HAWAII IBP SYNTHESIS:
2. THE MAUNA LOA TRANSECT ANALYSIS

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Introduction

The Mauna Loa transect relates to the area within Hawaii Volcanoes National Park, which stretches from Red Hill Resthouse at 10,000 feet elevation to Thurston Lava Tube at 3900 feet. Located on the east flank of Mauna Loa, this transect represents a major tradewind intercepting environmental gradient on a geologically very young, high oceanic island.

Environmental gradient analysis is a widely used ecological field approach, which involves testing the response of biological organisms in relation to predictable environmental changes associated with a spatial gradient. Many ecologists have used this approach in various field situations, for example, to study changes of plant groupings from the shore going inland or in relation to changes in soil moisture regime from dryland to bogs, changes in relation to grazing intensities, or changes of weed communities in relation to different fertility states in agricultural crop fields. Whittaker (1967) presented a thorough review of this subject. He also formalized a sampling approach with data analysis for mountain gradient analysis, which he carried out in various temperate mountain systems (Appalachian, Siskiyou, and Santa Catalina). In his literature review, Whittaker found four diferent answers to the basic question, which he had asked, namely "How are species and communities distributed along environmental gradients?"

He came to the conclusion from his own studies in temperate mountains that only the fourth pattern applies to reality. The other three he considers to be in the minds of the investigators rather than forming an expression of reality.

We thought that we could add another dimension by asking: "How are species and communities of a number of different organism groups distributed along a young island mountain gradient in the tropics?"

In so approaching our study, we were also attempting to answer a question of MacArthur (1972: 161), which I would like to quote here in full:

"A critical question remains: Do different plant species change synchronously, or does each have independent distribution? If they change synchronously, vegetation types are more than a mere convenience; they are real and hence necessary as a subject of study. Whittaker (1969) has spent much of his life investigating this and has shown fairly convincingly for mountains in the United States that plants appear and disappear independently as we go up a mountain. Holdridge might dispute this, for the tropics at least, where he believes plants change synchronously. However, no one has carried out in the tropics a study like those of Whittaker and we must await such a study before we can pass final judgment on whether life zones are real in nature or whether they are the scientist's convenient but arbitrary classifications."

Sampling Scheme

Our sampling scheme involved 14 sites (Fig. 1). Each participating investigator sampled his organism group at these IBP sites for the near-total species assemblage and for the quantities of each major species present. Organism groups sampled were: higher plants, soil fungi and algae, birds, rodents, their ectoparasites, canopy arthropods on 'ohi'a and koa, wood borers (*Plagithmysus* beetles), Diptera flies breeding in koa, litter and roaming adult flies, and two groups of soil arthropods (springtails and orobatic mites). In all, 14 different organism groups (or types of biota) were sampled.

Results

For plotting our results we used a diagrammatic display method, which was universally applicable to all organism groups. It was in principle similar to the display of the bell-shaped species-population curves as used by Whittaker. But instead of drawing all species-population curves on one axis, we separated each species-population curve and, moreover, ordered these according to their distribution trends. This is best illustrated by showing a couple of examples of such species distribution diagrams:

Rodent species distribution along the Mauna Loa transect is shown in Figure 2. Of this introduced group only three species occurred, the house mouse, the roof rat, and the Polynesian rat. We can read from this diagram that the three species overlapped broadly, but showed different upper elevation limits. Also, their quantitative distribution shows separations, e.g., that the house mouse is associated mostly with grassy vegetation and the roof rat with woody vegetation. The latter is much more prevalent in the rain forest.

The distribution of soil fungi is shown in Figure 3 where the following patterns were observed: species restricted to alpine and subalpine ecosystems, species prevalent in the Mountain Parkland, species prevalent in the kipuka savanna, species prevalent in the rain forest, and species distributed over the entire transect.

Such segregations were shown also for higher plants, fungus gnats, Drosophila species, Plagithmysus borers, also for native birds; although the latter had fewer species.

For the higher-level synthesis Chapter 8 which followed the individual data sections (Chap. 7), I compared the various organism groups for their degree of gradient sensitivity and for their spatial association tendencies along the mountain gradient. It became evident that the distribution patterns could be reduced to seven:

1. Species of unrestricted, wide-ranging distribution [The organism group with the greatest proportion of species in this group were the springtails]

2. Species that were spatially associated, but forming overlapping groups [common in plants, fungi, birds, Drosophilids, and others]

3. Species that were individually distributed [a common pattern also]

4. Species with distinct bimodality

5. Species with multi-modal population curves (e.g., soil arthropods)

6. Species with broadly overlapping ranges, but decreasing tolerances upslope (e.g., the introduced rodents)

7. Species with common population modes, but broadly overlapping ranges (e.g., exotic plant species)

Whittaker's fourth distribution pattern, that of individually and randomly distributed species is here shown once more at the bottom. However, individual species populations were lifted each on a separate x-axis. This pattern is the same as our pattern 3. Pattern 2, however, is an equally important species distribution trend, which gives a valid basis for the recognition of plant communities. This pattern corresponds to Whittaker's third distribution hypothesis for which he had found little evidence in his own studies in temperate mountains.

General Conclusions

1. Zonal (or community) boundaries are evident from our data on species distributions, but boundary criteria need to be defined.

2. Different organism groups show different gradient sensitivities which are peculiar to the organism group.

3. Spatially associated species groups occur in nearly all organism groups.

4. Native species show a higher degree of spatial integration than introduced species among plants, birds, and Drosophilids. However, the origin (whether a species is native or non-native) is not a general predictor for species distribution patterns. These depend on the species ecological properties and the degree of naturalization (i.e., habitat saturation) among the exotics.

5. There is not only one generalized pattern of species distribution as Whittaker has claimed for temperate mountain gradients. Instead we can recognize at least three dominant patterns:

   1) Individually distributed species

   2) Spatially associated, but overlapping species groups

   3) Various forms of widely distributed species. The dominance of the latter groups are probably a characteristic related to biota distribution on young island mountains.

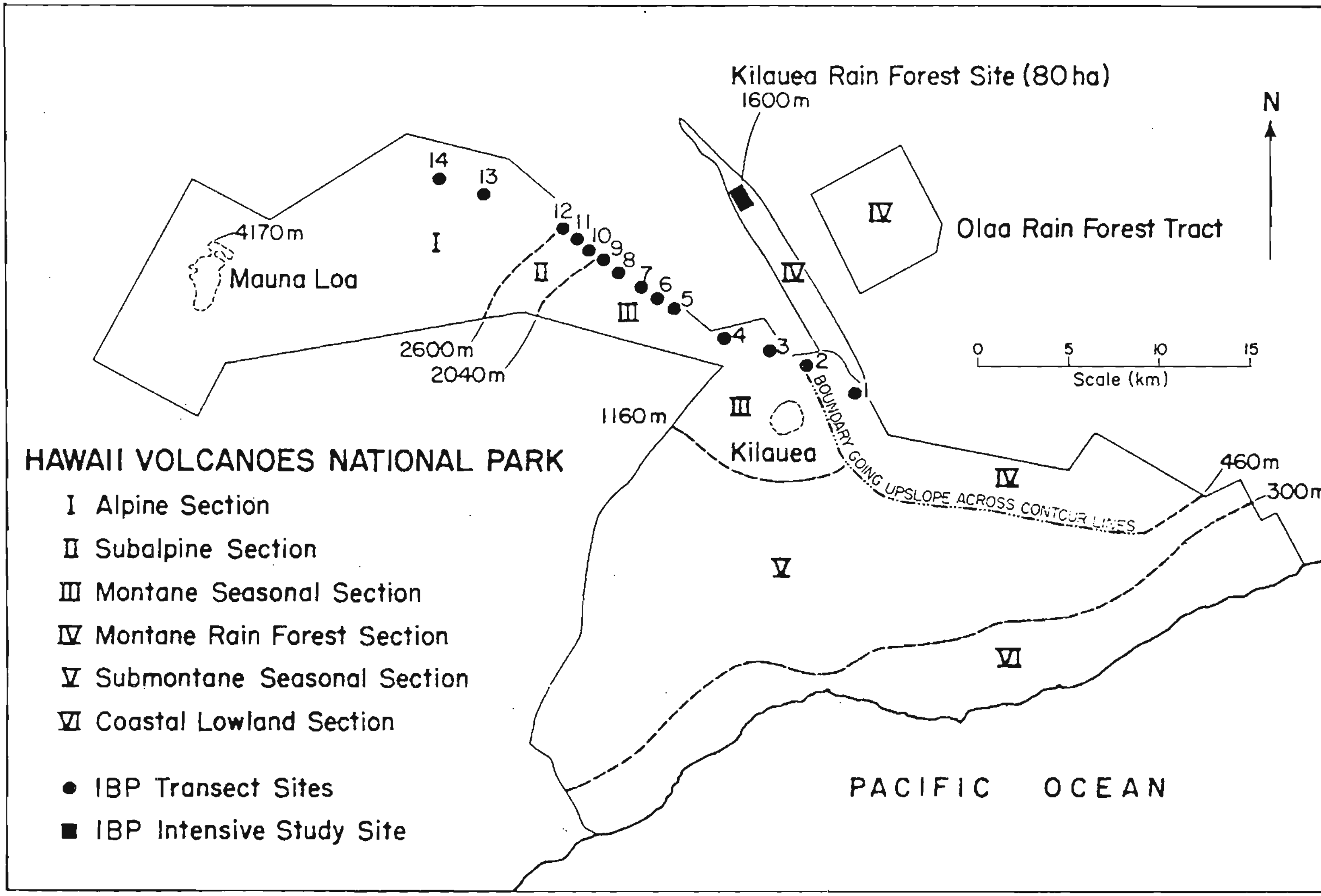


FIGURE 1. Map of Hawaii Volcanoes National Park showing the six environmental sections, the 14 Mauna Loa Transect sampling sites, and the Kīlauea Rain Forest site.

FIGURE 2. Distribution of the three rodent species sampled along the Mauna Loa transect (Oct. 71 through Sept. 73). Abundance scale in equal units of 5 animals trapped per year: Maximum is 9 units = 41-45 animals (M. musculus at site 4), 8 units = 36-40 animals, 7 units = 31-35, 6 = 26-30, etc., horizontal line = 1 animal (e.g., R. rattus at site 12). K = closed kīpuka forest in savannah zone IV. Origin: TeC = Temperate-continental Asia, TeL = Temperate-littoral Asia, TrP = Tropical-Pacific Asia.

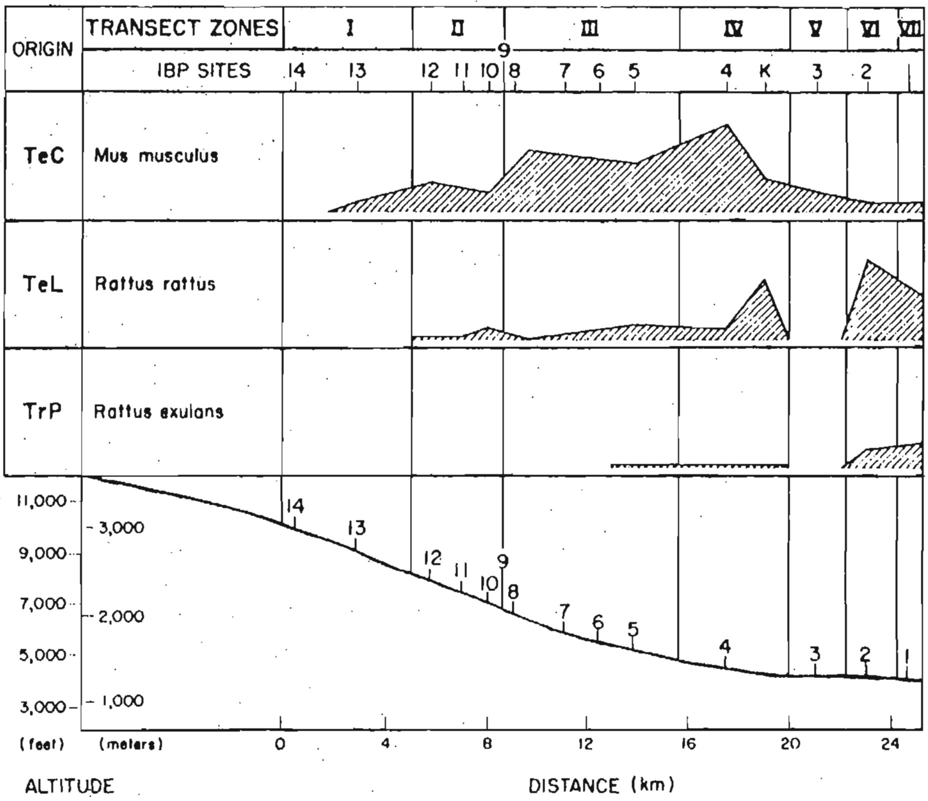
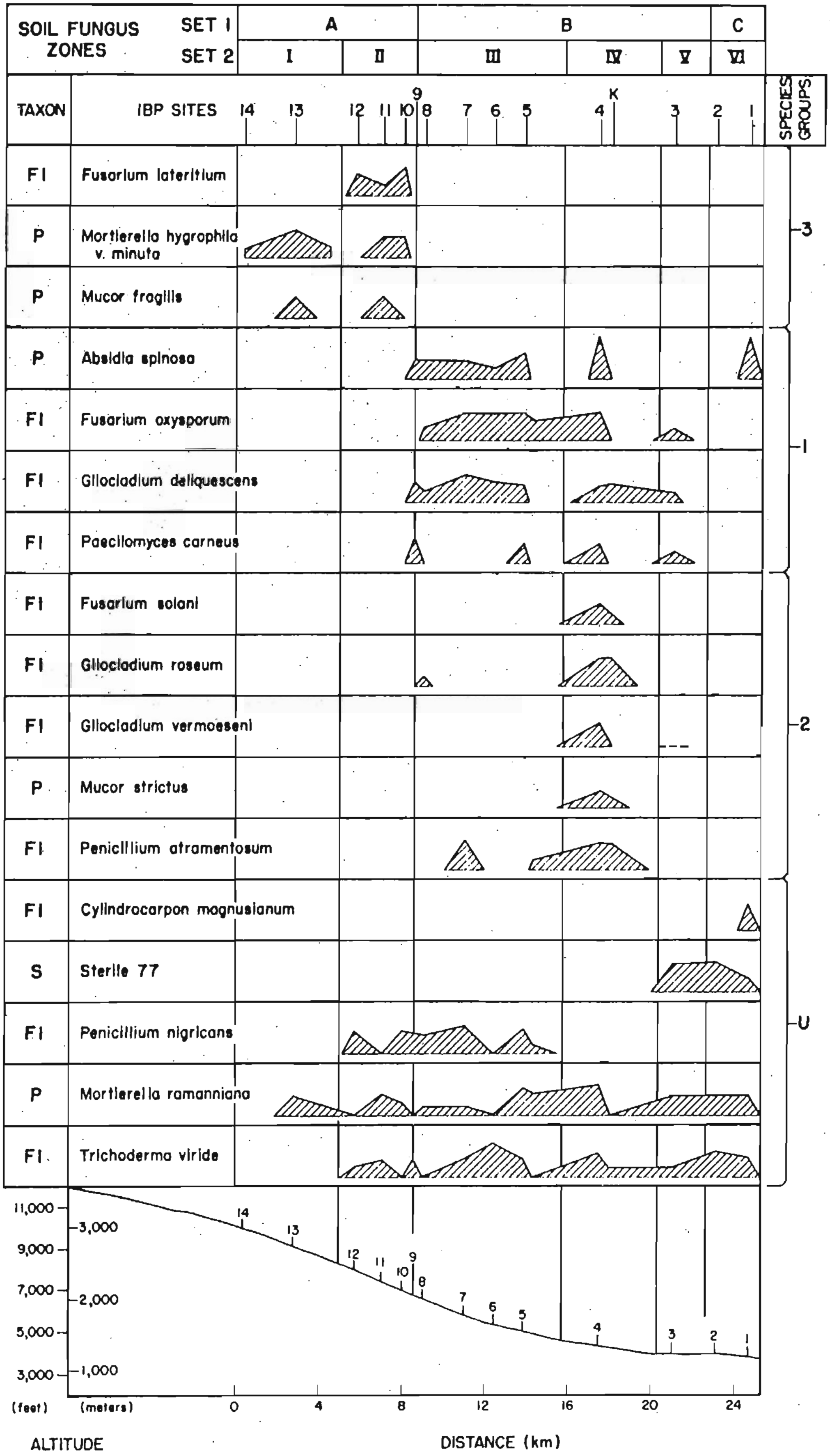

ORIGIN
TRANSECT ZONES
I
II
III
IV
V
VI
VII
IBP SITES
14
13
12 11 10
9
8
7 6 5
4 K
3
2
TeC
Mus musculus
TeL
Rattus rattus
TrP
Rattus exulans
11,000
9,000
7,000
5,000
3,000
3,000
2,000
1,000
(feet)
(meters)
0
4
8
12
16
20
24
ALTITUDE
DISTANCE (km)

FIGURE 3. Distribution diagram of populations of selected fungal species from soils along the Mauna Loa transect. Curve heights are based on relative population levels rated from very low to high. Dashed lines imply presence at very low levels. Species group numbers along the right-hand column refer to spatially associated groups in the two-way table (50/10 rule). Ungrouped species are at the bottom of the diagram. FI = Fungi Imperfecti, P = Phycomycete, S = Sterile Isolate.



SOIL FUNGUS ZONES
SET 1
SET 2
A
B
C
I
II
III
IV
V
VI
TAXON
IBP SITES
14 13 12 11 10 9 8 7 6 5 4 K 3 2 1
SPECIES GROUPS
FI Fusarium lateritium
P Mortierella hygrophila v. minuta
P Mucor fragilis
P Absidia spinosa
FI Fusarium oxysporum
FI Gliocladium deliquescens
FI Paecilomyces carneus
FI Fusarium solani
FI Gliocladium roseum
FI Gliocladium vermoeseni
P Mucor strictus
FI Penicillium atramentosum
FI Cylindrocarpon magnusianum
S Sterile 77
FI Penicillium nigricans
P Mortierella ramanniana
FI Trichoderma viride
3
1
2
U
11,000
9,000
7,000
5,000
3,000
3,000
2,000
1,000
(feet)
(meters)
0 4 8 12 16 20 24
ALTITUDE
DISTANCE (km)