acid (Stanley and LeFavoure 1965). To determine lipid content, an aliquot was poured off and the solvent (n-hexane) allowed to evaporate. The weight of the remnant product was multiplied by its ratio to the total volume of extract to obtain the total lipid weight of each bird. Fat free weight was calculated by subtracting lipid weight from total weight.

Although female Dunlins are slightly heavier than males (Holmes 1966, MacLean and Holmes 1971, Kaiser and Gillingham 1981; unpubl. data), the sex ratios within our samples are such that they tend to be a conservative test of the weight change hypothesis (see Table 1). We have

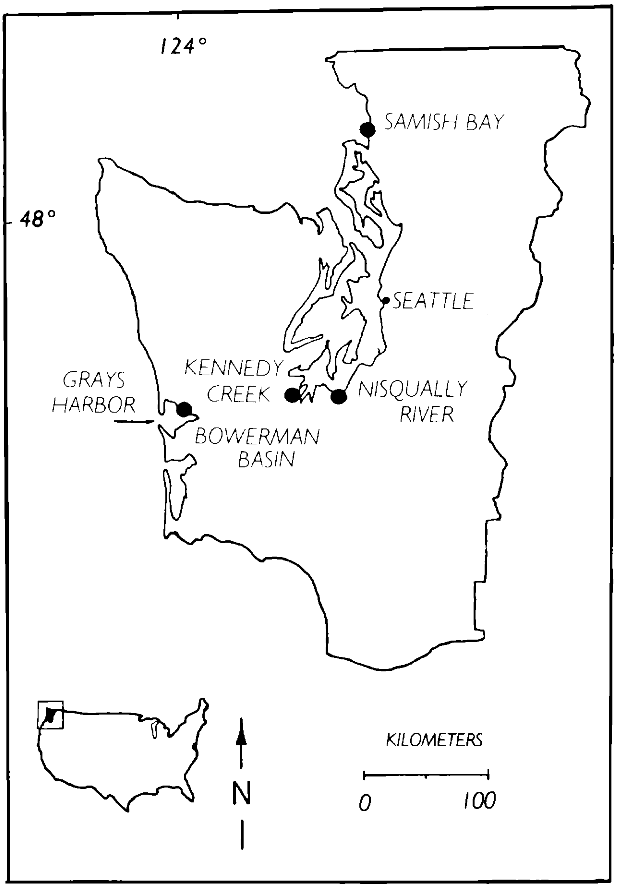

FIGURE 1. Geographic locations of the 4 study areas in western Washington state.

found no difference in mean total weight between immature and adult Dunlins (Brennan et al. 1984).

Food habits and prey availability.—All food habits and prey availability sampling were done during March 1981. In the laboratory, the esophagus and stomach were removed from each Dunlin and the contents washed into a petri dish with a 10% formalin solution. We calculated the relative percentage of each invertebrate taxon present. Sediment cores were taken immediately after Dunlins were collected, from areas where we had observed them foraging during the early part of the falling tide period. All sediment samples were taken using a 10.5 cm inside diameter by 10 cm steel cylinder. The samples were placed immediately in glass jars and fixed with 30% formalin. Two replicates were taken at

TABLE 1. Overwinter changes in % lipid, and total, lipid, and fat free weights of Dunlins. Samples were collected from 4 estuaries in western Washington during early and late winter 1980–1981.

Area Collection date	Type of weight measure (g)								Total sample
	Total weight		Lipid weight		% Lipid		Fat free weight		
	x̄	SD	x̄	SD	x̄	SD	x̄	SD	(♂; ♀)
Bowerman Basin									
Nov. 1980	54.8	3.1	4.2	1.2	7.6	1.9	50.6	2.7	16 (8; 8)
Mar. 1981	50.6	4.3	2.2	0.5	4.4	0.9	48.4	4.2	8 (5; 3)
Significance[a]	*		***		***		NS		
Kennedy Creek Delta									
Dec. 1980	54.4	3.4	4.7	1.1	8.7	1.9	49.7	3.2	16 (8; 8)
Mar. 1981	57.5	4.1	3.8	0.4	6.6	0.5	53.7	3.9	8 (6; 2)
Significance	NS		**		***		*		
Nisqually River Delta									
Dec. 1980	53.0	3.2	4.0	0.8	7.5	1.3	49.0	2.9	16 (12; 4)
Mar. 1981	49.1	2.5	2.0	0.5	4.0	0.9	47.1	2.3	8 (5; 3)
Significance	**		***		***		NS		
Samish Bay									
Dec. 1980	56.2	4.4	5.9	1.6	10.4	2.4	50.3	3.7	16 (12; 4)
Mar. 1981	50.0	2.6	2.5	0.5	5.0	1.0	47.5	2.6	8 (6; 2)
Significance	***		***		***		*		

[a] Based on pairwise *t*-tests; NS = not significant, * = $P < .05$, ** = $P < .01$, *** = $P < .001$.

each sample location. In the laboratory, sediment cores were rinsed through a 0.8 mm screen and all potential food items were identified and tallied. The density values of each taxon were used to calculate a relative measure (%) of abundance.

The identification of invertebrates was based on keys by Banse and Hobson (1974), Kozloff (1974), Otte (1975), Smith and Carlton (1975), and Staude et al. (1977).

To follow overall winter population trends and movements each site was visited weekly between December 1980 and March 1981.

RESULTS

At 3 study areas (Samish, Nisqually, and Bowerman) the mean total weights of Dunlins decreased between December and March, while at Kennedy, there was a substantial increase. Lipid weights and percentages decreased significantly at all 4 areas. Fat free weights decreased at Samish, Nisqually, and Bowerman, although significantly only at Samish ($P < .05$). Mean fat free weights of the Kennedy Dunlins increased significantly ($P < .05$) (Table 1).

The lipid and fat free weight data illustrate a unique pattern of mean

TABLE 2. Percentages of total food items in the esophagi and stomachs of 58 Dunlins collected in western Washington.

	Bowerman n = 19	Kennedy n = 13	Nisqually n = 7	Samish n = 19
Annelida				
Polychaeta		76	1	
Mollusca			1	4.5
Arthropoda				
Ostrocoda	1	14	8	1
Pancolus californiensis	1		5.5	14
Leucon sp. and *Leptocuma* sp.	70			
Corophium sp.	24	6	12.5	58
Diptera larvae	1		60	13
Other	3	4	12	9.5

total weight changes for Dunlins at Kennedy Creek Delta. The mean lipid weight of Dunlins from Kennedy declined 20% between early and late winter; much higher losses were noted at Samish (58%), Nisqually (51%), and Bowerman (47%). Moreover, the mean fat free weight of the Kennedy Dunlins increased 7% between December and March while overwinter losses were observed at Samish (6%), Nisqually (4%), and Bowerman (4%).

Dunlin food habits varied among the 4 sites (Table 2). Dunlins at Samish had a relatively large amount (58%) of *Corophium insidiosum* and lesser amounts of *Pancolus californiensis* (14%) and Diptera larvae (13%) in their stomachs and esophagi while Diptera larvae appeared to be the primary food item of the Nisqually Dunlins. At Bowerman, the arthropods *Leucon* sp. and *Leptocuma* sp. combined to make up 70% of the total food items while *Corophium salmonis* constituted 24%. At Kennedy polychaete worms made up 76% of the total food items.

The relative abundances of invertebrate prey available to Dunlins also varied among the 4 sites. At all areas annelid worms of the Classes Polychaeta and Oligochaeta were the most abundant invertebrates available, however, Dunlins consumed annelid worms in proportion to their availability only at Kennedy (Tables 2 and 3).

DISCUSSION

The pattern of overwinter weight loss observed in Samish, Nisqually, and Bowerman Dunlins is similar to that observed in Dunlins at the Wash estuary (Pienkowski et al. 1979). In their analysis of Dunlin weight changes Pienkowski et al. (op. cit.) found that total weights peaked in December and then decreased steadily until reaching their lowest level in March. Dunlin weights then increased during April and May, prior to migration. They also observed that the only deviation from this pattern was represented by weights that remained nearly unchanged

TABLE 3. Relative abundances (%) of invertebrate prey available to Dunlin at 4 estuaries in western Washington state. Sample sizes (n) are the number of sediment cores analyzed from each area.

	Bowerman n = 12	Kennedy n = 14	Nisqually n = 12	Samish n = 12
Rhynchocoela			7.2	0.03
Oligochaeta	4.5	17.0	53.7	73.9
Polychaeta	54.7	81.5	28.8	21.0
Malacostraca	5.2			2.1
Cumacea	22.8		0.5	0.1
Diptera	3.8		0.2	0.9
Other	9.0	1.5	9.6	1.1

through the winter. When the environmental rigors of winter are considered with the reduced activity and increased depth of invertebrate prey (Goss-Custard 1969, Smith 1974), a decrease in Dunlin weights and lipids is expected. Thus, the overwinter weight gain observed in the Kennedy Dunlins appears to be contrary to the general weight loss pattern of Dunlins in winter.

It is unlikely that the increase in Dunlin weights observed at Kennedy was influenced by heavier birds migrating into the area. We made regular visits to all 4 sites through the winter and it was our impression the populations were stable (see Brennan et al. 1985). The first indication of spring migration was not detected until 10 days after we collected at Kennedy, when an additional 800 birds arrived at this site. In addition, our lipid data are a by-product of an organochlorine contamination study at these same areas. In the case of the Kennedy Dunlins, there was no significant change in the ratio of DDE to PCB contaminants over the winter. Both the early and late winter samples of the Kennedy Dunlins had levels of PCB contamination that were significantly greater ($P < .05$, Student-Newman-Keuls test) than the other 3 study areas.

Although a multitude of factors can potentially affect Dunlin food habits, we hypothesize that the food habits described herein are influenced by the relative densities of the available prey. The density of polychaete worms available to Dunlins at Kennedy was 27% greater than at Bowerman, 53% greater than Nisqually, and 61% greater than Samish. Other factors, such as subtle substrate differences (Quammen 1982) or vertical migrations of invertebrates (Vader 1964) may have influenced the food habits described above. However, after experimentally varying prey size, prey density, prey depth, and substrate penetrability, Myers et al. (1980) concluded that prey density had the single greatest impact on the diet of the Sanderling (*Calidris alba*).

Although we do not have mid-winter data, it is possible that the Kennedy Dunlins experienced no overwinter weight loss. These birds appeared to increase their weight between late fall and the end of winter. Pienkowski et al. (1979) and Dick and Pienkowski (1979) suggest that

Dunlins need to carry only as much fat reserve as is necessary for survival. Both of these studies suggest that Dunlins possess the ability to restore this reserve if it has been depleted. In contrast to the other 3 study areas, the Kennedy Creek Delta is not diked and most high tides cover the entire salt marsh, thus forcing the birds to fly as far as 30 km to roost during high tide. It is possible that the Kennedy Dunlins must maintain a large fat reserve through winter to compensate for long daily flights between roosts and feeding areas. This reserve could serve as insurance in the event that salt marsh roosting habitat is unavailable during high tides.

Lipid deposition studies of other bird species (Connell et al. 1960, Evans 1969, Fry et al. 1970) have shown that the fat free weight of a bird is often a more reliable measure of actual weight variation than total weight. This suggests that the Kennedy Dunlins may have been increasing body mass, possibly in the form of flight muscles.

Goss-Custard (1977) has suggested that polychaete worms available to shorebirds as prey are calorically superior to amphipods. Our data also suggest that there may be differences in the "quality" of invertebrate prey available to Dunlins in winter and that intersite differences in Dunlin foraging strategies and physiological needs may influence the pattern of their overwinter weight changes.

SUMMARY

The total and fat free weights of Dunlins at 3 estuaries in western Washington state decreased significantly between early and late winter (December–March). Total and fat free weights of a fourth winter population increased during the same study period. Total lipid weights of Dunlins decreased significantly during the same winter at all sites. In an analysis of food habits and prey availability, we found that the Dunlin population with the overwinter weight increase consumed the highest percentage of polychaetes and was the only one of the 4 populations studied that selected polychaete worms in proportion to their availability.

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