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A Comparison of Three Methods for Measuring Arthropod Abundance in Tundra Habitats and its Implications in Avian Ecology

Abstract

Arthropod abundance was sampled in the alpine tundra of the Beartooth Mountains, Wyoming during the summer of 1981. Sticky board and pitfall traps showed similar patterns of capture success, with maximum captures in late July; capture success using a sweep net showed a similar peak but fluctuated more than the other methods. Proportions of major taxa and size distribution of arthropods captured differed significantly between all three methods. Pitfall traps caught relatively more Coleoptera and Araneae. Sticky boards and sweep nets captured proportionately more Diptera. Sticky boards and pitfall traps caught a larger proportion of arthropods > 4 mm in length than did sweep nets, and significantly more taxa per sampling period than did sweep netting. Sweep netting was a poor technique for sampling surface-active tundra arthropods. A combination of pitfall traps and sticky boards sampled a wider variety of prey taxa and may provide a more accurate estimate of abundance. Researchers working in tundra habitats should use care in making ecological inferences related to prey availability based on capture data from a single sampling method, as multiple methods are required to adequately sample the tundra arthropod fauna.

Introduction

Temporal and spatial patterns of arthropod abundance may have important consequences for avian predators in arctic and alpine habitats. Arthropod abundance may influence avian breeding phenology, habitat use, and resource partitioning (Pitelka 1959, Holmes and Pitelka 1968, Hoffman 1974, Seastedt and MacLean 1979). Accordingly, several avian ecologists have attempted to measure patterns of arthropod abundance in tundra and meadow habitats. These attempts have generally involved a single relative method (MacLean and Pitelka 1971, Hussell 1972, Conry 1978, Seastedt and MacLean 1979, Winternitz 1980). Although relative techniques, which measure populations in unknown units, may accurately describe arthropod abundance, they are also subject to numerous interpretational and sampling problems (Southwood 1978).

The purpose of this paper is to compare the relative efficiency of using sticky boards, pitfall traps, and sweep nets to sample arthropod abundance in a high montane meadow. Temporal and spatial changes in abundance within and among taxa at the class or species level are not discussed. Rather, data on seasonal activity patterns, and size and order of arthropods captured, are used to evaluate the effectiveness of the three techniques, and to discuss implications for ornithological research. To my knowledge, a com-

parative study of this nature has not been previously undertaken in an alpine or arctic habitat.

Methods

Arthropods were sampled in a high montane meadow at 3000 m near the upper tree limit in the Beartooth Mountains, Park County, Wyoming (44°56'N, 109°30'W) during the summer of 1981. The study area contained three habitat types: 1) dry meadow, with short, sparse vegetation; 2) moist meadow, with vegetation intermediate in size and density; and 3) wet meadow, with tall, dense vegetation. This terminology follows that of Pattie and Verbeek (1966), although the plant communities did not correspond exactly to those described on the Beartooth Plateau; a major difference was that their "wet meadow" contained more willow (*Salix* spp.), which was almost absent from my study site.

Arthropods were sampled between 22 June and 14 August 1981. Twenty sticky boards (MacLean and Pitelka 1971) of 10 cm x 20 cm plexiglass coated with Tanglefoot™ were placed at ground level using a grid established for bird censusing and coordinates chosen with a random numbers table. Single pitfall traps (7.5 cm diameter plastic cups) were buried flush with the ground surface at 1 m from the center of each sticky board. Ethylene glycol was used as a preservative. Sweep netting was conducted along a 200 m transect through the area sampled with

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sticky boards and pitfall traps; 200 sweeps were taken along each transect.

Sticky boards and pitfall traps were operated simultaneously for 24 hr at about one-week intervals. Sweep net transects were run at 1200 MST on days that arthropods were collected from traps. All arthropods captured were identified to order, measured and assigned to size class categories (2.1-4.0, 4.1-6.0, . . . 18.1-20.0, > 20.0 mm). Arthropods < 2.1 mm in length were not counted, as tundra-foraging birds rarely capture smaller prey (Holmes and Pitelka 1968, Hussell 1972, Seastedt and MacLean 1979). Analyses of taxonomic and size class composition are based upon total captures during the study. The G-statistic (Sokal and Rohlf 1981) was used to compare differences in capture frequencies for taxa and size class categories among the methods.

Results

Sticky board and pitfall traps showed similar capture success, with maximum captures between 13

July-31 July for pitfall traps and 24 July-31 July for sticky boards (Figure 1). The abundance peak was broader for pitfall traps, with a greater proportion of captures earlier in the season. Sweep net captures peaked on 24 July, dropped sharply on 31 July and 7 August, then rose; this fluctuation was not mirrored by sticky boards and pitfall traps.

Pitfall traps captured significantly different proportions of arthropod taxa than either sticky boards or sweep netting (Tables 1, 2; G-tests, $P < .001$). Proportions of major taxa captured also differed significantly between sticky boards and sweep nets (G-test, $P < .001$), but differences were not as great (Table 2). The most common taxa captured in pitfall traps were Araneae (entirely Arachnida), Diptera and Coleoptera (Table 1). Diptera, Hymenoptera, and Homoptera (mostly Cicadellidae) were the most common orders captured by sticky boards and sweep netting. Between-method comparisons using Kendall's rank correlation (Sokal and Rohlf 1981) indicated concordance of taxa ranked according to total

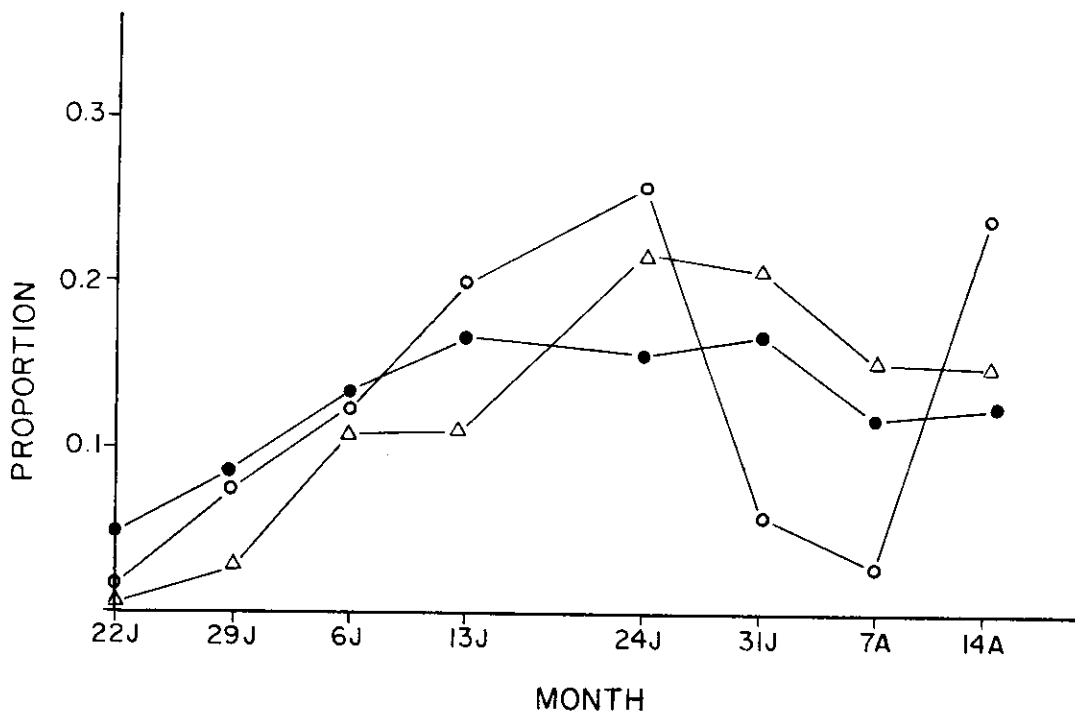


Figure 1. A comparison of abundance patterns of surface-active arthropods as measured by sweep net (○), sticky board (△), and pitfall trap (●) between 22 June and 14 August 1981. Proportions are based on total number of arthropods captured by each method.

TABLE 1. Proportion of total arthropods in each order captured by sweep net (SN), sticky boards (SB) and pitfall traps (PF); n = total captures over sampling period.

Sampling Method	n	Order								
		Araneae	Orthoptera	Hemiptera	Homoptera	Lepidoptera	Diptera	Coleoptera	Hymenoptera	Other*
SN	887	.007	.003	.028	.063	.002	.847	.001	.037	.010
SB	6651	.007	.019	.005	.049	.047	.806	.002	.064	.000
PF	1651	.307	.040	.040	.031	.010	.260	.219	.053	.039

*Includes Acarina, Tricoptera, and unidentified arthropods.

number of captures for sticky boards and sweep netting ($\tau = 0.611$, $P < .05$). Rankings of orders captured in pitfall traps were not concordant with those captured by sticky boards ($\tau = 0.084$, $P > .05$) and sweep netting ($\tau = 0.084$, $P > .05$).

TABLE 2. G-values for between-method comparisons of taxonomic and size-class composition of captures for sweep net (SN), sticky boards (SB) and pitfall traps (PF). All taxonomic and size-class values are significantly different at the .001 level.

	Comparison		
	SB-PF	SB-SN	SN-PF
Taxonomic Composition	3253.640	131.880	1143.468
Size-class Composition	169.540	137.860	201.498

Abundance patterns of Araneae and Coleoptera, as measured by pitfall traps, showed broad peaks, with only moderate weekly changes in capture success (Figure 2). Fluctuations in numbers of these orders captured on sticky boards were much greater, perhaps because of small sample sizes. Abundance patterns for other common arthropod orders were similar for sticky boards and pitfall traps (Figures 2, 3). Numbers of Araneae, Coleoptera, Lepidoptera, and Orthoptera cap-

tured in sweep nets were inadequate to show changes in abundance during the sampling period. Numbers of Diptera, Homoptera, and Hymenoptera showed different peaks and fluctuated more severely than did numbers of these orders captured by pitfall traps and sticky boards. Sweep netting also captured significantly fewer orders during each trapping period than did either pitfall traps or sticky boards [Tukey-Kramer Method (Sokal and Rohlf 1981); $P < .05$ for both comparisons].

Size frequency distributions of captured arthropods (Table 3) differed significantly among all inter-method comparisons (Table 2). Pitfall traps captured higher proportions of arthropods in size categories > 6.1 mm than did sweep netting or sticky boards, while sweep netting captured a higher proportion of arthropods in the 2.1-4.0 mm range than did the other methods.

Discussion

The trapping efforts in this study yielded results similar to those from studies elsewhere. Beetles and spiders are important ground surface predators in Colorado and Norwegian alpine tundra, and are caught frequently in pitfall traps (Tolbert *et al.* 1977, Hågvar *et al.* 1978). In both areas, these taxa display early and late season

TABLE 3. Proportion of total arthropods in each size class captured by sweep net (SN), sticky boards (SB) and pitfall traps (PF); n = total captures over sampling period.

Sampling Method	n	Size Class (mm)					
		2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0	10.1-12.0	> 12.1
SN	887	.543	.323	.103	.019	.011	.001
SB	6651	.355	.452	.108	.036	.025	.023
PF	1651	.302	.361	.217	.065	.025	.030

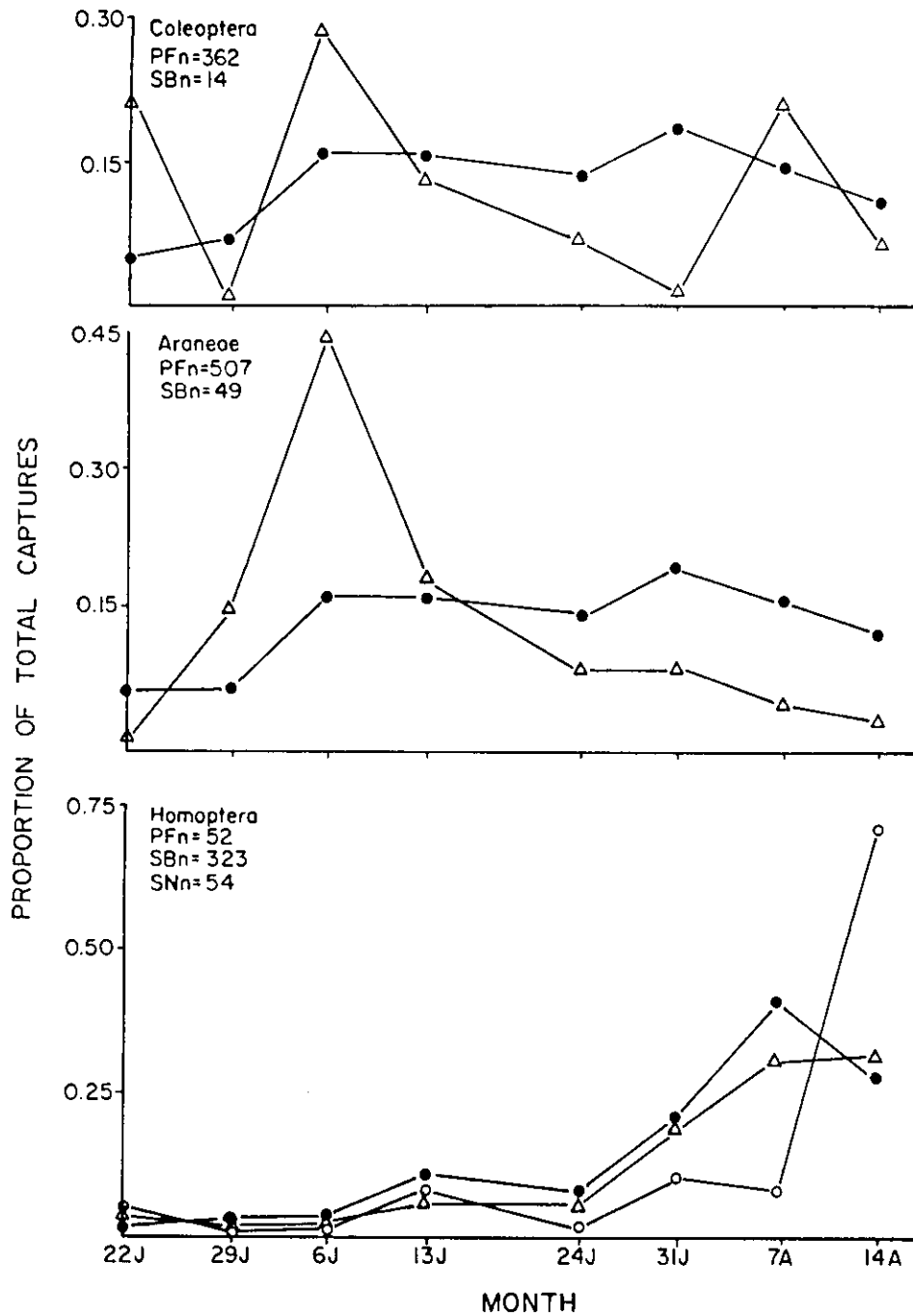


Figure 2. Abundance patterns of Coleoptera, Araneae, and Homoptera captured by sweep net (SN, ○), sticky board (SB, △), and pitfall trap (PF, ●) between 22 June and 14 August 1981. Sample sizes for the methods are given for each order. Proportions are based on the total number of arthropods captured by each method.

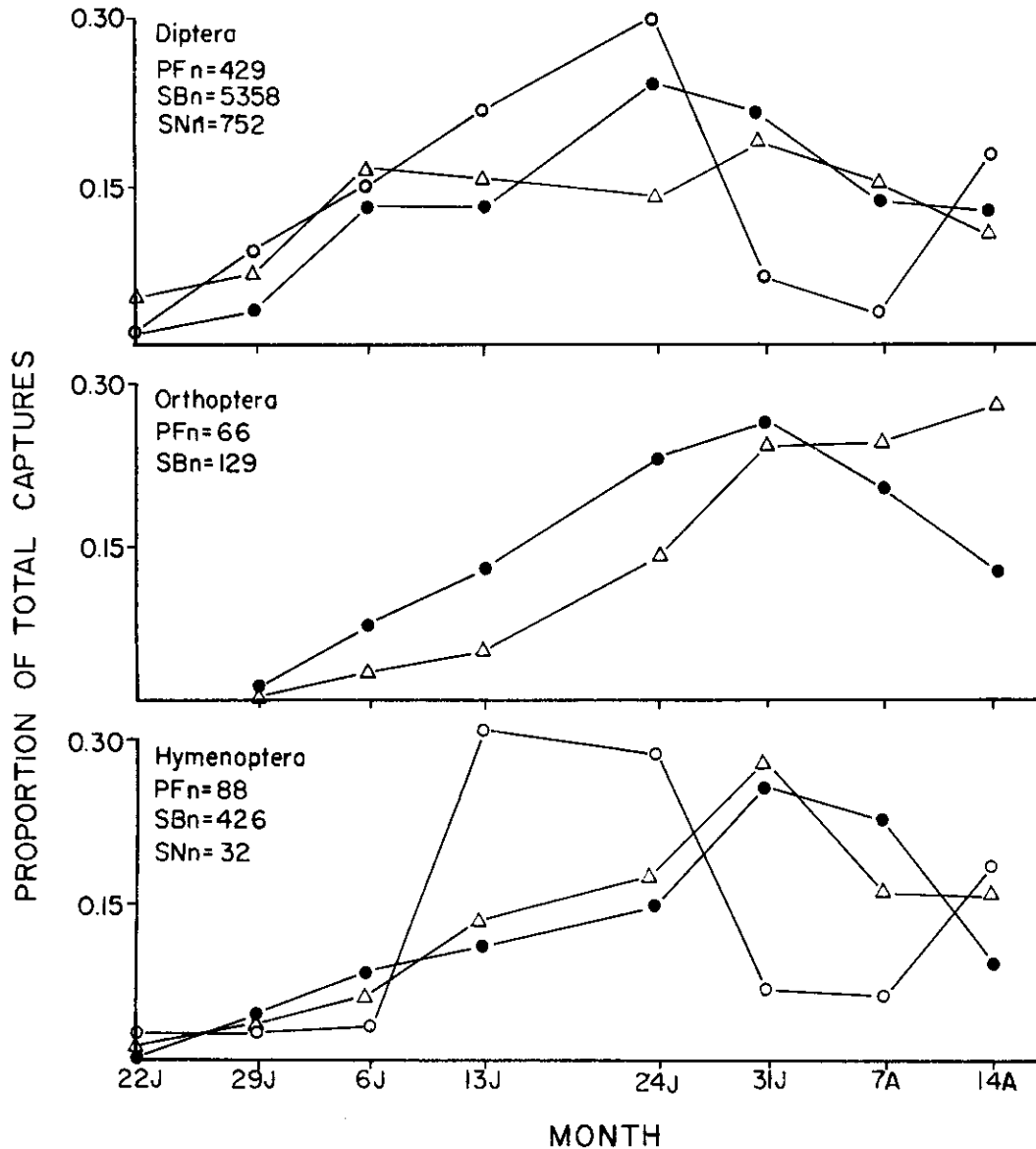


Figure 3. Abundance patterns of Diptera, Orthoptera, and Hymenoptera captured by sweep net (SN, ○), sticky board (SB, △), and pitfall trap (PF, ●) between 22 June and 14 August 1981. Sample sizes for the methods are given for each order. Proportions are based on the total number of arthropods captured by each method.

abundance peaks. As in the present study, Hågvar *et al.* (1978) and Norvell (1985) captured large numbers of Diptera and Hymenoptera in pitfall traps. In a study using sticky boards in Colorado alpine tundra, dipterans were captured 15 times

more frequently than any other order (Conry 1978).

Arthropod populations are difficult to measure accurately (Southwood 1978). While data from absolute methods (suction sampling, direct

count, Berlese-funnel), which measure populations in numbers of animals/unit area (Southwood 1978), are preferable to those from relative methods, ornithologists may lack the time or equipment necessary to accurately quantify arthropod populations. Thus there is a need for relative methods that require simple equipment and less time (Southwood 1978), yet accurately depict activity patterns of arthropod prey.

The results of this study and those collected elsewhere can be used to make recommendations regarding the use of sweep nets, pitfall traps, and sticky boards in tundra habitats. Of these methods, sweep netting seems to be the least effective. Total number of captures was lowest, and some orders of ground-dwelling arthropods were missed almost entirely. This method was also more vulnerable to disruption by short-term changes in weather conditions (high winds or afternoon convectional storms) than either pitfall traps or sticky boards, which were operated for 24-hr periods. In addition, experience of the collector may also influence the results obtained by sweep nets (W. J. Turner, Washington State University, pers. comm.). These limitations make sweep netting an unreliable technique for estimating arthropod activity, although it has been used for this purpose in a Colorado montane meadow (Winternitz 1980).

Pitfall traps are useful in illustrating seasonal variations in activity of different taxa of surface-active arthropods (Uetz and Unzicker 1976, Hågvar *et al.* 1978), although the data are subject to interpretational errors (Uetz and Unzicker 1976, Adis 1979). Thus, it is not surprising that Araneae and Coleoptera were captured frequently in pitfall traps during the study. However, pitfall traps may yield little information on flying arthropods. In this study, few Lepidoptera and Homoptera were captured using this method, even though both taxa include important foliage herbivores in alpine tundra (Tolbert *et al.* 1977). Diptera were probably also underrepresented in these samples, as they comprised 27 percent of the total pitfall captures, versus 80 percent of all sticky board captures.

In this study, sticky boards were most effective in capturing flying and/or hopping arthropods, as has been found in other studies of tundra arthropods (MacLean and Pitelka 1971, Conry 1978). Hadley (1969) has shown that sticky traps and direct enumeration give similar infor-

mation on emergence patterns for a tipulid in a British bog. Other important taxa of surface-active arthropods were probably underrepresented, particularly Coleoptera and Araneae. These taxa are important components of other alpine tundra faunas (Tolbert *et al.* 1977, Hågvar *et al.* 1978) and were taken frequently in pitfall traps. Conry (1978) trapped few spiders on sticky boards in Colorado alpine tundra, while MacLean and Pitelka (1971) trapped few ground beetles on sticky boards in arctic Alaskan tundra.

Estimates of arthropod activity and emergence patterns in tundra and meadow habitats, based on data from a single capture method, have been used to make inferences regarding avian ecology in a number of studies. Since any one method will not sample all types of available arthropod prey adequately, such inferences may be misleading. For example, Conry (1978) captured few arthropods early in the season on sticky boards. On this basis, she hypothesized that Water Pipit (*Anthus spinoletta*) populations were most likely limited by early-season food shortages. However, other studies show that sticky boards do not adequately sample spiders and ground beetles, which are relatively abundant in the alpine in early season (Tolbert *et al.* 1977, Hågvar *et al.* 1978, present study). Although Water Pipit diets have not been studied intensively throughout the breeding season in the North American alpine, spiders and ground beetles are important components of early season Meadow Pipit (*Anthus pratensis*) diets in the Norwegian alpine (Hågvar and Østbye 1976), and Conry (1978) found that Water Pipits frequently fed their nestlings spiders. Thus Conry's inference cannot be supported because her sampling method missed an important, and possibly abundant, component of pipit diets.

A second example in which an important component of the diet of a tundra-nesting species may have been sampled inadequately is found in Husell's (1972) comparison of arthropod abundance and hatching dates for Snow Buntings (*Plectrophenax nivalis*). In both 1968 and 1969, a large number of bunting broods hatched prior to the emergence of flying arthropods captured by sticky boards. Presumably, nestlings from these broods would have been fed other kinds of arthropod prey, including larvae, pupae, and spiders, which are an important early-season food source for buntings on Devon Island (Pattie

1977), but the sampling method was ineffective in capturing these forms.

From the above discussion, several recommendations can be made. First, ornithologists seeking to estimate arthropod prey activity should use more than one relative method. Uetz and Unzicker (1976) and Adis (1979) suggested that studies using pitfall traps should employ a second method to reduce interpretational problems. Holmes (1966) used four sampling techniques in a study of the feeding ecology of the Dunlin (*Calidris alpina*) in arctic Alaska; each method was selected to sample an important dietary component. Such decisions can only be made on the basis of at least a partial understanding of the natural history of both the avian predator and its prey.

Selection of a single sampling technique requires sufficient information to justify such a decision. The conclusions of Custer and Pitelka (1977) and Seastedt and MacLean (1979) concerning the impact of temporal and spatial patterns of prey abundance on Lapland Longspur (*Calcarius lapponicus*) breeding ecology were based entirely on data from sticky board captures. However, dietary analyses showed that the major longspur prey taxa are sampled by sticky boards, validating their conclusions.

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- Second, sweep netting is not an appropriate technique for obtaining indices of relative arthropod abundance in tundra habitats. It seriously underestimates some important prey taxa, and is more influenced by inclement weather.
- Third, a combination of sticky boards and pitfall traps will probably give an accurate estimate of the relative abundance of adult arthropods through time in tundra habitats. However, sampling of immature forms, which may constitute an important dietary component of some tundra-breeding species (Hågvar and Østbye 1976, Conry 1978, Seastedt and MacLean 1979), would require the use of an absolute sampling method.

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