observations were particularly low on the tundra and seeded plots. Longspurs represented 83 percent of the total number of observations on all plots combined (Table 14).

Table 14. Relative abundances of bird species (percent of total) on individual study plots and on all study plots combined at Lake State 1(A), Prudhoe Bay, Alaska, 1990.

	Study Plot					
Species	Seeded	Unseeded	"Road"	Gravel Spray	Tundra	All Plots
Lapland Longspur	94	79	93	75	90	83
Snow Bunting	4	20	5	4		8
Semipalmated Sandpiper	1		<1	10		4
Pectoral Sandpiper		1	1	7	7	3
Red-necked Phalarope			<1	3		1
Greater White-fronted Goose	1					<1
Northern Pintail				<1		<1
White-rumped Sandpiper				<1		<1
Dunlin				<1		<1
Buff-breasted Sandpiper				<1		<1
Parasitic Jaeger		<1		<1	3	<1
Yellow Wagtail				<1		<1

Lake State 1 (B)

The mean numbers of observations per 2.5-hr period were much greater on the unseeded gravel and impoundment plots than on the seeded gravel and tundra plots (Fig. 10a). The mean number of species observed per period was greatest on the impoundment and lowest on the tundra. When the level of use was adjusted to size of the smallest plot (seeded and unseeded, Table 10), the numbers of observations per period on the impoundment and tundra plots dropped substantially (Fig. 10b).

Species richness was greatest at the impoundment (12 species) (Fig. 10c), mainly because shorebirds used that plot but not others (Table 15). Richness on the other plots ranged from 2 to 3 species. Likewise, the species diversity index was much greater at the impoundment and was much lower on the other plots.

For Lapland Longspurs, feeding was the primary behavior observed at all plots except tundra (Fig. 11a). The high percentage of "other" behavior on the tundra reflects our inability to discern behavior types in vegetation. For birds other than longspurs, behavior followed a similar trend (Fig. 11b), although

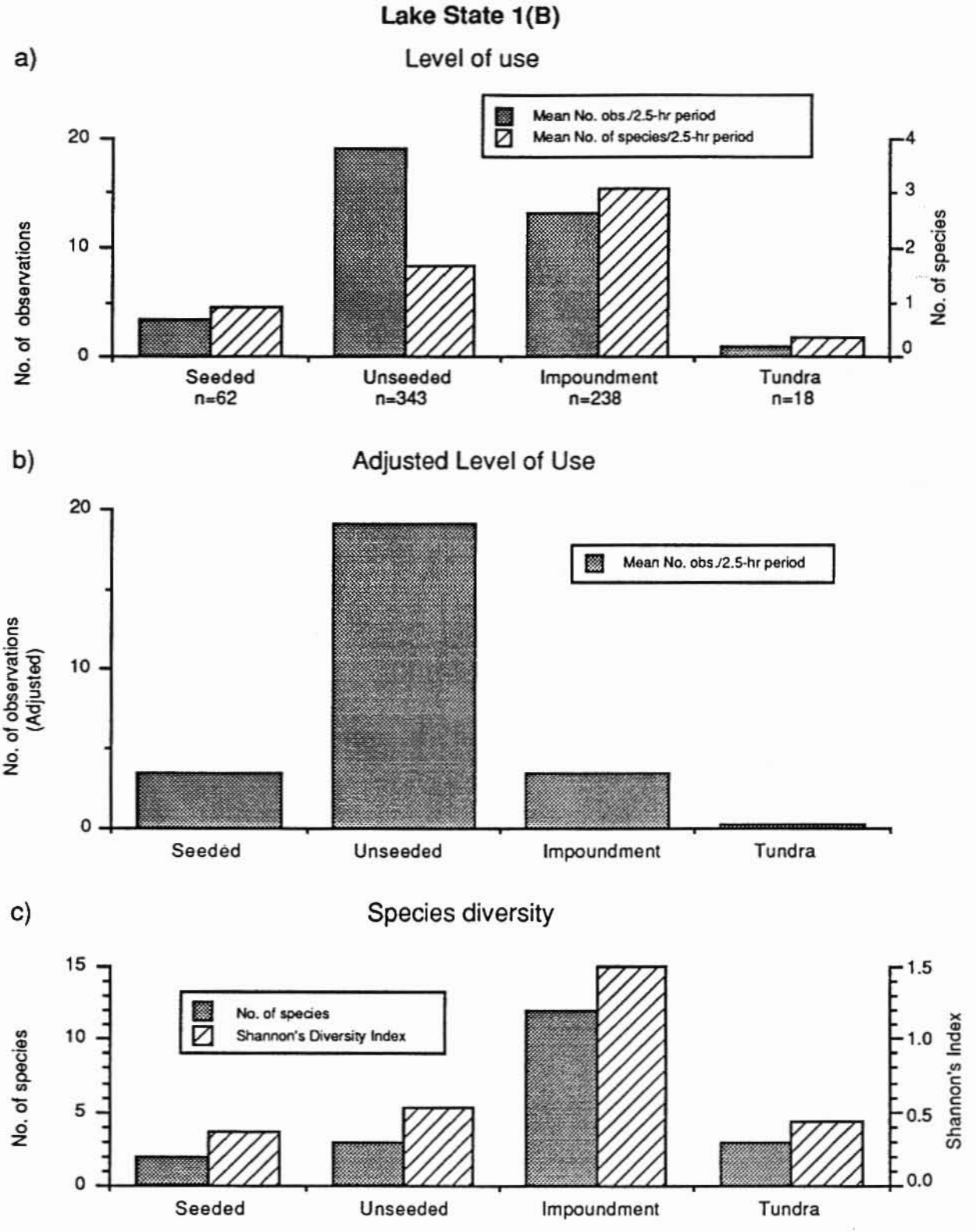

Fig.10. Levels of bird use (a), levels of use adjusted to standard plot size (b), and species diversity (c) on study plots at Lake State 1(B), Prudhoe Bay, Alaska, 1990. In (a), n is the total number of observations. The seeded, unseeded, and impoundment plots represent disturbed habitats; the tundra plot is undisturbed habitat.

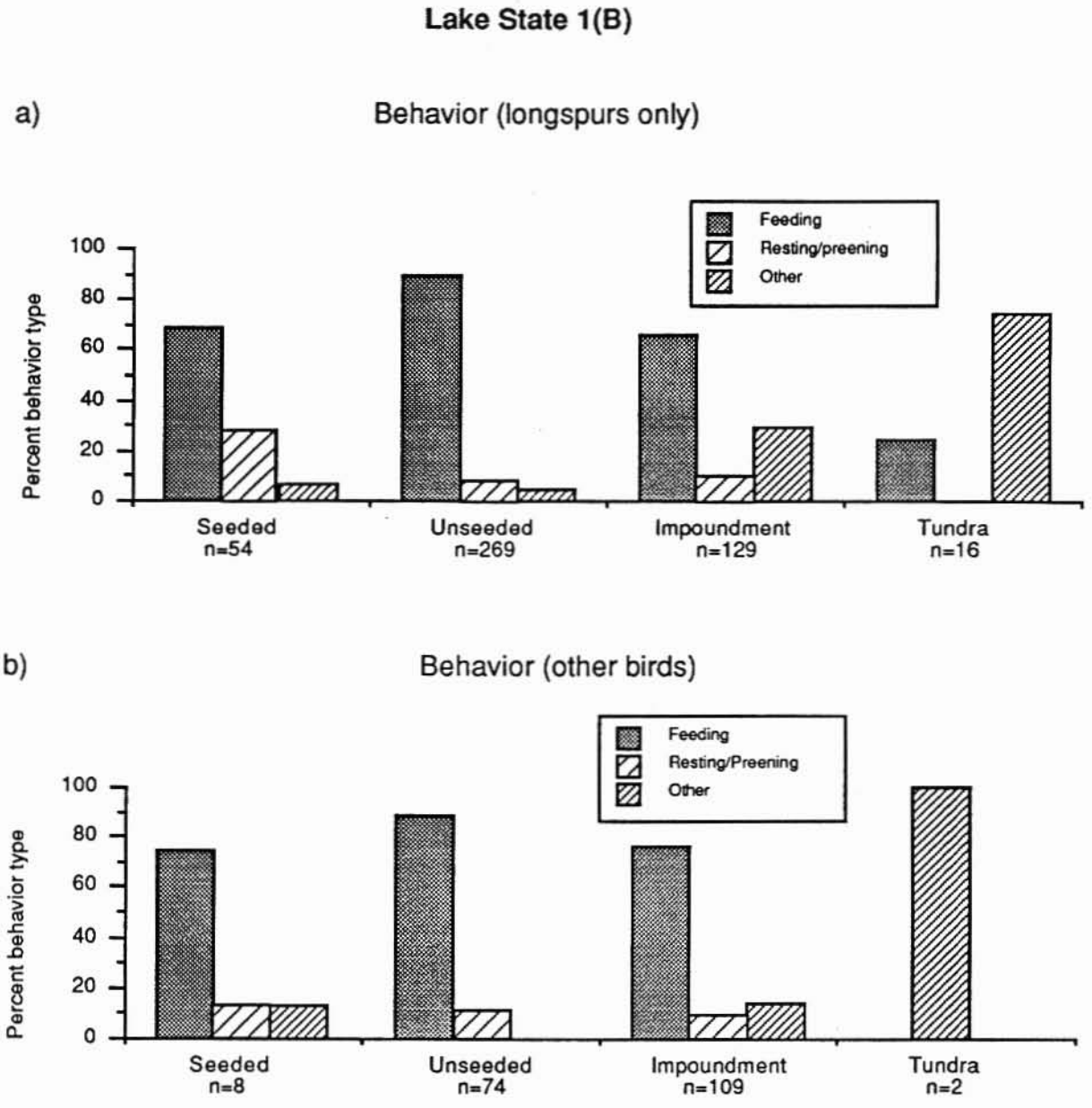

Fig. 11. Proportions of behavior types for Lapland Longspurs (a), and for all other bird species (b) on study plots at Lake State 1 (B), Prudhoe Bay, Alaska, 1990. (n is the total number of observations.) The seeded, unseeded, and impoundment plots represent disturbed habitats; the tundra plot is undisturbed habitat.

numbers of observations were low on the tundra and seeded plots. Longspurs represented 71 percent of the total number of observations on all plots combined (Table 15).

Table 15. Relative abundances of bird species (percent of total) on individual study plots and on all study plots combined at Lake State 1(B), Prudhoe Bay, Alaska, 1990.

Species	Study Plot				
	Seeded	Unseeded	Impoundment	Tundra	All Plots
Lapland Longspur	87	78	54	89	71
Snow Bunting	13	21	1	6	13
Pectoral Sandpiper			20	6	7
Semipalmated Sandpiper		1	8		3
Long-billed Dowitcher			8		3
Dunlin			3		1
Northern Pintail			1		<1
Lesser Golden Plover			1		<1
White-rumped Sandpiper			<1		<1
Red-necked Phalarope			1		<1
Parasitic Jaeger			<1		<1
Yellow Wagtail			1		<1

Discussion

Invariably, the microhabitat characteristics of the landscape on and near abandoned gravel pads affected the levels of use, species diversity, and behaviors we observed on them.

Level of Use

Among the plots that had no water, average levels of bird use (observations per time period) generally were higher on gravel than on natural tundra. This was the case for the berm at Term Well C, which was a mixture of gravel and overburden, and for all plots at Lake State 1 (A and B). Only at Delta State 2 did the gravel plot have a lower level of use than the tundra plot, though at Term Well C the large among-day variability lowered our confidence that the sample represented reality.

Pollard et al. (1990) observed larger numbers of Lapland Longspurs on vegetated gravel pads than on pads without appreciable vegetation, and differences in levels of use during the current study also appeared to be related partly to presence or absence of vegetation on gravel plots. Where vegetation was totally absent (as at Delta State 2 and the main gravel pad plot at Term Well C), level of use was low. Where vegetation was present (as on the berm at Term Well C and on all gravel plots at Lake State 1), level of use was higher.

The type of vegetation on a particular plot also appeared to affect the level of use. For instance, a variety of vegetation types was present on the plots at both Lake State 1 sites (A and B). Observations of birds were two to five times higher on plots that had natural plant colonization than on plots seeded with cultivars. This was true even in comparisons where colonizing plant species were very sparsely distributed [e.g., on the unseeded plot at Lake State 1(A)] and where cultivars formed a dense vegetative cover (e.g., the seeded plot). (See Jorgenson et al. 1990 for a quantitative description of the vegetated gravel at the Lake State 1 site.) The gravel spray plot at Lake State 1(A) and the unseeded plot at Lake State 1(B) both had abundant colonizers and higher levels of use than other plots. The reason for this apparent preference by birds (especially longspurs) for plots with colonizing vegetation rather than cultivars is unclear, but it may be related to relative differences in seed productivity, quality, or accessibility.

The Storage Pad site was unique in that the level of use of the tundra plot was as high as that of gravel plots. This high level of use may have been related to the geobotanical character of the tundra plot. The undisturbed plots at all other sites were composed of moist and wet graminoid tundra on non-patterned ground or strangmoor. The tundra plot at Storage Pad was an upland habitat type composed primarily of high-centered polygons. Custer and Pitelka (1977) found that an extensive complex of high-centered polygons represented optimal habitat for longspurs at Barrow. Over 90 percent of the birds observed at Storage Pad plots were longspurs. Thus, if the tundra plot represented optimal tundra habitat type for longspurs, a higher level of use would have been expected there.

Plots with some water present usually had relatively high levels of use. At Term Well C, only the berm had more use than the reserve pit and the pond, and the impoundment at Lake State 1(B) was surpassed in level of use only by the unseeded gravel plot. At Delta State 2, the reserve pit had the highest level of use. Although water was not a predominant feature of the gravel spray plot at

Lake State 1(A), the presence of small thermokarst pools on the plot seemed to attract birds, and this plot had a higher level of use than other plots at this site.

Adjusted Level of Use

When levels of use were adjusted to account for differences in plot sizes, overall trends were similar but between-plot differences were often accentuated. For example, the berm at Term Well C had a high observed level of use and a small size, thus the adjusted level of use exacerbated the difference between it and the other plots there. The same was true for the "road" plot at Lake State 1(A). At Lake State 1(B) the adjusted level of use of the impoundment relative to the other plots dropped dramatically because of the high level of use and small size of the unseeded plot.

We suspect that differences in levels of use among various plots were related partly to the relative sizes of the microhabitat "patches" on which the plots were located. That is, one would expect birds to concentrate themselves more in cases where a habitat that offered unique resources was relatively small. This concept is discussed further in the following section on behavior.

Species Diversity

Species diversity (Shannon's index) and species richness were always highest on plots with water. The reserve pit and the pond at Term Well C each had higher species diversity than did the gravel and the berm. Diversity indices at the reserve pit at Delta State 2 and at the impoundment at Lake State 1(B) were both higher than at other plots at those sites. At the gravel spray plot at Lake State 1(A), the general habitat type was not aquatic, but small thermokarst pools were present and species diversity was high. Where water was present, use of study plots by shorebirds, gulls, and waterfowl caused higher species diversity indices and species richness; where water was not present, Lapland Longspur was always the most common species and often accounted for more than 90% of the observations.

Behavior

Because we did not begin the observational study until after most nesting had been completed, we did not expect to find breeding-related behaviors such as displaying or incubating. Of the few nests that were still active, none were located on our observational plots. Most young birds had fledged by this time, and activities of adults and young were oriented toward preparation for

migration. Feeding was the most consistently observed behavior on the majority of study plots at all sites.

Plots where feeding was not the most consistently observed behavior were the gravel plot at Term Well C, and all of the tundra plots except at Storage Pad. It is probable that the predominant behavior of birds on tundra also was feeding, but our ability to discern bird behavior was hampered by the vegetation. On the tundra plot at Storage Pad, we were able to detect behavior, and most of the behavior observed there was feeding. The predominant behavior of the birds on the gravel plot at Term Well C was resting/preening; most of this occurred in the area around the well head where elevated perches were available.

Most of the observations we classified as feeding were of birds pecking at the surface of the gravel, and an alternative interpretation of these observations might be that birds were simply picking up grit. However, if high levels of use on gravel plots solely were the result of birds picking up grit, vegetated and unvegetated gravel plots should have had relatively equal use levels—during the current study, they did not. Thus if birds did use gravel pads as a source of grit, that use was probably secondary to feeding.

Most of the birds observed at gravel sites were Lapland Longspurs. If their predominant behavior was feeding, the question arises: what were they eating? Custer and Pitelka (1978), analyzed longspur stomach samples and found that diets at Barrow consisted primarily of insects, but that seeds composed up to 70 percent of their diet early in the season (late May), and 24 to 30 percent late in the season (August). These birds were collected within 10 km of the Naval Arctic Research Laboratory at Barrow and presumably were feeding on tundra habitats, although this is not clear. Seastedt (1980) found that adult longspurs fed nestlings various combinations of adult and larval insects at Barrow and at the Yukon-Kuskokwim Delta. He was not able to study diet after birds were capable of flight.

Because no birds were collected during this study, we have no stomach sample data with which to determine the exact diet composition for longspurs feeding at gravel sites. As mentioned earlier, most of our feeding observations were of birds pecking at the surface of the gravel; it was usually impossible to determine what they were eating or how successful they were. However, on occasion longspurs were observed eating seeds of plant species such as *Eriophorum* spp., *Sagina intermedia, Minuartia rubella, Saxifraga hirculus*, and *Dryas integrifolia.* Pollard et al. (1990) also observed longspurs feeding

on seeds of plant species growing on gravel pads, notably *Draba* spp., *Braya purpurascens*, and *Cochlearia officinalis*.

Although insects formed the bulk of the diet of longspurs in the studies by Custer and Pitelka (1978) and Seastedt (1980), it seems unlikely that longspurs were feeding on insects at gravel sites in our study. Densities of insects generally are much higher on tundra habitats than on gravel pads (pers. obs.), and it is more likely that the many forb species, which are prolific seed producers and common colonizers of gravel sites (Robus et al. 1986; Jorgenson 1988, 1989; Pollard et al. 1990), attracted longspurs to gravel because of the abundance of seeds at some of these sites.

Arctic tundra is composed of patches of different habitat types (Holmes 1970, Pitelka et al. 1974). Bird populations, including longspurs, are widely dispersed over these patches which provide them with their normal food and cover requirements. In this context, the gravel pads in this study can be considered to be patches of disturbed habitat surrounded by a mosiac of tundra habitat patches.

It has been proposed that habitat selection (or patch choice, in this case) falls within the realm of optimal foraging theory (Rosenzweig 1985). According to this theory, natural selection should favor a forager which behaves "optimally" by making dietary or patch choices that minimize the individual's cost:benefit ratio in terms of time and/or energy (Emlen 1966, MacArthur and Pianka 1966, Pyke 1984).

Some abandoned gravel pads may provide longspurs with habitat patches which are optimal for feeding, at least after the breeding season when seeds become more important in longspur diet. Seastedt and MacLean (1979), while studying longspurs on breeding territories at Barrow, felt that food density, rather than total quantity of food, was more important to the birds. Thus, longspurs may be attracted to those abandoned gravel pads where concentrations of seed-producing forbs enable them to obtain food at the least cost. Preferred forage also may be more visible on gravel than on tundra, and thus more accessible.

Conclusions

Data from the post-breeding observational study have increased our understanding of how and why birds use abandoned gravel fill. Some bird species (especially Lapland Longspur) are attracted to abandoned gravel pads during the post-breeding season. During the post-breeding period, these birds often are concentrated at abandoned gravel sites in higher densities than on nearby undisturbed tundra habitats.

Most of the birds attracted to abandoned gravel pads during this study were Lapland Longspurs, and one reason for the high level of use by longspurs of some pads probably is related to the vegetation found there. Where native forb species have naturally colonized abandoned gravel sites, levels of bird use often were high; this was true even where colonizing plants were distributed sparsely. Where pads were unvegetated or seeded with cultivated grass species, we observed little bird use. The most consistently observed behavior of longspurs on vegetated gravel sites was feeding. We suspect that they were feeding on the seeds of colonizing forb species, many of which are prolific seed producers.

Levels and types of bird use of abandoned gravel pads also are related to the presence or absence of standing water on pads. Where impounded water such as reserve pits or thermokarst pools were present at gravel sites, shorebirds (and sometimes waterfowl) were attracted, and their behavior primarily was feeding. Consequently, microhabitats with water had relatively high levels of use and always had higher species richness and species diversity than did dry gravel microhabitats.

These findings will be useful to managers beginning to consider wildlife-oriented goals for abandoned-site rehabilitation. Vegetating abandoned gravel pads (or portions of them) with native forb species probably would encourage high levels of use by bird species such as Lapland Longspur that use seeds as part of their diet. Creating ponds and pools with mud shorelines on or near abandoned gravel pads probably would increase the utility of rehabilitated sites to shorebirds and waterfowl and would result in greater species diversity than would occur in the absence of water.

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