NATIVE TERRESTRIAL INVERTEBRATES

Understandings of the basic biology, ecology, and especially systematics of Hawaiian invertebrates are just beginning.

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The first collections of terrestrial invertebrates from the Hawaiian Islands were made during Captain James Cook's voyages in 1778 and 1779. Little of this material was examined scientifically other than by Fabricius (1792-1794), who described the large ichneumon wasp Echidnophora fuscator and the vespid hornet Odynerus radula from these collections. The ultimate disposition of specimens, and which ones subsequently survived, became immensely complicated (Whitehead 1978).

The collections of terrestrial mollusks, including the genus Achatinella (large tree snails endemic to O'ahu) and other groups of tree snails, assembled throughout the 1800s by early explorer-naturalists, curious missionaries, and their offspring gained considerably more attention than other invertebrates (Kay 1972), presumably because of comparative ease of preservation in addition to spectacular color patterns. Toward the close of the 19th century and for many decades following, professional malacologists (mollusk researchers), including C.M. Cooke, Jr. and Y. Kondo at B.P. Bishop Museum in Honolulu, published several large systematic treatments of these groups, documenting several hundred endemic species. The recognition of intra-specific variation, speciation, and endemcity of Hawaiian landshells by John Gulick helped bring the implications of Darwinian evolution before the global scientific body (Gulick 1932). The importance of basing taxonomic relationships and therefore classification of mollusks on the entire animal rather than only the shell was also recognized.

Apart from some largely incidental collections made during various expeditions from 1778 to 1877 (see Illingworth 1923), other Hawaiian arthropods (insects, spiders, sowbugs, and so forth) remained largely unknown. Excepting a collection of true bugs (Hemiptera) made during the visit of the Swedish frigate Eugenie in 1853 (Stal 1859), it was not until the arrival of the Rev. T. Blackburn in 1877 (resident in Hawai'i for about a decade) that the first major systematic collections of insects were assembled (Blackburn 1877, 1881). Thus, a century of Western exploration passed while the terrestrial invertebrates, other than large land snails, remained largely unknown.

The most important collections of terrestrial arthropods were assembled by the extraordinary naturalist R.C.L. Perkins from 1893 to 1903. He was sponsored by the Royal Society of London and the British Association for the Advancement of Science, which, in conjunction with the B.P. Bishop Museum,
published the results of Perkins' labors in three monumental volumes of the *Fauna Hawaiensis* series (Sharp 1899-1913). Duplicate material was deposited at the British Museum of Natural History and the B.P. Bishop Museum (Manning 1986).

For a number of major groups, especially the Coleoptera (beetles) and many Hymenoptera (bees, wasps, and ants), *Fauna Hawaiensis*, though now seriously dated, is still the "state of the art." Revisions of several genera and higher taxonomic groups (see natural classification in Glossary) and biological studies of aquatic insects (Williams 1936-1944) appeared in the decades following publication of *Fauna*. In 1948, E.C. Zimmerman began the immense task of updating the Hawaiian arthropods in his *Insects of Hawaii* series. Fourteen volumes have appeared thus far, with the Diptera or flies authored in five volumes by D.E. Hardy (1960-1981).

Swezey (1954) summarized the host associations of all insects known to be associated with native trees. Examination of his *Forest Entomology* and Zimmerman's volumes shows that the life histories of the bulk of the described native species are still unknown.

Work on the Hymenoptera for the *Insects of Hawaii* volumes by C.Y. Yoshimoto and J.W. Beardsley is currently in progress. Nothing of this magnitude is yet in the works for the Coleoptera. G.A. Samuelson and G.M. Nishida of the Entomology Department at B.P. Bishop Museum are computerizing the card file of Hawaiian terrestrial invertebrates, both native and alien, developed by the late Amy Suehiro. Gustav Pauley of the University of Washington has prepared a computer listing of all known endemic terrestrial invertebrates. When these projects are completed, we will know how many species have been described, as well as their biogeographic status.

Recent estimates of the number of endemic arthropod species lie between 7,000 and 10,000 (Simon 1987; F.G. Howarth, personal communication). For the mites, Goff (1987) has provided an up-to-date catalog containing 466 species. But the endemicity of acarines (mites and relatives) is exceptionally difficult to determine, and Goff does not attempt to do so. Suman (1964) provided a catalog of Hawaiian spiders totalling 149 species, of which 55% are endemic, 1% are indigenous (naturally occurring in Hawai‘i but naturally found elsewhere also), and the rest are alien.

Edwin H. Bryan, Jr., the first to popularize Hawaiian invertebrates, published a series of nature notes in the *Honolulu Star-Bulletin* newspaper during the 1920s (Bryan 1935). He also published a short, elementary account of common, large arthropods for use in the schools (Bryan 1940).

It was not until the 1970s that focus was brought upon the conservation status of terrestrial invertebrates (Gagné 1975; Hart 1978; Hadfield 1986). Following Hart's article, the U.S. Department of the Interior (USDI) placed the entire genus *Achatinella* on the *Endangered* Species list. Several hundred other terrestrial invertebrates were placed under review by USDI, but prospects for timely official listing of any of these now appear dim, given the prevailing political climate. Not hindered by such constraints, the International Union for the Conservation of Nature and Natural Resources (IUCN) has listed several Hawaiian arthropod groups in its *IUCN Red Data Book on Invertebrates* (Wells et al. 1983). The conservation status of endemic terrestrial invertebrates in general was discussed by Gagné and Christensen (1985); that of Lepidoptera (butterflies and moths) by Gagné and Howarth (1983); that of a vulnerable damselfly by Moore and Gagné (1982); and that of Hawai‘i's cave invertebrates by Howarth (1983).
In recent years, major strides have been made in elucidating the **systematics** and evolution of a few major groups: the *Drosophilidae* (see Carson and Kaneshiro 1976), cave-adapted and aeolian (dependent on wind-distributed food) arthropods (Howarth 1983, 1987), and predatory inch worms (Montgomery 1983). The ecology and altitudinal distribution of these and several other groups are discussed by various authors in Mueller-Dombois et al. (1981). A review of the significance of all these studies to entomology was made by Simon et al. (1984) and Simon (1987). Several recent issues of natural history magazines and scientific journals have brought international attention to our native biota.

**MAJOR PROBLEMS**

We are far from completion of a full systematic treatment of all terrestrial invertebrates in Hawai‘i, particularly groups with many species, such as the small mollusks, nematodes, spiders, mites, and insects. The biology, ecology, and evolution of these and the remaining invertebrates is largely a vast unknown. Nor do we know much about the importance of invertebrates to the rest of the native biota. For example, pollination biology is nearly a virgin field.

With support of the U.S. Fish and Wildlife Service, I intend to sample canopy arthropods to see if there are any correlations with distributions of certain Endangered forest birds. What is the nature of other interdependencies of native arthropods and the remainder of the biota? What is the role of native invertebrates in nutrient cycling? These and other equally critical research questions should be answered.

In regard to popularized treatments of Hawaiian invertebrates, there are but two (Williams 1931; Fullaway and Krauss 1945), which are very dated, long out of print, and not readily available. Frank Howarth, William Mull, and I are preparing a copiously illustrated, popularized account of native insects.

**RESEARCH AND MANAGEMENT NEEDS**

Much ecological work involving terrestrial invertebrates is potentially hamstrung by the rudimentary knowledge of their systematics and a lack of trained and paid systematists to carry out this work. There are less than a half-dozen invertebrate systematists in Hawai‘i, who are paid to study 7,000-10,000 species. There are no Hawai‘i-based workers to study the systematics of terrestrial arachnids, myriapods, crustaceans, annelids, mollusks, and a number of insect groups.

This near impasse at the systematic level makes intelligent management of the immense invertebrate resource difficult, if not impossible. The recent work of Howarth, Loope, Medeiros, and Gambino on the impacts of introduced invertebrates upon the endemic biota points to a sense of urgency (see Howarth and Medeiros, this volume). The conservation biology of native species will proceed with still more blind spots and potential pitfalls unless further research is supported.
RECOMMENDATIONS

A number of actions are needed to remedy the problems cited above:

1. Secure sufficient long-term funding to complete a thorough survey of native terrestrial invertebrates of the Hawaiian Islands. This endeavor might take a full-time team of 12 systematists at least a decade.
2. Hire systematists and house them at the B.P. Bishop Museum and the University of Hawaii to carry out Recommendation 1.
3. Encourage and foster graduate students to work on the systematics and ecology of Hawaii's invertebrate resources.
4. Complete an assessment of the conservation status of native terrestrial invertebrates.
5. Accelerate research on conservation biology and interdependencies of terrestrial invertebrates with the remainder of the native biota.

Although existing discoveries and research of the past have brought international attention to the remarkable evolutionary and ecological importance of our insular invertebrates, understandings of the basic biology, ecology, and especially systematics of the Hawaiian arthropods, are just beginning. There is a critical need to support much expanded work in all these areas and to interpret the importance of this work through educators to decision-makers and the general public.

Important References

(References to Hawaiian insects in vol. 2, p. 269 and vol. 3, p. 463.)