WORKING TOWARDS AN ASSESSMENT OF THE CONSERVATION STATUS OF HAWAII'S ENDEMIC ARTHROPODS, WITH EMPHASIS ON THE MOTHS OR LEPIDOPTERA

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INTRODUCTION

For the past two years we have been assessing the conservation status of Hawaii's endemic terrestrial arthropods under a contract from the Office of Endangered Species of the U.S. Fish and Wildlife Service. We have made preliminary analyses of over 700 species thus far. These species we have so chosen to represent a spectrum of ecological functional groups (e.g. aquatic, anthophagous, phytophagous, detritivorous, entomophagous), those of special scientific interest (e.g. pomace flies or Drosophilidae) or to draw attention to perceived or anticipated environmental threats (e.g. souring beetles or Nitidulidae). In the Lepidoptera, we have analyzed leafrollers of the genus Hedylepta (Family Pyralidae), have begun analysis of the endemic Sphingidae or hawk moths, and have made preliminary analyses of the remaining Macrolepidoptera and some Microlepidoptera.

The assessment is planned to result in the categorization of the endemic species as "common", "threatened" or "endangered". Certain of the endemic species so categorized as "endangered" will be selected for formal placement on the U.S. List of Threatened and Endangered Species which would give them special statuatory status for legal protection. However, their eventual official recognition as "endangered" is presently moot as this Federal administration places very low priority on further official listing of insects and other invertebrates. Only seven species, all non-Hawaiian, have thus far been recognized in the U.S.

This paper focusses upon the Lepidoptera (moths and butterflies) because of their wide ecological amplitude as an order so functioning as a sentinel for other arthropods, and because of their importance as food for other species. They play a possible role as pollinators.

MATERIALS AND METHODS

Project methodology has concentrated upon three areas, viz: (1) Computerization and refinement of the existing data base for the damselflies, genus Megalagrion (Odonata, Coenagrionidae), native bees, genus Nesoprosopis (Hymenoptera, Hylaeidae), leafrollers of the genus Hedylepta (Lepidoptera, Pyralidae), and weevils of the genera Stenotrupis and Pentarthrum (both Coleoptera, Curculionidae), (2) preparation of the data base from bibliographic and museum collection sources and computerization of the endemic pomace flies (Diptera, Drosophilidae) and souring beetles (Coleoptera, Nitidulidae), and (3) limited field work to bolster or truth the data base.

Computerization of data base

The project, through the Bishop Museum, has contracted with Pacific Area Computer Services, Inc. (PACS) to provide computer processing power and services through a HP-2647A Graphics microcomputer terminal at the Museum which is connected to a HP-3000 computer at PACS data processing center. PACS has created a specific program to serve our contractual needs which can interface with and be adaptable to other collection computerization activities within our Entomology Department.

There are two features to our system prepared by PACS: file maintenance and reports. The file maintenance consists of the user being able to add, modify or delete records in the data base. The reporting gives the capability of continuously updating specific types of information requested by the Office of Endangered Species and other interested parties by specifying ranges of information necessary. Data entry and maintenance particularly are simplified and accelerated in that much of the individual species' data are compressed onto one easy to read screen.

One result of this system is a printed reportwhich contains only those records requested from the individual species computer file. A family-level bibliography is being numerically cross-referenced into the species-level file. Each species is assigned a number for its "Index of Rarity" which denotes its conservation status as "Common", "Threatened" or "Endangered".

On-going data base preparation

Two major groups of Hawaiian arhtropods, the Nitidulidae comprising some 140 species and the Drosophilidae comprising some 550 species, are now in the final stages of data base computerization. There is a comparative dearth of information on the Nitidulidae which have not received nearly the attention that the Drosophilidae have in recent decades because of the intense research on the evolutionary biology of these flies. Other genera are in the preliminary phases of data base assimilation.

RESULTS AND DISCUSSION

The native terrestrial biota reflects the extreme isolation of the Hawaiian Archipelago and so is represented by those few groups that dispersed across more than 3000 km of open ocean and which successfully colonized the islands. Some of those that won the dispersal "sweepstakes" adapted to new habitats and life styles and evolved into extensive species complexes giving Hawai'i its unique and bizarre fauna. The Lepidoptera are no exception, and the few colonists now represent a dominant group in the islands' ecosystems. Native species are found from the sea coasts to the alpine zones of the highest mountains, although now much diminished in elevations below 1000 feet (Gagné 1979).

Table 1 presents a summary of the endemic Hawaiian Lepidoptera. Several hundred recent immigrant or exotic species of human derivation are excluded. The composition of the fauna reflects a recent origin of the Hawaiian Archipelago (Zimmerman 1948). There are no higher taxonomic categories (Subfamily and above) which are endemic, but about half of the 57 native genera are endemic as well as all of the 930+ native species. The low number of ancestral colonizing species (52-55) contrasts with the high number (930+) of endemic species. The breakdown of taxa in Table 1 follows Zimmerman's Lepidoptera volumes in the Insects of Hawaii (1958 a,b; 1978). The other major insect orders in Hawai'i have basically the same patterns presented in Table 1.

An analysis of the perturbations contributing to the endangerment or extinction of native arthropods has shown the following to be the major contributors (in roughly descending impact): (1) habitat destruction and alteration by pre-historic and historic agricultural transformations, feral mammals and fire, (2) introduction of polyphagous parasites and predators, (3) destruction of certain host plants, (4) exotic flora naturalization and (5) lack of effective quarantine for in-bound commercial activity. I have discussed these elsewhere in more detail (Gagné 1981). Davis (1978) analyzed the accidental exotic insect introductions, probably accruing mostly from in-bound commerce, and found that such species were detected in Hawai'i at an average of over 17 species per year between 1961 and 1978.

An analysis was also made of the possible perturbations (Gagné and Howarth in press) contributing to the probable extinctions of 27 species of endemic Lepidoptera (Table 2). This breakdown is shown in Table 3. The impact of introduced polyphagous insects, especially parasitoids, is not expected to be as high for other orders. A number of parasitoids were introduced particularly for army worm (Noctuidae) control earlier this century (Howarth pers. comm.) and several of these are now found to have attacked a wide range of host species. Consequently, even some formerly common, pestiferous Lepidopteran species have disappeared or are now rare.

Two additional anticipated threats or perturbations to the endemic arthropods are: (1) increasing light pollution from expanding urbanization which attracts and confuses nocturnal species and (2) the proposed Tri-Fly Eradication Program to eliminate three species of fruit-attacking dacine flies.

MANAGEMENT RECOMMENDATIONS

Nature of oceanic island ecosystems

Island ecosystems and their native species are not inherently fragile as compared to their continental counterparts as is often widely assumed. In fact, island species have been recently shown by Mueller-Dombois et al (1981: 516) to have as great a degree of competitive resilience as do exotic species. Island species have had to adapt to a suite of environmental and biotic factors as complex as those on the continents. Endangerment and subsequent extinction comes not from any intrinsic qualities of a species but from the impacts of novel perturbations to which the organism is not preadapted to cope. One has only to witness the sudden demise of some elm, chestnut and pine species on the North American continent a stark examples of this phenomenon there as well. In other words, the perturbation must be defined in terms of how it affects a

given organism, not as it is perceived by the researcher.

The insights gained from research by the International Biological Program in Hawai'i (Mueller-Dombois et al loc. cit.) showed that at least in ecological, rather than geological time, the extinction of island biotas is not inevitable unless no conservation measures are taken. The same can be said of continental biotas. The realization that very similiar conservation scenarios are being staged on other islands and continents places a greater burden on human activities in conservation and points to the urgency of finding solutions to prevent further loss of species diversity.

Habitat acquistion and protection activity

A crux of the survival of endemic arthropods is no different from that of other biotic groups, i.e. adequate habitat, and this is where the National Parks play an important role. Protection and acquisition of habitat presently falls on the shoulders of four organizations in Hawai'i: two national, one State and one private. Although the National Park Service has jurisdiction over four parks in the islands, only two - Hawai'i Volcanoes and Haleakala National Parks have significant natural areas within their borders. Both parks must continue their active programs to rid themselves of feral goats, feral pigs, exotic plants and rodents. Means of eliminating certain exotic insects should also be more aggressively explored.

The Fish and Wildlife Service's refuges are primarily devoted to waterfowl and migratory shore birds here. Little interest is yet shown in native plants and invertebrates on such refuges. However, the North West Hawaiian Islands Wildlife Refuge contains two high islets (Nihoa and Necker Is.) which contain native terrestrial biota with high endemicity. Nihoa I. represents a window on the past in that it contains a lowland flora and associated fauna that likely bares some resemblance to that now all but exterpated on the main islands. Thorough arthropod surveys of these islets during the optimal activity during the rainy season should be completed. The biological chain reaction which ensued when rabbits were introduced to Laysan I., stripping the vegetation of host plants for several miller moth species which subsequently became extinct along with the Laysan miller bird presumably in turn dependent upon these insects for food, allows little room for complacency when such vulnerable habitats exist.

The Department of Land and Natural Resources (DLNR) is responsible for the management of eight formally designated natural area reserves. The goal of designating representative examples of terrestrial ecosystems from State lands on each of the major islands from several dozen candidate natural areas is far from being realized for it has taken over a decade to get just the eight areas now officially gazetted. A clear policy needs to emerge from the conflicting demands from hunting interests, feral mammals and native ecosystem protection. The DLNR and the National Park Service have also fenced a few pockets of rare native plants from feral pig and cattle depredations. But, as yet the State Park system appears to have put little cognizance in the need for native ecosystem protection where they occur within their borders.

The private agency involved in habitat protection here is the nation-

wide Nature Conservancy (TNC). Real estate speculation in Hawai'i has caused prices to skyrocket of all private lands (which are the primary focus of TNC for acquisition), no matter what their land use zoning, remoteness or topographical ruggedness. As a consequence, TNC have had to confine their acquisition efforts to those areas containing endangered birds since these have the highest public appeal among potential monetary donors. This contrasts with the present relatively low appeal of areas mostly of botanical and entomological interest. TNC is now also beginning to grapple with exotic mammal and plant removal on areas now under their control.

The establishment of a system of scientific natural areas and ecological reserves under university and/or private sponsorship needs to be conceptualized and fostered. Ours is one of the few states in the nation lacking this avenue to habitat protection and research.

Efforts to eliminate, or at least ameliorate perturbations to endemic Hawaiian Lepidoptera and other arthropods only now are taking their first steps. The focus is now upon the more obvious and visible impacts arising from feral goats, sheep and cattle. Feral pigs are recognized by most biologists here to be highly detrimental to native ecosystems, but their effective management presents a most challenging and frustrating political and social problem. The National Park Service must also be encouraged to explore avenues to eliminate or ameliorate the more insidious but less recognized problems arising from rodents, weeds and exotic insects. The State's investigations of the biological control of forest weeds must also incorporate an analysis of the relationship of the disturbance-adapted species with feral mammals fostering them, otherwise one displaced disturbance-adapted weed may well only be replaced by another.

It continues to be difficult to balance the more immediate species-directed conservation in favor of long-run habitat and ecosystem conservation. Birds garner most of this attention, plants much less and invertebrates hardly any. This is in spite of the biological reality that the invertebrates, including the Lepidoptera, represent significant portions of such ecosystems when evaluated by biological parameters such as diversity, biomass, numbers, food sources, pollination, etc (Gagné 1980).

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TABLE 1. Tabular summary of native Hawaiian Lepidoptera (primarily after Zimmerman 1958a,b; 1978).

Taxon	Native Families	Endemic Families	Native Genera	Endemic Genera	Endemic Species*	Ancestral Species
Macrolepidoptera	5	0	23	14	135	19 (or 20)
Microlepidoptera	8	0	22	14	605**	22
Pyraloidea	1	0	12	7	190	11-13
Totals	14	0	57	35	930	52-55

* Native lepidopteran species are 100% endemic

** Over half (ca. 350 species) are in the genus Hyposmocoma

TABLE 2. List of presumed recently extinct Hawaiian Pyraloidea and Macrolepidoptera (after Gagne and Howarth in press).

Species	Distribution	Date last seen	Reason(s) for demise
Pyralidae*			
Hedylepta asaphombra	Kauai, O'ahu, Molokai Hawai'i	1970's	Loss of host plant (*Joinvillea adcendens*)
H. continuatalis	All main islands	1958	Loss of habitat; biocontrol introductions
H. epicentra	O'ahu	early 1900's	Ditto
H. euryprora (?)**	Hawai'i	?	Loss of host (banana); biocontrol introductions
H. fullawayi (?)	Hawai'i	?	Ditto
H. laysanensis	Laysan	1911	Rabbits: loss of hosts and habitat
H. meyricki (?)	Hawai'i	?	Loss of host (banana); biocontrol introductions
H. musicola (?)	Maui, Molokai	?	Ditto
H. telegrapha	Hawai'i	?	Biocontrol introductions (host plant unknown)
Oeobia sp.	Laysan	1911	Rabbits: Loss of hosts and habitat
Genophantis leahi	O'ahu	early 1900's	Loss of hosts and habitats
Noctuidae			
Agrotis crinigera	All main islands	1926?	Biocontrol introductions***
A. fasciata (?)	Midway	?	Loss of habitat, big-headed ants
A. kerri	French Frigate Shoals	1923?	?

Table 2 continued

Noctuidae (continued)			
A. laysanensis	Laysan	1911	Rabbits: loss of hosts and habitats
A. procellaris	Laysan	before 1900	Ditto
Hypena laysanensis	Laysan	1911	Ditto
H. newelli (?)	Hawai'i	?	Biocontrol introductions ?
H. plagiota (?)	Kauai, O'ahu	?	Ditto
H. senicula (?)	Kauai	?	Ditto
Helicoverpa confusa	Main islands	after 1927	Sterile coupling between *H. confusa* ♀ with *H. zea* ♂; possibly hybridization with *H. zea*; biocontrol introductions
H. minuta	Lisianski	before 1911	Rabbits: loss of hosts and habitats
Geometridae			
Scotorythra (Acrodrepanis) nesiotes	O'ahu	early 1900's	Biocontrol introductions; loss of habitat ?
S. (A.) megalophylla	Hawai'i	early 1900's	Ditto
S. (S.) paratactis	O'ahu	early 1900's	Ditto
Tritocleis microphylla	Hawai'i	1890's	?
Sphingidae			
Manduca blackburni	Main islands	1960's	Loss of hosts; biocontrol introductions

*Species of *Mestolobes*, *Orthomecyna*, *Tulla*, *Tamsica* and other pyralids have also became extinct, but revisions are necessary for for precision

** Questioned species may be synonyms of congeners

*** Larvae called *poko* by Hawaiians; once an important pest such that the mynah (*Acridotheres tristis*) was introduced

TABLE 3. Most probable reasons for extinction of 27 species of Macrolepidoptera and Pyraloidea listed in Table 2.

Species extinctions	Perturbation*
16	Biocontrol introductions
8	Habitat loss
6	Exotic mammals
5	Host loss
2	Unknown
1	Exotic insects (excluding biocontrol introductions)
1	Hybridization with exotic species

* Not mutually exclusive