*Wilson Bull.*, 103(2), 1991, pp. 286–292

**Summer diets of some introduced Hawaiian finches.**—Approximately 25 species of finches (families Estrildidae, Fringillidae, Passeridae, Emberizidae) have been introduced to Oahu, Hawaii. Although at least 12 of these have failed to establish wild populations, 15 have been successful (Berger 1981, Pratt et al. 1987). Several reports have appeared regarding the diets of introduced finches in Hawaii, but we know of no comprehensive studies of diets of introduced finches in any particular habitat. For instance, Fleischer and Williams (1988) documented the use of discarded human food by House Sparrows (*Passer domesticus*), as did Bancroft (1982) for Red-crested Cardinals (*Paroaria coronata*). Ralph (1984) reported observations of four introduced finches: House Finches (*Carpodacus mexicanus*); Java Sparrows (*Padda oryzivora*); Northern Cardinals (*Cardinalis cardinalis*); and Nutmeg Mannikins (*Lonchura punctulata*) feeding at the flowers of a tiger's claw tree (*Erythrina variegata*) in downtown Honolulu. Paton (1981) observed gleaning by Yellow-fronted Canaries (*Serinus mozambicus*) on the island of Hawaii but unfortunately was not able to determine what food items the birds were taking. The goals of the present study were to study the diets of successfully introduced finches in urban parks on Oahu, Hawaii, to describe the diets of these birds, and to determine diet similarity among these species.

*Methods and materials.*—At least 13 species of introduced finches representing four families are known to occur in urban parks on Oahu (Ferris 1989). The families and their representative species are Emberizidae: Northern Cardinal, Red-crested Cardinal, Saffron Finch (*Sicalis flaveola*); Fringillidae: House Finch, Yellow-fronted Canary; Passeridae: House Sparrow; and Estrildidae: Red Avadavat (*Amandava amandava*), Common Waxbill (*Estrilda astrild*), Lavendar Waxbill (*E. caerulescens*), Nutmeg Mannikin, Chestnut Mannikin (*L. malacca*), Warbling Silverbill (*L. malabarica*) and Java Sparrow. Two other species of finches, the Orange-cheeked Waxbill (*Estrilda melpoda,* Estrildidae) and the Yellow-faced Grassquit (*Tiaris olivacea,* Emberizidae), have been introduced to Oahu but were not seen in the study by Ferris (1989).

We studied foraging of these species in urban parks along the southern coast of Oahu during the summers of 1983 and 1988. We made most of our observations in Kapiolani Park, Blaisdell Park, Sand Island State Park, and Campbell Industrial Park. In 1983, a few observations were also made at Keehi Lagoon Park and at the Woodlawn Cemetery in the Manoa Valley. In 1988, a few observations were made at Ala Moana Park. We chose these parks because they span the southern coast of Oahu, and previous field experience suggested that the majority of introduced species occurred in these parks.

We made observations through 10 × 50 power binoculars. Typically, birds of all species would stop foraging and freeze or flush if one approached too close. We attempted to record approximately equal numbers of separate foraging bouts for each species, but some species were seen too infrequently. During each bout, we recorded the number of bill strikes at each of six food-type/substrate categories. These categories were as follows: grass seeds on a plant; forb (=herbaceous dicots) seeds on a plant; sedge seeds on a plant; insects; garbage (=discarded human food); and fruit (=naturally occurring fallen fruit). The food-type categories we selected are crude, yet in our experience we felt they were adequate for establishing general patterns. In the field, we made tape recordings of each bout and later transcribed each bout.

We estimated proportional use of a particular resource in both years for each species by calculating the frequency of foraging bouts in which we observed at least one bill strike assignable to that resource. The use of proportions here reduces any potential bias due to interspecific differences in food size or feeding time (Ramsey and Marsh 1984).

TABLE 1

NUMBER OF FORAGING BOUTS PER SPECIES IN SEVEN URBAN PARKS FOR 1983 AND 1988

| Species | Year | ALA[a] | BLA | CIP | KAP | SIP | KLP | WLC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| *Paroaria coronata* | 1983 | — | 0 | 2 | 16 | 1 | 0 | 0 | 19 |
| | 1988 | 5 | 3 | 0 | 5 | 7 | — | — | 20 |
| *Carpodacus mexicanus* | 1983 | — | 3 | 5 | 26 | 10 | 6 | 0 | 50 |
| | 1988 | 0 | 28 | 3 | 35 | 0 | — | — | 66 |
| *Passer domesticus* | 1983 | — | 1 | 2 | 21 | 2 | 3 | 0 | 29 |
| | 1988 | 1 | 11 | 0 | 7 | 10 | — | — | 29 |
| *Padda oryzivora* | 1983 | — | 0 | 0 | 21 | 0 | 0 | 8 | 29 |
| | 1988 | 0 | 8 | 0 | 55 | 0 | — | — | 63 |
| *Lonchura malacca* | 1983 | — | 48 | 5 | 0 | 0 | 0 | 0 | 53 |
| | 1988 | 0 | 51 | 2 | 0 | 0 | — | — | 53 |
| *L. punctulata* | 1983 | — | 0 | 0 | 21 | 33 | 1 | 0 | 55 |
| | 1988 | 0 | 0 | 2 | 55 | 3 | — | — | 60 |
| *Estrilda astrild* | 1983 | — | 0 | 35 | 0 | 0 | 0 | 0 | 35 |
| | 1988 | 0 | 0 | 21 | 0 | 0 | 0 | 0 | 21 |
| *Serinus mozambicus* | 1988 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 42 |
| *Amandava amandava* | 1988 | 0 | 0 | 4 | 0 | 4 | — | — | 8 |
| *Sicalis flaveola* | 1988 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 |

[a] ALA = Ala Moana Park; BLA = Blaisdell Park; CIP = Campbell Industrial Park; KAP = Kapiolani Park; KLP = Keehi Lagoon Park; SIP = Sand Island Park; WLC = Woodlawn Cemetery. A dash (—) indicates that the park was not visited during that year, whereas an '0' indicates that although the park was visited, no foraging observations for the species were made.

We estimated niche widths by calculating Levins' Measure (Levins 1968, Krebs 1989):

$$LM = 1/\sum (p_k^2)$$

Levins' Measure is the reciprocal of the sum of the squared proportions ($p_k^2$) for k food type categories. Lower values of Levins' Measure indicate relatively more specialized species, whereas higher values indicate more generalized species (Krebs 1989).

We determined similarity in dietary composition for each species-pair by calculating the coefficient of community ($CC_{ij}$), using the frequencies of use of the food-type/substrate categories. For these calculations, we used the formula provided by Ricklefs and Lau (1980):

$$CC_{ij} = \sum p \text{ min (i or j)},$$

where $CC_{ij}$ = the coefficient of community over all categories between species i and j and p min = the minimum shared proportion of species i and j for food type category k.

*Results.*—We recorded 637 separate foraging bouts for 10 species during the two field seasons (Tables 1 and 2). The species for which we were unable to obtain foraging observations were Northern Cardinal, Lavendar Waxbill and Warbling Silverbill. We found two fairly distinct foraging groups: grass-seed eaters, and forb-seed eaters. Eight of the 10 species can, with some caution, be categorized into one of these groups. The grass-seed eaters group includes the Java Sparrow, Chestnut Mannikin and Nutmeg Mannikin. It is likely that the Common Waxbill also belongs in this group. Although it fed chiefly on grass seeds in 1988, it mostly consumed sedge seeds in 1983. One possible reason for this shift is that Common

TABLE 2

TOTAL RECORDED FORAGING TIME, PROPORTIONAL USE OF SIX FOOD-TYPE CATEGORIES, AND SUMMER DIET BREADTH (LEVINS' MEASURE) FOR 10 SPECIES OF INTRODUCED FINCHES DURING 1983 AND 1988

| Species | Year | TIME | FO[a] | IN | GA | GR | FR | SD | LM |
|---|---|---|---|---|---|---|---|---|---|
| *Paroaria coronata* | 1983 | 386.0 | 0.16 | 0 | 0.14 | 0.11 | 0 | 0 | 1.715 |
| | 1988 | 332.4 | 0.55 | 0 | 0.35 | 0.10 | 0 | 0 | 2.298 |
| *Carpodacus mexicanus* | 1983 | 1095.0 | 0.96 | 0 | 0 | 0.08 | 0 | 0 | 1.079 |
| | 1988 | 717.7 | 0.94 | 0 | 0 | 0 | 0.06 | 0 | 1.127 |
| *Passer domesticus* | 1983 | 519.0 | 0.17 | 0.24 | 0.31 | 0.28 | 0 | 0 | 3.831 |
| | 1988 | 329.7 | 0.35 | 0.03 | 0.21 | 0.48 | 0 | 0 | 2.516 |
| *Padda oryzivora* | 1983 | 593.0 | 0.21 | 0 | 0 | 0.83 | 0 | 0.03 | 1.363 |
| | 1988 | 851.1 | 0.02 | 0 | 0 | 0.98 | 0 | 0 | 1.041 |
| *Lonchura malacca* | 1983 | 1542.0 | 0 | 0 | 0 | 1.00 | 0 | 0 | 1.000 |
| | 1988 | 659.6 | 0 | 0 | 0 | 1.00 | 0 | 0 | 1.000 |
| *L. punctulata* | 1983 | 1468.0 | 0.02 | 0 | 0 | 1.00 | 0 | 0 | 1.000 |
| | 1988 | 557.8 | 0 | 0 | 0 | 1.00 | 0 | 0 | 1.000 |
| *Estrilda astrild* | 1983 | 531.0 | 0.03 | 0 | 0 | 0.40 | 0 | 0.69 | 1.560 |
| | 1988 | 164.2 | 0.05 | 0 | 0 | 0.95 | 0 | 0 | 1.105 |
| *Serinus mozambicus* | 1988 | 478.5 | 0.71 | 0 | 0 | 0.31 | 0 | 0 | 1.656 |
| *Amandava amandava* | 1988 | 74.6 | 0 | 0 | 0 | 1.00 | 0 | 0 | 1.000 |
| *Sicalis flaveola* | 1988 | 76.6 | 0.80 | 0 | 0 | 0.20 | 0 | 0 | 1.471 |

[a] FO = forbs; IN = insects; GA = garbage; GR = grass; FR = fruit; SD = sedge; LM = Levins' Measure.

Waxbills may have only been recently introduced by 1983 (Falkenmayer 1988), and the total population size in that year may have been quite small. If so, our observations could have been biased. Most of our observations in 1983 came from a single flock of approximately 80 individuals at Campbell Industrial Park. Moreover, all of our observations were made in a period of just a few days. In 1988, our foraging observations for this species still were limited to Campbell Industrial Park but came from several different flocks scattered over several weeks.

It is possible that the Red Avadavat also belongs in the grass-seed eaters group. Unfortunately, our data (eight observations over 74.6 seconds) are too limited to make such an assignment. Nevertheless, the individuals that we did observe clearly fed on green grass seeds.

The forb-seed eaters group would include the House Finch, and the confamilial Yellow-fronted Canary. Some caution must be exercised in classifying the latter. All our observations for the Yellow-fronted Canary were from a very specific region of Kapiolani Park in 1988 where as many as 30 individuals of this species congregated in the early evenings near a stand of ironwood trees (*Casuarina equisetifolia*). If the total population of this species was small, our observations for this species could be biased as well. A third species that might belong in this group is the Saffron Finch, but we had only five observations (76.6 seconds), which would not be sufficient for us to unequivocally assign this species to any foraging group.

The Red-crested Cardinal and the House Sparrow do not appear to fit easily into one of the two foraging groups. In 1983 Red-crested Cardinals mostly consumed garbage. Indeed, 74% of the recorded foraging bouts for this species included at least one bill strike at some form of garbage. Individuals of this species also took grass seeds (11% of foraging bouts) and forb seeds (16% of foraging bouts). In 1988, however, we observed a shift in the use of two of these categories. The proportion of bouts that included the use of garbage dropped to 35%, whereas the use of forbs increased to 55% of recorded bouts. Interestingly, use of grass seeds was approximately equal in the two field seasons (1983—11%; 1988—10%).

Similarly, House Sparrows increased their use of forb seeds between 1983 (17% of bouts) and 1988 (34% of bouts). This species also increased its use of grass seeds between 1983 (28% of bouts) and 1988 (48% of bouts), while reducing its use of insects (1983—24%; 1988—3%) and garbage (1983—31%; 1988—21%). Since both species used a variety of food-types in both years, we feel it is safest to label these species as opportunists that are able to shift resource use to accommodate shifts in resource availability.

We limited our analysis of niche widths for the eight most common species, as indexed by Levins' Measure. Niche widths ranged from the most specialized with a low of 1.00 (Chestnut Mannikin, Nutmeg Mannikin, 1983, 1988) to a high of 3.831 (House Sparrow 1983, see Table 2).

Our results suggest that the majority of successful introduced finches tend to have relatively narrow diets. The House Finch, Chestnut Mannikin, Nutmeg Mannikin, and Java Sparrow all had small values for Levins' Measure in both years. The Red-crested Cardinal and House Sparrow had relatively higher values in both years, indicating somewhat broader diets. We must exercise caution when interpreting Levins' Measure with respect to the Common Waxbill and the Yellow-fronted Canary due to possible bias inherent in studying small populations. Nevertheless, Common Waxbills appeared to concentrate on grass seeds in 1988, when the total population was likely greater, whereas Yellow-fronted Canaries appeared, for the most part, to use forb seeds.

Coefficients for community for all species are listed in Table 3. Because overlap indices such as the coefficient of community are influenced by sample size (Ricklefs and Lau 1980), we also limited our overlap analysis to the eight most common species. In both years dietary similarity among species closely followed taxonomic relationships. Thus we found that the greatest similarity values were between congeneric species of the genus *Lonchura* (the Chestnut Mannikin, Nutmeg Mannikin) and the Java Sparrow. Moreover, if we ignore data for the Common Waxbill in 1983 for reasons previously discussed, high similarity values extend to all confamilial pairs. Thus, species in the family Estrildidae were most similar to each other.

In 1983, the House Finch was not particularly similar to any other species, although in 1988 it was most similar to the Yellow-fronted Canary. (There were no 1983 data for the canary.) However, if our 1988 data for the canary accurately reflect the diet of this species, the two members of the family Fringillidae also were most like one another.

Red-crested Cardinals and House Sparrows had their highest similarity with each other in both years, although in 1988 the Yellow-fronted Canary was equally similar to both these species.

*Discussion.*—Our results suggest two general and potentially important patterns. First, it appears that at least the summer diet widths of the majority of introduced finches are quite narrow. Second, similarity in diet appears to be associated with taxonomic similarity. These results both may hold only for urban parks and possibly only in summer.

In estimating diet composition of introduced species, one encounters several potential sources of bias in addition to the problems already mentioned as associated with small populations. One example involves the sampling of individuals in a single large flock, all feeding on an atypical food-type. In our data this might have contributed to the disparity

TABLE 3

COEFFICIENTS OF COMMUNITY FOR ALL POSSIBLE SPECIES PAIRS IN 1988 (FIRST LINE) AND 1983 (SECOND LINE). NUMBERS ACROSS THE TOP LINE CORRESPOND TO THE SPECIES LISTED IN THE FIRST COLUMN. AN "X" INDICATES INSUFFICIENT DATA FOR A COMPARISON

| Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. *Paroaria coronata* | * | 0.55 | 0.65 | 0.12 | 0.10 | 0.10 | 0.15 | 0.65 | 0.10 | 0.65 |
| | | 0.24 | 0.58 | 0.27 | 0.11 | 0.13 | 0.14 | X | X | X |
| 2. *Carpodacus mexicanus* | | * | 0.34 | 0.05 | 0 | 0 | 0.05 | 0.71 | 0 | 0.80 |
| | | | 0.25 | 0.29 | 0.08 | 0.10 | 0.11 | X | X | X |
| 3. *Passer domesticus* | | | * | 0.50 | 0.48 | 0.48 | 0.53 | 0.65 | 0.48 | 0.54 |
| | | | | 0.45 | 0.28 | 0.30 | 0.31 | X | X | X |
| 4. *Padda oryzivora* | | | | * | 0.98 | 0.98 | 0.97 | 0.33 | 0.98 | 0.22 |
| | | | | | 0.83 | 0.85 | 0.46 | X | X | X |
| 5. *Lonchura malacca* | | | | | * | 1.00 | 0.95 | 0.31 | 1.00 | 0.20 |
| | | | | | | 1.00 | 0.40 | X | X | X |
| 6. *L. punctulata* | | | | | | * | 0.95 | 0.31 | 1.00 | 0.20 |
| | | | | | | | 0.42 | X | X | X |
| 7. *Estrilda astrild* | | | | | | | * | 0.36 | 0.95 | 0.25 |
| | | | | | | | | X | X | X |
| 8. *Serinus mozambicus* | | | | | | | | * | 0.31 | 0.91 |
| | | | | | | | | | X | X |
| 9. *Amandava amandava* | | | | | | | | | * | 0.20 |
| | | | | | | | | | | X |
| 10. *Sicalis flaveola* | | | | | | | | | | * |

in proportional food use between years seen in Common Waxbills and perhaps in Java Sparrows.

A separate problem could arise in species that are at once highly opportunistic and abundant. For such species diet composition would be largely dependent on resource availability. We believe that this is probably the case for the Red-crested Cardinal and House Sparrow.

Our results are all based on summer observations, and it is possible that some of these species change diet seasonally. Some species, particularly grass-seed eaters, are much less abundant in urban parks during winter, probably because of reduced availability of grass seeds (Ferris 1989). Unfortunately, we do not have quantitative data for all ten species to test the idea that seasonal shifts in resource availability and finch abundance are correlated.

We limited our study to urban parks and the question arises as to how applicable our results are to introduced finches throughout Oahu. The answer to this question rests on the importance of urban parks to introduced finches. If some of these species were more abundant in other habitats, one could argue that the diets of individuals in urban parks were atypical. A partial answer to the question of how important parks are to these species can be obtained by comparing the abundances of those species that were rare in parks to their abundances in other habitats. For those species that are more abundant in other habitats, the importance of parks could be negligible.

Of the 13 species in urban parks only five (Saffron Finch, Red Avadavat, Warbling Silverbill, Northern Cardinal, and Lavendar Waxbill) could be considered rare. Of these, the Warbling Silverbill recently invaded Oahu (Conant 1984). Of the remaining four species, two (Saffron Finch and Lavendar Waxbill) may occur only in urban or residential areas, and possibly only in urban parks. Only two species (Red Avadavat and Northern Cardinal) appear to be more abundant in other habitats. In our experience, Red Avadavats are more frequently encountered in agricultural fields, whereas Northern Cardinals are more frequently observed in both dry Kiawe (*Prosopis pallidus*) forests and wet forests. We also note that both species of introduced finches that we did not see in urban parks (i.e., the Orange-cheeked Waxbill and Yellow-faced Grassquit) occur in residential habitats (i.e., urban lawns) not included in our study.

*Acknowledgments.*—We thank R. Pyle for sharing his knowledge of introduced finches with us. We also thank S. Conant, L. Freed, S. Pimm, C. Ralph, and D. McLain, and an anonymous reviewer for their comments on various drafts of this paper. Funding for this work was provided by the National Geographic Society (grants 2494-82, and 3799-88) and by Georgia Southern College (now Georgia Southern Univ.).

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*Wilson Bull.*, 103(2), 1991, pp. 292–295

**Intruders on Yellow-eyed Junco territories.**—Yellow-eyed Juncos (*Junco phaeonotus*) are "apparently monogamous" and defend Type A territories within which all feeding, mating, and nesting activities occur (Hinde 1956). Both sexes chase same-sex adult conspecifics from the territory (Moore 1972, pers. obs.). Consequently, only male and female territory holders should be captured in local mist nets. However, we have captured 47 intruding adults since 1984. Here we examine the identity of these 47 birds, the conditions under which they were captured, and their status.

We have color banded Yellow-eyed Juncos in and around Rustler Park (31°55'N, 109°17'W) in southeastern Arizona since 1984. The study site (elevation 2560 m) is comprised of forest with little understory, areas of bracken fern (*Pteridium* sp.), short grass meadows, rocky outcroppings, and talus slopes. The predominant tree species are *Pinus ponderosa, P. strobiformis,* and *Pseudotsuga menziesii* (see Balda 1967 for a complete description of the study site).

We color banded nestlings 6–10 days after hatching. At this time we mist-netted territory holders, color banded unmarked adults, and replaced worn bands on banded adults. When capturing adult juncos at an active nest (172 occasions involving 144 nests) we erected 1–2 mist nets for 10–30 min within 1 m of the nest site. When capturing adults away from nest sites (90 occasions involving 58 territories, as part of on-going studies, Weathers and Sullivan 1989), we erected 5–8 mist nets on the territory for 1–4 h.

Since the end of the 1985 breeding season, we have routinely used playback tapes when capturing both male and female adult juncos. Tape recordings of local birds were played for 30 sec–1 min intervals near the mist nets. We alternated tapes of male song, nestling distress calls, female chipping, and fledgling begging until the desired bird was captured. If the desired bird was not captured within 3–5 min, we turned off the tape player, waited for approximately 10 min, then played the tapes again. If we still failed to capture the desired bird, we waited for 10–60 min and played the tapes a third time.

Captured adults were assigned to one of four categories: (1) territory owners, (2) intruding neighbors (birds from adjacent territories), (3) intruding local residents (territory holders