ALTITUDINAL DISTRIBUTION AND COMPOSITION OF ARTHROPODS IN 'ŌHI'A (METROSIDEROS COLLINA SUBSP. POLYMORPHA) CANOPIES IN HAWAII VOLCANOES NATIONAL PARK WITH ECOLOGICAL IMPLICATIONS FOR SOME NATIVE BIOTA

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INTRODUCTION

At the two previous Conferences in Natural Science, the Banko's (Banko & Banko 1976; Banko 1978) claimed that the decline of certain of the Hawaiian arthropods may have contributed to the decline of some of the native insectivorous Hawaiian avifauna. They hypothesized that the depredations of exotic ants in the lower elevations and certain introduced polyphagous parasitoids (e.g., wasps and flies) at higher elevations on native arthropods "may be a major factor limiting population size and range of forest birds today" (Banko 1978: 18) especially through depletion of potential food supplies. The historical decline of native Lepidoptera is reviewed by Zimmerman (1958a, 1958b). Arthropods are a major component of forest bird food at certain (e.g., nestling food) or all stages of their life cycle (Perkins 1903, 1913). This was especially true for three drepaniid species studied by Baldwin (1952).

The data we collected during the International Biological Program (IBP) in Hawai'i during the 1970's are amenable for analysis of certain canopy arthropod population parameters on 'ōhi'a (Metrosideros collina subsp. polymorpha var. incana) from sea level to tree line in Hawaii Volcanoes National Park (HVNP). The IBP analysis dealt especially with arthropod zonation patterns on 'ōhi'a canopies on the Mauna Loa Transect, i.e., from tree line above the Mauna Loa Strip Road downwards to the Thurston Lava Tube (Gagné 1979, 1981; Gagné & Howarth 1981). Unfortunately, the integrated design and other constraints of this project did not permit similar detailed examination of arthropod distribution trends at lower elevations.

It is the purpose of this paper to examine again this data base over the whole of the transect, and to try to develop certain aspects of it pertinent to biological problems confronting native biota--arthropods and insectivorous birds in particular--to lend some support to the hypotheses and concerns expressed by Banko (1978) and Banko & Banko (1976) regarding consequences for the native arthropods and dependent avifauna.

MATERIAL AND METHODS

The collection technique has been detailed in Gagné (1979). Briefly, the method consists of fogging the canopies of 'ōhi'a with synergized pyrethrum during low wind, early morning conditions. The arthropods thus killed or stunned, fall onto cloth funnels suspended beneath four adjacent trees. Bottles containing 70% alcohol are attached to the bottoms of the cloth sheets into which the "catch" on the sheet is shaken. In small-statured 'ōhi'a the sheets are suspended at ground level and the catch is aspirated off the sheet.

The size of the cloth funnels varies. In short-statured communities, 5.8 m^2 flat sheets are used; in small-statured forest, cloth funnels 5.8 m^2 and 1.2 m deep are fastened to the trunks of four trees. For taller, mature stands, the funnels are 24 m^2 and 2.4 m deep.

Sampling was carried out bimonthly and replicated at each of 9 sampling sites extending from 15 m to 2400 m elevation (Table 1). Arthropod sample numbers were standardized for sample sheet size.

RESULTS

Approximations were made of arthropod species richness, endemicity, quantity, and quality of the canopy-associated arthropods along the transect.

Species richness (Fig. 1A) was measured as the total number of taxa taken at each sampling site. Richness was highest in the middle portions of the transect and declined at both the upper and lower extremes. At the two lower sites the presence of two pugnacious ant species (*Pheidole megacephala* (F.) and *Plagiolepis allauadi* Emery) probably contributed to some of the decline in richness while at the upper sites, declining ambient temperatures and lower vegetation productivity might have contributed (see Janzen et al. 1976).

Endemicity (Fig. 1B) is the percentage of the total taxa at each sampling site which is native to Hawai'i. Endemicity gradually increased with altitude. This is probably a reflection of the character of most exotic arthropods being associated with human perturbed, lowland environments and so are poorly adapted to higher environments where native biota predominate.

Quantity (Fig. 1C) indicates the average arthropod biomass at each sampling site. Fresh weights of canopy samples were taken on an irregular basis. These weights were standardized for sample sheet area. Unfortunately, groups with high food value were not then weighed separately. Mean arthropod biomass was relatively uniform between 115 m and 215 m elevation (0.7-0.9 gm/sample). It was lower at 760 m elevation (0.2 gm/sample) and subject to considerable fluctuation at the ends of the transect. At 15 m elevation, large roaches (Dictyoptera) and their parasites (Hymenoptera) raised the otherwise low biomass comprised mostly of ants and other non-herbivores to an average of 2.3 gm/sample; none of these three insect groups are known to be desirable food items for native insectivorous birds (Baldwin 1952). At and above 760 m elevation, spiders (Arachnida) and true bugs (Heteroptera), both comprised largely of native taxa, contribute to most of the biomass. In absolute numbers, however, bark lice (Psocoptera) usually outnumbered all other taxa. Springtails (Collembola) and honey bees (*Apis mellifera* L.) are the only groups which fluctuate wildly in numbers of individuals on a seasonal basis. The former appears to correspond to high rainfall periods and the latter to concentrated 'ōhi'a blooms. Neither are considered of high food value for insectivorous birds.

Quality (or palatability) (Fig. 1D) indicates the percentage of total taxa at each sampling site which was potential food items for native birds as indicated by the previous studies of Perkins (1903, 1913) and Baldwin (1952). The latter found that the majority of arthropod food items recovered from three native species of insectivorous birds (*Himatione sanguinea*, *Loxops virens*, and *Vestiaria coccinea*) fell in the 1.5 mm to 10 mm length range. The analysis of quality of food items focuses on those taxa 1.5 mm long or over which are favored food items: larval Lepidoptera, adult and immature Homoptera, lacewing larvae, spiders, and bark lice. Also, "types which are seemingly by-passed in large degree despite their availability are heteropterans, ants, roaches, larger wasps and flies, moths, adult lacewings..." (Baldwin 1952: 321). A better measure of quality would have been the percent of the weights of the samples represented by acceptable food items. In this way, light bodied taxa (e.g., bark lice) would not have equal ranking with heavier bodied taxa (e.g., Lepidoptera larvae). This method would have tended to skew the curve represented in Figure 1D upwards in the middle and downwards at its ends. Unfortunately, this measure would now be difficult to extract from the IBP data base, so I offer the much cruder estimation instead. Quality is likely underestimated in the middle portions of the transect in other aspects. Here we encounter the highest species richness and a number of potential food items such as crickets and katydids only irregularly encountered on the remainder of the transect that surely must be taken by insectivorous birds when they encounter them. There are studies now underway by others which might help resolve these apparent discrepancies. At higher elevations the arthropod biomass is comprised mainly of Lepidoptera larvae, spiders, and heteropterans. Since two former groups are heavily utilized by insectivorous birds, we could state that the quality is high there also.

DISCUSSION

There are few published, directly comparable studies in the Hawaiian Islands. Nishida et al. (1980) sampled jumping plant lice (Psyllidae) from 'ōhi'a at four sampling sites (15 m, 1060 m, 1212 m, and 2120 m) along an altitudinal transect in Hawaii Volcanoes National Park. They also found the maximum diversity of these insects in the middle portions of the transect. In addition, they found the lowest "carrying capacity" at the Kalapana site and the highest at the mid-elevation site.

Gon (1978) surveyed insects on an altitudinal transect from 580 m to 1670 m in the S. Kona area of the Big Island. He restricted his attention to those groups attracted to light and sampled visually from all plants at each of five sites at night. He limited his analysis to the family level. He found that insect family diversity decreased with altitude increase but that a diversity "hump" occurred at 1400 m elevation. I feel that in restricting his analysis to the family level he may have masked diversity at the specific level. He also found a strong correlation between plant diversity and insect diversity, although he classified the former only to the specific level.

Sweep samples of arthropods at 200, 1600, 3550, and 3600 m elevations in secondary vegetation in the Venezuelan Andes also show that the greatest number of arthropod species occurs at intermediate elevations, that at higher elevations there are a reduced number of species, and that large insects are much less abundant at high than low elevations (Janzen et al. 1976). But their highest biomass was at the intermediate elevation.

I feel that my estimations of quality for intermediate elevations is excessively low. Although Baldwin (1952) indicates certain arthropod groups (e.g., beetles and heteropterans) of low food preference, these and several other groups usually appear in over 10% of the bird stomachs of the three insectivores that he examined. Later, he states that these are "seemingly by-passed in large degree despite their availability" (Baldwin 1952: 321). If these groups were to be added to the quality parameter, the curve presented in Figure 1 would be skewed upwards the most for the middle elevation sampling sites.

On the other hand, the apparent lower biomass of samples in the middle portions of the transect could indicate more "cropping" of the arthropod biomass by insectivores. Conant (1975, 1976) found the highest density and diversity of insectivorous birds in the 1250 m to 1800 m elevational range on the Mauna Loa Transect.

The long-term temporal aspect of arthropod population parameters is unfortunately missing. Older literature would indicate that there was greater abundance and diversity of native insects which would likely serve as potential insectivore food. That is, the overall quality of potential food items appears to have declined. Hawaii Volcanoes National Park contained a number of insect species, Lepidoptera for example, which have not been encountered since their original collections at the turn of the century. Examples are *Tritocleis microphylla* Meyr. (Geometridae), *Hedylepta euryprora* (Meyr.), and possibly *H. telegrapha* (Meyr.) (both Pyalidae). If the avifauna, especially nestlings, was adapted to an abundance of these and other now apparently extinct or rare species as food, one could postulate detrimental repercussions for birds. The decline of suitable food items was more severe at lower elevations, which contributed to the otherwise hostile (e.g., from diseases and predators) lowlands (Atkinson 1977).

CONCLUSIONS

If the arthropod population parameters of richness, endemicity, quantity, and quality can be accepted as potential indicators of habitat equability, then the higher richness and quality of potential food items in 'ōhi'a canopies at mid- to upper-elevations indicate aspects presently more favorable to insectivorous bird life there than at lower elevations. Generally lower measures of richness and endemicity at lower elevations might indicate comparatively inequable conditions for native arthropods and biota dependent on them there now. The effect of other perturbations (e.g., habitat loss or alteration, exotic species, competition, parasitism, and disease) on native arthropods and their dependent biota is also only beginning to be elucidated.

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TABLE 1. Grouping of International Biological Program (IBP) sampling sites from *Metrosideros collina* by elevation and ecosystem type.

IBP Sampling Site	Elevation (m)	Ecosystem Type	Number of Canopy Releves (Arthropod Community Samples)
18	15	Open dry forest	23
17	760	Open dry forest	23
1	1195	Closed rain forest	21
2	1220	Open rain forest	13
3	1220	Open dry forest	13
4	1280	Savanna	22
6	1600	Mountain parkland	19
10	2130	Subalpine scrub forest	23
12	2440	Treeline ecosystem	11
		TOTAL SAMPLES	168

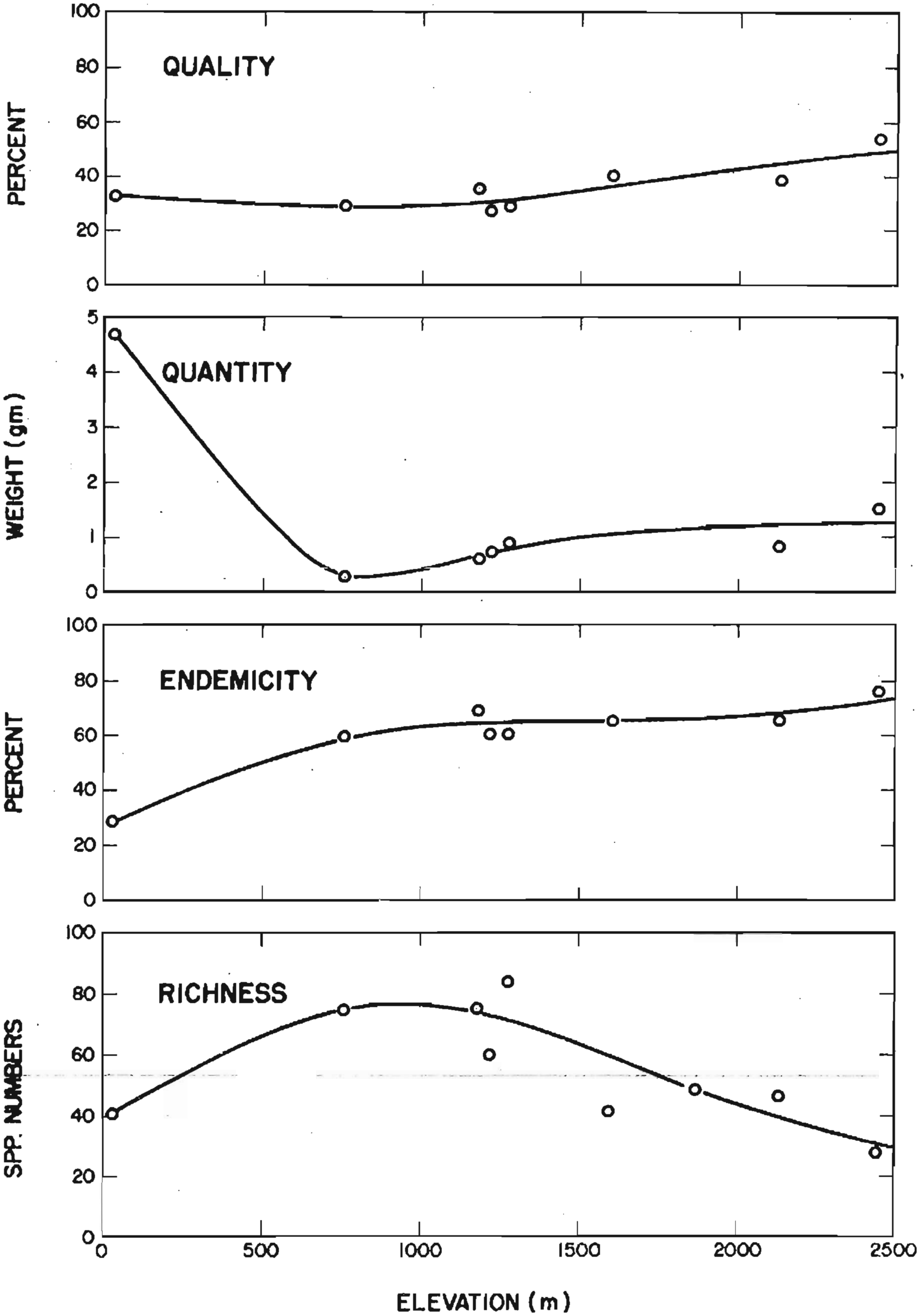

FIGURE 1. Measures of arthropod species richness, endemicity, quantity, and quality of the canopy-associated arthropods along an altitudinal transect on _Metrosideros collina_ in Hawaii Volcanoes National Park.