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Potential Effects of Alien Fruit Fly Eradication on Natural Areas of Hawai'i: An Exploratory Investigation in Haleakala National Park

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Introduction

The Hawai'i Fruit Fly Symposium, "Fighting Alien Fruit Flies in the Unique Hawaiian Environment," held on Kaua'i on 11-13 December, 1990, identified the urgent need for work on environmental impacts before proceeding with a proposal to eradicate four species of alien fruit flies (Tephritidae) in the Hawaiian Islands (Kido 1991). The four species are the Mediterranean fruit fly or medfly (*Ceratitis capitata*), the melon fly (*Bactrocera cucurbitae*), the oriental fruit fly (*Bactrocera dorsalis*), and the Malaysian fruit fly (*Bactrocera latifrons*). Sophisticated techniques for local elimination of individual fly species have been developed over the past 20-30 years, and there is an understandable desire in the agricultural community to move ahead with eradication programs. Unfortunately, little is known about the impact of these eradication techniques on the native Hawaiian biota. Although some detailed impact studies are currently underway in the Moloa'a district of Kaua'i (Messing and Asquith 1991), this is primarily an agricultural area, and almost nothing has been done to date to explore potential impacts of eradication in a large pristine natural area.

Impetus for the Fly Eradication Program

In his keynote address for the December 1990 fruit fly conference, Hawai'i Senator Daniel Akaka stated that he viewed the conference as a springboard for the "technical war" against the four species of pest fruit flies. He stated that Hawai'i is at a crossroads in its agriculture, with sugar and pineapple giving way to diversified crops. Diversified agriculture is much more likely to thrive if these alien fruit flies are eradicated. The Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA) has had a major fruit fly laboratory in Honolulu since 1912, in recent years devoted primarily to developing the technology for the eradication of these flies. In fiscal year 1991, $8 million was budgeted, primarily to ARS, for fruit fly research on Kaua'i.

Although there is considerable impetus for this program to control pest fruit flies within the state of Hawai'i, another driving force is within the state of California. At the December conference, Dr. Isi Siddiqui of the California Department of Food and Agriculture (CDFA) gave an excellent rundown of California's point of view. California, with 3% of the nation's farmland, produces 50% of the nation's fruits, vegetables, and nuts, which along with other crops have an annual value of $17.6 billion. Without their active pest prevention program, annual costs from response to medfly establishment alone would amount to $0.7-$1.1 billion. CDFA has been working with USDA for 90 years to keep alien pestiferous flies out. Their view is that the exclusion system is showing much strain, as manifested by dozens of fruit fly outbreaks, primarily in the Los Angeles area, in 1987-90. Response has included massive campaigns of spraying malathion in urban areas, which CDFA feels have been repeatedly successful in eradicating outbreaks (at a cost of $56 million). Dr. Siddiqui cited impressive evidence that the problem is massive failure of the quarantine system to keep flies from getting in, with Hawai'i being a major source (Siddiqui 1991).

Eradication Techniques and Preliminary Impact Assessment

In the early 1980s, the Animal and Plant Health Inspection Service (APHIS) of USDA contracted to have a Draft Environmental Impact Statement (EIS) for the so-called Tri-fly Eradication Program prepared; it was released in 1984 and made final in 1985 (USDA-APHIS 1985). A major component of the proposed program discussed in the EIS was use of malathion "bait sprays," a combination of protein hydrolysate (a feeding stimulant, often corn or yeast-based) and the toxicant malathion, distributed from aircraft over the target area. APHIS received nearly 1000 comments on the Draft EIS, most of them negative, and the decision was made to regroup and continue refining methods for eradication which minimize pesticide use. The largest number of persons responding to the Draft EIS were concerned about possible effects of pesticides to human health. However, a significant number mentioned threats to Hawai'i's native biota, including the Superintendents of Haleakala and Hawai'i Volcanoes National Park and the Director for the National Park Service Pacific Area.

Much experimental work has been done by ARS researchers in the past 15 years to perfect the so called sterile insect technique (SIT) which involves flooding an area with sterile male flies (Cunningham *et al.* 1980; Vargas *et al.* 1991), and several laboratories in Hawai'i are devoted to producing huge numbers of flies which have been sterilized using radiation. The theory is that the sterile males will mate with wild females, which mate only once, thus resulting in no offspring. A second technique involves flooding an area with parasitic wasps, in order to reduce the wild population, prior to inundating the surviving wild flies with sterile ones (Wong 1991).

A third technique, called male annihilation, involves attracting large numbers of male flies to chemical attractant baits ("trimedlure" for the medfly, methyl eugenol for the oriental fruit fly, and "cuelure" for the melon fly). These are the

same attractants used in surveys to assess the status of pest fruit fly populations (Liquido 1991). The baits are usually applied to fiberboard blocks, to trees, or to telephone poles and combined with a very small dose of the insecticides naled or malathion (Cunningham 1991). Cunningham (1991) believes that in order for the eradication of the oriental fruit fly to succeed in Hawai'i, use of male annihilation will be necessary in many areas at elevations below 2000 ft (610 m) where oriental fruit fly populations are very high.

Of the three major potential techniques, the sterile insect technique (SIT) appears to be by far the safest from the standpoint of environmental concerns (Beardsley 1991). The most serious concern raised to date involves potential impacts of low flying aircraft used to disperse the sterile flies (Howarth 1991).

The second technique, using parasitic wasps, is of concern in so far as complete tests must be performed prior to release to assure the absence of significant impact on native biota. Howarth (1991) raises concerns for statewide application of such techniques without extensive prior research. Haleakala National Park expressed concern in November 1987 when the ARS announced a parasitoid enhancement experiment in Kula, Maui, that the parasitoid *Diachasmimorpha (Biosteres) tryoni* might attack endemic fruit fly species in the same family (Tephritidae) as the pest species in Haleakala National Park. Dr. Tim Wong, an ARS researcher, and the ARS lab's former director, Dr. J.E. Gilmore, were responsive to our concerns and initiated a project to investigate the native tephritid flies associated with silversword and other Asteraceae of Haleakala's northwest outer slopes and crater. The field and lab work are complete for this project, but the results are not yet published. The bottom line of the study is that none of the released parasitoid wasps have been yet detected in the Park, none of the native tephritids tested are parasitized by this wasp species, and lab attempts to infect the native fly larvae with the mass-produced parasitoids have given negative results. At this point, parasitoid enhancement using *D. tryoni* seems to be environmentally acceptable in Haleakala National Park. Beardsley (1991) cites the need to examine possible effects of enhanced numbers of *D. tryoni* on the poorly known and apparently rare gall-forming genus *Phaeogramma* (Tephritidae) which develops in stems of native koko'olau shrubs (*Bidens* spp.).

However, the most serious environmental concerns relate to the third method, the use of the so-called male annihilation technique, and to a lesser extent, to very extensive use of traps baited with lures for survey purposes or for population reduction. Previous research has documented that a variety of non-target organisms are attracted to chemical lures (e.g. Suda and Cunningham 1970), especially drosophilid flies, one of Hawai'i's more diverse native groups (Conant 1981).

Haleakala National Park was established to preserve the outstanding scenic, geological, and biological resources of Haleakala Volcano, the Kipahulu Valley, and adjacent coastal lands for visitor enjoyment and scientific study. Curious about potential impacts of full-scale fruit fly eradication on biota of Haleakala National Park and with cooperation from the ARS, in May-June 1990, we conducted an exploratory assessment in Kipahulu Valley, in conjunction with a more comprehensive biological monitoring project.

Study Area

Rain forests of Kipahulu Valley are among the most pristine in Hawai'i and, together with nearby reserves managed by State Department of Land and Natural Resources and The Nature Conservancy, comprise the most important nucleus for preservation of Hawaiian biological diversity on the island of Maui. The area is managed as a scientific reserve, closed to the general public. As a response to establishment of feral pigs in this area in the 1960s and 1970s, the National Park Service has initiated seriously needed intensive management of the area. A network of barrier fences has been installed at a cost of over $1 million, dividing the rain forest into relatively manageable units, enabling effective pig control. Alien plant control is another high-priority need.

Land in lower Kipahulu Valley below about 1500 ft (460 m) elevation was cultivated by ancient Hawaiians, was later used for pineapple, sugar cane, and cattle grazing, and is currently dominated by alien vegetation although native plants and animals occur throughout the area all the way to sea level. Above 2000 ft (610 m) elevation, native species dominate, although high concentrations of alien species, especially strawberry guava (*Psidium cattleianum*) are present between 2000 and 3000 ft (610-915 m). Strawberry guava occurs sporadically as high as 4500 ft (1370 m), but the biota is almost entirely native above about 3000 ft (915 m). Common guava (*Psidium guajava*) is most abundant below 2000 ft (610 m), but occurs as high as 4100 ft (1250 m). At 2000-4000 ft (610-1220 m), there is a substantial amount of interdigitation of guava and native communities. This guava/native forest interface appears to be the type of site which may suffer the most from the effects of a fruit fly control program on non-target organisms (Howarth 1991).

Methods

A preliminary investigation to assess alien fruit fly populations in Kipahulu Valley was made in May-June 1990 as part of the start of a project to establish biological baseline data for elevational stations. Stations were located at 1000 ft (305 m) elevational intervals—at 2000 ft (610 m), 3000 ft (915 m), 4000 ft (1220 m), and 5000 ft (1525 m) elevation. Sampling was done for vegetation as well as invertebrates through the use of traps and visual search for selected groups. Included were traps baited with chemical attractants specific for each of these three fruit fly species—trimedlure (for Mediterranean fruit fly), cuelure (for melon fly), and methyl eugenol (for oriental fruit fly). As no traps were available at the time for attracting Malaysian fruit fly, we were unable to assess the status of that species.

The traps used are commonly called "bucket traps," with 980 ml capacity and four entry holes, 2.5 cm in diameter. Traps were baited with a cotton dental wick, holding 8 ml of lure. Methyl eugenol and cuelure traps included the lure mixed with naled (Dibrom), an active insecticide, in a 3% concentration. Medfly traps were baited with pure trimedlure and contained a 3 cm strip of dog collar as insecticide ("Bansect" brand, 15% naled). "Tangle Foot" was used on the trap wires to exclude ants and other non-flying organisms.

One trap of each type was placed at each of the four elevational stations. Traps were left in the field for approximately four weeks, then brought to the laboratory for counting of alien fruit flies and sorting non-target organisms. Non-target taxa were

Table 1. Numbers of pest fruit flies trapped at four elevations in Kipahulu Valley, Haleakala National Park, using one trap with trimedlure, one with cuelure, and one with methyl eugenol at each elevation.

Trap Site Elev. (ft)	Set Date	Collect Date	Total Days	Mediterranean Total	Mediterranean F/T/D*	Melon Total	Melon F/T/D	Oriental Total	Oriental F/T/D
5000	5/14/90	6/13/90	30	0	0.00	0	0.00	0	0.00
4000	5/15/90	6/13/90	29	0	0.00	0	0.00	9	0.31
3000	5/16/90	6/14/90	29	0	0.00	0	0.00	255	8.79
2000	5/17/90	6/14/90	28	0	0.00	1	0.04	4791	171.11

* F/T/D = flies per trap per day

identified to the lowest taxonomic category possible by William Perreira of the Hawai'i Evolutionary Biology Program (HEBP) at the the University of Hawai'i.

Results and Discussion

Although this investigation is extremely limited due to its small sample size, we feel that this preliminary assessment supports the position that further study to determine the impacts of alien pest fruit fly control on native biota is a major prerequisite if the control program is to move ahead.

Our data indicate that the oriental fruit fly occurs at least as high as 4000 ft (1220 m) elevation in the valley, and is abundant in lower elevation areas with strawberry guava (Table 1). It is doubtful that such large numbers of pest flies could be eliminated by such benign methods as release of sterile males and/or release of parasitoids. Non-target organisms, including 24 species of native Drosophilidae, were caught in methyl eugenol traps as well (Table 2). The abundance of non-target flies in methyl eugenol traps at the 2000 ft (610 m) site (16 species and 2400 individuals of Drosophilidae!) suggests that some native flies may have been attracted to the smell of dead oriental fruit flies rather than by methyl eugenol, consistent with research done by Conant (1981). However, 11 taxa of non-target arthropods (including two native drosophilid flies) were caught in the methyl eugenol trap at 5000 ft (1525 m) elevation where no oriental fruit flies were caught. Future investigations should use screening to exclude oriental fruit flies from one set of traps to determine which non-

Table 2. Numbers of non-target arthropod individuals and species** trapped at four elevations in Kapahulu Valley, Haleakala National Park, using one trap with trimedlure, one with cuelure, and one with methyl eugenol at each elevation.

Trap Site Elev. (ft)	Trap Type	Diptera	Coleop.	Homop.	Hymenop.	Lepidop.	Psocop.	Spiders	Total
5000	Med	8 (4)	1	0	0	0	0	0	9
	Melon	6 (4)	0	0	0	1	0	0	7
	Oriental	8 (7)	0	0	0	0	2 (2)	1	11
4000	Med	194 (4)	0	0	0	0	0	0	194
	Melon	1 (0)	0	0	0	0	0	0	1
	Oriental	13 (5)	0	0	0	0	0	0	13
3000	Med	7 (5)	0	0	1	0	0	0	8
	Melon	2 (1)	0	0	0	0	0	0	2
	Oriental	151 (5)	1	0	0	0	0	0	152
2000	Med	4 (3)	0	1	0	0	2 (1)	5 (3)	12
	Melon	38 (7)	1	0	0	1	0	0	40
	Oriental	2400(16)	4 (3)	0	0	0	0	0	ca.2400

** Numbers in ( ) indicate approximate number of species.

target flies are attracted solely to methyl eugenol.

With the caveat that trimedlure is thought by many to be a notoriously poor attractant (Barinaga 1991), numbers of medfly seem to be extremely low in Kipahulu Valley, at least during May-June. Not one medfly was collected in our sampling with four traps for four weeks (Table 1). However, a large number of non-target organisms (223 individuals of roughly a dozen species, including 9 species of native Drosophilidae), were present in the trimedlure bait trap (Table 2).

A single melon fly was trapped (Table 1), suggesting low populations during the May-June trapping period. Non-target organisms (50 individuals of at least 9 species, including 5 species of native Drosophilidae), were also present in the cuelure bait trap (Table 2).

A listing of native Drosophilidae encountered in this preliminary investigation is given in Appendix 1. The attraction of the chemical lures for non-target native species such as these should be explored thoroughly.

The apparently low levels of medfly and melon fly populations in Kipahulu Valley during the single sampling period may represent only strong seasonality. To determine their annual range, it would appear necessary to sample for these two fly species more intensively and at other times of year.

It appears that the abundance of the oriental fruit fly in middle-elevation (2000-3000 ft, 600-910 m) areas of native forest may be due to the presence of strawberry guava and common guava in these forests. Strawberry guava occurs over large areas at high densities and, at the periphery of high-density areas, mixes extensively with native forests. Formulation of an eradication plan for oriental fruit fly without seriously damaging native ecosystems will thus present a great challenge.

In late 1991, the medfly was again detected in monitoring traps in the Los Angeles area (Ransom 1991). This latest medfly outbreak in California seems to lend credence to a view that competes with that of the California Department of Food and Agriculture, involving repeated quarantine failure (Siddiqui 1991). Carey (1991) presents indirect evidence that medfly has established a persistent population in the Los Angeles Basin. At this time, it is not clear how events in California will influence progress of the eradication program in Hawai'i.

Acknowledgements

This work would not have been possible without the efforts of John Herr of the USDA-ARS. He assisted in placing the traps in the field, in curating and tabulating material from the traps, and in providing valuable comments on the manuscript. It would also not have been possible without the identifications of native drosophilids by William Perreira of the Hawai'i Evolutionary Biology Program (HEBP) at the University of Hawai'i. William Minyard and Sabine Jessel assisted in lab work. Reviewers Pat Conant and Frank Howarth gave many constructive suggestions for improvement of the manuscript.

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Appendix 1

Identification of *Drosophila* and *Scaptomyza* (Diptera) specimens collected in fruit fly traps in Kipahulu Valley, Haleakala National Park, May-June 1990. Identifications by William Perriera (Hawai'i Evolutionary Biology Program, University of Hawai'i at Manoa).

1) *Drosophila balioptera* Hardy. Endemic to East and West Maui. Oriental fruit fly trap, 3000 ft.
2) *Drosophila comatifemora* Hardy. Endemic to East Maui. Melon fly trap, 2000 ft.
3) *Drosophila cracens* Hardy. Endemic to East Maui and Hawai'i. Oriental fruit fly trap, 4000 ft.
4) Drosophila crassifemur Grimshaw. Endemic to Maui, Moloka'i, Hawai'i, O'ahu, and Kaua'i. Oriental fruit fly trap, 2000 ft.
5) *Drosophila curvata* Hardy. Endemic to Maui? Melon fly trap, 2000 ft.
6) *Drosophila diamphidiopodus* Hardy. Endemic to Moloka'i, East and West Maui. Melon fly trap, 2000 ft.
7) *Drosophila disjuncta* Hardy. Endemic to East Maui. Oriental fruit fly trap, 2000 ft.
8) *Drosophila fasciculisetae* Hardy. Endemic to Moloka'i and East Maui. Oriental fruit fly trap, 3000 ft.
9) *Drosophila fundita* Hardy and Kaneshiro. Endemic to Maui. Oriental fruit fly trap, 2000 ft.
10) *Drosophila fusticula* Hardy. Endemic to East Maui. Oriental fruit fly trap, 2000 ft.
11) *Drosophila grimshawi* Oldenberg. Endemic to Moloka'i, Lana'i, Maui, and Hawai'i. Oriental fruit fly trap, 2000 ft.
12) *Drosophila joycei* Hardy. Endemic to East Maui, very rare. Oriental fruit fly trap,

2000 ft.

13) *Drosophila limitata* Hardy and Kaneshiro. Endemic to Maui, Lana'i, and Moloka'i. Oriental fruit fly trap, 2000 ft.
14) *Drosophila orphnopeza* Hardy and Kaneshiro. Endemic to Maui. Oriental fruit fly trap, 2000 ft.
15) *Drosophila* aff. *vicaria* Hardy. Endemic to Maui. Melon fly trap, 2000 ft.
16) *Drosophila* picture wing sp. #1. Oriental fruit fly trap, 2000 ft.
17) *Drosophila* picture wing span #2. Oriental fruit fly trap, 2000 ft.
18) *Drosophila* endemic sp. A. Oriental fruit fly trap, 2000 ft.
19) *Drosophila* endemic sp. B. Oriental fruit fly trap, 2,000 ft.
20) *Drosophila* endemic sp. C. Oriental fruit fly trap, 2000 ft.
21) *Drosophila* endemic sp. D. Oriental fruit fly trap, 2,000 ft.
22) *Drosophila* endemic sp. E. Oriental fruit fly trap, 4000 ft.
23) *Drosophila* endemic sp. F ("spoonfoot group"). Oriental fruit fly trap, 4000 ft.
24) *Drosophila* endemic sp. G. Medfly trap, 2000 ft.
25) *Drosophila* endemic sp. H. Medfly trap, 3000 ft.
26) *Drosophila* endemic sp. I. Medfly trap, 5000 ft.
27) *Drosophila* endemic sp. J. Medfly trap, 5000 ft.
28) *Drosophila* endemic sp. K (*Antopoceras* group). Medfly trap, 2000 ft.
29) *Drosophila* endemic sp. L ("spoonfoot group"). Medfly trap, 4000 ft.
30) *Drosophila* endemic sp. M ("modified tarsi group"). Medfly trap, 4000 ft.
31) *Scaptomyza (Trogloscaptomyza) adunca* Hardy. Endemic to Hawai'i and Maui. Melon fly trap, 5000 ft.
32) *Scaptomyza (Trogloscaptomyza)* sp. A. Oriental fruit fly trap, 4000 ft.
33) *Scaptomyza crassifemur*. Oriental fruit fly trap, 3000 ft and 5000 ft.
34) *Scaptomyza (Tantalia) gilvivirilia* Hardy. Endemic to East Maui. Oriental fruit fly trap, 2000 ft.
35) *Scaptomyza* sp. A. Oriental fruit fly trap, 2000 ft.
36) *Scaptomyza* sp. B. Oriental fruit fly trap, 5000 ft.
37) *Scaptomyza* sp. C. Medfly trap, 4000 ft.

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HAS Suggests Changes in Monitoring Leases on State Lands

In September, the Hawaii Audubon Society, along with the Hawai'i Chapter of the Sierra Club and Environment Hawai'i, *presented the following paper at the 1992 Forest Legislation Symposium.*

A comprehensive assessment of the Hawai'i Department of Land and Natural Resources' (DLNR) administration of state leases and month-to-month revocable permits for state-owned lands is proposed. The assessment, to be conducted by the Legislative Auditor, should review the resource, administrative, and statutory limitations the Department faces in achieving its legal mandate and objectives.

The public, as represented by the State of Hawai'i, is the largest landowner in the state, with approximately 1.4 million acres. The DLNR is authorized to manage, administer, and exercise control over public lands as defined by state law (HRS § 171.2). Within DLNR, the Division of Land Management (DLM) is responsible for the planning, administration, development, and disposition of state lands in such a way as to contribute to the social, environmental, and economic well-being of the people of Hawai'i nei. Lands that have not been set aside for public purposes, in accordance with state law (HRS § 171-11) and federal law relative to ceded land, are made available to the public by sale in fee simple, lease, lease with option to purchase, license, or permit. Most dispositions of state lands are made at public auction.

In fiscal year 1990-91, DLM administered 914 state leases. These covered 192,369 acres and generated an income of approximately $4.9 million. Month-to-month revocable permits for the use of state lands were also administered by DLM. DLM's 38 employees work to acquire, administer, and develop public lands; conduct sales of state lands; issue leases and permits for the use of state lands; enforce state lease and permit conditions; identify natural and cultural resources on state lands; and provide administrative support for the above.

Income generated from state leases and permits goes directly to the State General Fund. In turn, DLNR and DLM submit biennial budget requests to the Legislature for operational expenses relating to the administration of state leases, permits, and other programs. A revolving fund to develop public lands and water resources is available to DLM; however, it cannot be used to hire staff, pursuant to current state law.

A comprehensive assessment of the State's administration of state leases and month-to-month revocable permits—conducted by the Legislative Auditor—could identify those factors that prevent DLNR and DLM from fulfilling legal mandates and effectively administering state lands. Such an assessment should include the following:

DLNR's existing responsibilities relating to the administration of state leases/permits and existing staffing and resource allocations to DLM,

Staffing and resource improvements that may be needed for DLM to more effectively administer leases/permits in the public's best interest,

Staffing and resource improvements that may be needed for DLM to protect and enhance important natural and cultural resources on state lands,

Statutory and procedural constraints to DLM's administration of leases/permits and to the protection of important resources on state land,

Current lease/permit fee structure to evaluate the potential for increasing revenues generated by leases/permits on those lands deemed appropriate for leasing/permitting,

Establishment of a formal procedure by DLNR and DLM to identify state lands appropriate for leasing/permitting and to identify state lands containing important natural and cultural resources, which may *not* be appropriate for leasing/permitting,

Establishment of a formal and proactive program by DLNR and DLM to identify, protect, and enhance important resources on leased lands, complementing DLNR's resource management activities on non-leased lands,

Compliance with the Hawai'i Environmental Policy Act, HRS Chapter 343, as it relates to state leases and permits.

Reforestation of Native Species

In September, the Hawaii Audubon Society, along with the Life of the Land and Conservation Council, presented a paper on reforestation at the 1992 Forest Legislation Symposium. Following are excerpts from that paper.

Priority for tree propagation should be given to native tree species which have wildlife habitat value and/or economic value. Biodiversity should be protected through maintaining integrity of species and subspecies in their geographical area. These goals can be met without significant increase in funding by phasing out propagation of most non-native trees while phasing in propagation of native species, using existing Division of Forestry and Wildlife (DOFAW) nurseries on the various islands.

In the past, reforestation efforts have centered on an array of alien tree species. Major reasons for this include their watershed protection value, their anticipated economic value, their well-established propagation techniques, their relatively rapid growth rates, and their suitability to Hawai'i's conditions. At this time, however, we must reassess some of these reasons for preferring alien trees to native trees.

The anticipated economic value of these alien species has proven to be far less than expected. For example, efforts to market eucalyptus species have been unsuccessful. The per board foot value of lumber species such as pines is far less than native hardwoods such as koa.

Another major concern is that their habitat value for native animal and understory plant species is very low. Trees such as eucalyptus and pines suppress other plant growth (i.e., they are allelopathic) and therefore are not compatible with native plants which do have habitat value. These trees establish monocultures which severely limit biodiversity. In this sense, the selection of alien trees for reforestation has largely ignored habitat value.

On the positive side, propagation techniques for native tree species have improved dramatically. Many new methods are now established for native plant rearing, and the processes are not nearly so difficult as they once were thought to be. New techniques for species still considered difficult are on the near horizon, as basic research advances are made by various researchers working in this field. The expertise of private and government researchers can be utilized through cooperative agreements.

The economic value of native species for high quality hardwood is proving to be much greater than for introduced species. Also, many native understory plants have an economic value. The markets are demanding these woods and other products. It would be detrimental in the long run to ignore reforestation with trees such as ohi'a, milo, and Hawaiian ebony, to name a few, and with plants such as hapu'u tree fern and plants used in lei making. Efforts to reforest with koa should be increased.

The habitat improvement values of reforestation should become a higher priority than in the past. Use of trees which are allelopathic and incompatible with native biodiversity should be curtailed in areas with potential for reforestation of native biota. In the future, the mandate under Hawai'i state law for habitat reforestation should equal that for economic considerations. Therefore, certain native trees and plants which have high habitat and watershed value but little current economic value for lumber should be reared and used in reforestation.

Native trees and other plants are appropriate for Hawai'i's many microclimates. This is obvious, since they evolved here in the various conditions we find around our islands. Therefore, state nurseries can raise native trees/plants for the range of microclimates—coastal strand, dryland, mesic, wet forest, subalpine, and alpine.

To protect biodiversity, trees/plants should be planted only in the geographical area where they occur naturally. Many species or subspecies occur only on one island or in part of one island. By planting outside of their true natural area, genetic mixing occurs, decreasing biodiversity. Loss of species or subspecies can easily result from this form of mismanagement. Therefore, each island's DOFAW nursery should concentrate on raising native trees and plants appropriate to that island. Alternately, a central nursery (as on the Big Island) could accomplish the same objective through careful recordkeeping.

Nominating Committee Report

The Nominating Committee has presented a slate of officers and directors for the December election. The following members have been nominated:

Reginald David, President; Linda Paul, Second Vice President; Glenn Chang, Recording Secretary; and David Hill, E. "Jay" Lembeck, Lance Tanino, and Marjorie Ziegler, directors. All terms are for two years.

The terms of First Vice President Casey Jarman, Treasurer Lynne Matusow, Corresponding Secretary Carl Christensen, and directors Betsy Harrison Gagne, Kevin Shaney, and Joyce Stanney expire in December 1993.

Should any member wish to run or nominate additional candidates, the nomination must be sent to the Elections Committee, Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813. Write-in nominations must be received by 10 November. The written nomination must be accompanied by a four line biographical description of the nominee and the nominee's written consent that he or she is willing to run for election and will serve in the designated post if elected.

Scholarships Awarded

by Phil Bruner

Three undergraduate students from the University of Hawai'i and its associated community colleges have each been awarded the Rose Schuster Taylor Scholarship, made available by the Yao Shen Trust. They are Trixy Koide, a sophomore, and Sylvia Leupp, a senior, both attending the University of Hawai'i at Manoa, and Lance Tanino, a sophomore, who attends Windward Community College. Each stipend is for $1,340.

The students are following an educational program that will contribute to a better understanding of the unique natural resources of Hawai'i. We trust they will make significant contributions to the protection of our native wildlife as they progress through their studies.

April Field Trip: Tantalus Crater and the Early Evolution of Birds

by David Hill

If you don't know where Tantalus Crater is, Pu'u 'Ohi'a Trail traverses the west rim of the crater. Pu'u 'Ohi'a is the Hawaiian name for the hill called Tantalus. This side of the crater is covered in a steep bamboo forest. At least two trails descend off the Pu'u 'Ohi'a Trail, generally going north and east down into the crater. The crater used to be a native bog environment, but has dried with the introduction of grasses which predominate today. This open "meadow" is surrounded by large Cook pines, introduced into this 100,000 year-old crater by foresters in the early 20th century. Our party of seven discussed the confusion of Cook and Norfolk pines: the mislabeling of the first specimens years ago, hybridizaton of the two—a plant taxonomist's nightmare. Cook and Norfolk pines are very primitive as their nearly identical ancestors stood in the beginning of the dinosaur era 260 million years ago (mya). This is where the evolution of birds comes in.

Do you ever see that resemblance of birds to their ancient lizard kin? I thought about this and gave Dr. Alan Ziegler a call because he has entertained my inquiries into paleontology with good humor before. Alan consulted a book entitled *The Age of Birds* by Alan Feduccia to see what was current theory on the early evolution of birds. Three chapters address the issues. Here follows a condensed version of the story.

Archaeopteryx is probably the ancestor of all modern birds. This creature, known from Bavarian silt deposits of 140 mya, probably flew rather than glided. The telling points of flight in Archaeopteryx are big primary wing feathers with asymmetrical edges, clavicles fused into a furcula or wishbone, and a keeled sternum for attachment of large flight muscles. As to where Archaeopteryx came from, two main theories compete.

One theory holds that Archaeopteryx came from the primitive reptile line called thecodonts (socketed tooth). Thecodonts probably also gave rise to the crocodilians, dinosaurs, and pterydactyls (Pterydactyls, by the way, are considered to be a dead-end line despite their resemblance to birds). With thecodonts found in the fossil record 200-230 mya, this gives 60-90 million years for Archaeopteryx to appear. The evolution of the feather figures in this, too. If this theory holds, then feathers evolved on the cold-blooded thecodonts. One proposed explanation is that the feathers evolved to keep the reptile cool in hot, sunny conditions. A problem with this theory is that warm-bloodedness would have evolved later, parallel to other creatures evolving this thermoregulation mechanism.

The other main theory holds that Archaeopteryx evolved from the line of dinosaurs that were carnivorous. This line, of course, includes that movie star, Tyranosaurus rex, but also much smaller meat-eating dinosaurs who ran on two hind legs and had reduced forelimbs. This latter characteristic is cited as evidence against this theory, as Archaeopteryx had elongated forelimbs. These little dinosaurs appear in fossils 140 mya also, just when Archaeopteryx debuts. Some paleontologists cite this as a problem with this theory, but perhaps they had a common ancestor a few million years earlier, or perhaps fossils lie somewhere undiscovered with older small dinosaurs. This theory allows warm-bloodedness to have evolved only once, with the dinosaurs before Archaeopteryx (evidence of dinosaurs being warm-blooded was found in the 1970s and was based on calculations of stride length and mass as determined from fossil footprints). In this theory, feathers evolved to help keep heat in.

Both theories go back more than 100 years in some form and have provided many a paleontologist with thesis material. Personally, I like the dinosaur theory with warm-bloodedness evolving only once. I also like to ponder such things sitting under a Cook/Norfolk pine, knowing that this line of primitive trees presided over the whole mess. Don't get me wrong. I'd rather be sitting under a native 'iliahi tree watching 'I'iwi in Pu'u 'Ohi'a crater, but I've never been good at traveling backward through time. Of course, if you believe in creationism, then you can make this article into a paper airplane or confetti—your choice.

The family hike into Tantalus Crater via Manoa Cliffs Trail was very enjoyable because the day was cool yet mostly sunny, with balmy breezes. Though we kept our eyes peeled for native birds, we glimpsed but one 'Amakihi, and heard a few others. We saw and heard lots of Shama Thrushes, which were noisily in nesting mode. Also, bulbuls and Japanese White-eyes were everywhere. The Bush-Warbler was true to its name, hiding in thick brush, producing the two tones repeated indefinitely, reminding me of a London police siren.

The demise of native birds is of paramount importance to all good Auduboners. Let's work today so that our native birds don't go the way of the pterydactyls.

Your Bequest Can Help

A bequest to the Hawaii Audubon Society is an excellent way to help in our conservation efforts.

Although an attorney should be consulted in the drafting of your will, a model clause for bequests is set forth below.

"I hereby give, devise, and bequeath to the Hawaii Audubon Society, Honolulu, Hawai'i, the sum of _____ dollars (or set forth a description of property), to be used for the general purpose of said organization."

For more information and assistance, contact the Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813, (808) 528-1432.

Research Grants

The Hawaii Audubon Society makes grants for research in Hawaiian or Pacific natural history. Awards generally do not exceed $500 and are oriented toward small-scale projects within Hawai'i. Special consideration will be given to those applicants studying the Northwest Hawaiian Islands, dryland forests, and aeolian systems on Hawai'i. The deadlines for receipt of grant applications are 1 April and 1 October. For an application form send a self-addressed stamped envelope to Grants, Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813. For more information, call Phil Bruner, (808) 293-3820 (W).

Help Wanted--Please Sign Up

Hawaii Audubon Society desperately needs help in the following areas:

Phone Tree Coordinator. You will be responsible for maintaining the list of persons participating in the telephone tree and giving information to phone tree participants when calls need to be made. We need a self starter who is a good communicator and who can devote four to eight hours a month for a minimum of a year. This work can be done from home. Some knowledge of environmental issues and legislators is a plus. To volunteer call David Hill, 943-2784 (H).

Phone Tree Callers. We are growing a phone tree—a chain of people who can make calls to decision-makers on environmental issues. This allows the environmental community to respond very quickly with public pressure on important issues. To join our phone tree, call David Hill at 943-2784.

Testimony Presenters. Here we need self-starters who can tactfully and effectively present testimony at the legislature, county councils, and hearings of governmental boards and agencies, usually on weekdays during daytime hours. If you can't write the testimony, we will have someone else do it. A knowledge of Hawai'i, including issues, politicians, and who the players are is a big plus. A minimum of four hours a month is required. To volunteer call David Hill, 943-2784 (H).

Recordkeeper. This position, which requires you to spend one morning or afternoon a week at the office, entails integrating our membership records with our fundraising records and locating telephone numbers for all new members. The work is done manually. To volunteer call Lynne Matusow, 531-4260 (H).

Volunteer Coordinator. This hardworking, gregarious individual will match volunteers with available jobs, see that volunteers are trained, and maintain contact with volunteers to see if they are happy or have suggestions for improving things, and plan volunteer recognition events. This job will take two hours or more weekly. To volunteer call Lynne Matusow, 531-4260 (H).

Office Staff. We would like to have our office open five days a week. People are needed for morning or afternoon shifts Monday, Tuesday, Thursday, and Friday. Among the duties are answering the telephone, distributing the mail, referring problems to the appropriate officer or committee chair, filing, and responding to routine correspondence. To volunteer call Lynne Matusow, 531-4260 (H).

Writers and Editors for *'Elepaio*. A reporter is needed to write the monthly Volunteer Corner column. Also, if you can write stories, edit copy, and come up with story ideas call Lynne Matusow, 531-4260 (H).

The above is only a partial list. If you have a particular skill or interest, call Lynne Matusow, 531-4260 (H). Who knows, maybe we have the right opening but haven't publicized it yet.

Birding on O'ahu

A two-page guide listing areas on O'ahu where interesting birds may be found and where access is not a problem is now available. Written by Peter Donaldson, it offers important information for birders unfamiliar with Hawai'i. The guide is not designed to give detailed directions or information on bird identification. For a free copy, send a self-addressed stamped envelope to O'ahu Birding Guide, Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813.

Environmental Directory Available

In celebration of Earth Day 1990, the Hawaii Audubon Society published the Hawai'i Green Pages. The directory lists over 150 environmental efforts in Hawai'i. For a free copy, send a self-addressed stamped #10 envelope to Directory, Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813.

Moving?

Please allow four weeks for processing address changes. Because our records are kept in order by zip code, we need both old and new addresses.

Notice to Authors

'Elepaio invites submission of original scientific articles of between 1,500 and 3,000 words on the natural history of Hawai'i and the Pacific. Such articles are subject to peer review.

Scientific articles should be typewritten and double-spaced. Four copies must be submitted. In addition, authors are asked to submit the article on a computer diskette, with a clear indication of the word processing program used. Because we have a Macintosh computer, we prefer you use Macintosh compatible software, although we can convert DOS.

We do all layouts directly on the computer. For that reason, authors are asked to adhere to the following guidelines: only one space after periods; no indentations, except for paragraphs and tables; no underlines (if on a diskette underlines should be shown as italics); no bold face type; use upper and lower case, nothing is to be in all capital letters; Hawaiian glottals should be used; capitalization for all bird species should follow American Ornithologists' Union nomenclature; dates should be shown as date, month, year; and the address of all authors should be included.

Photographs/illustrations may be either color or black-and-white prints, 3.5 by 5 inches or larger. They should be clearly labelled as to subject and photographer/artist. Cropping lines (if needed) should be indicated. The originals of figures, maps, graphs, etc. should be clean and clear, with lettering large enough to remain legible after reduction to fit journal format. Submit two good-quality xerographic copies along with each original illustration.

Manuscripts should be sent to *'Elepaio*, Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813.

Wildlife Information

Do you need information regarding recent rare or unusual wildlife observations within the main Hawaiian Islands? Call Bruce Eilerts at 487-1806. He will advise you on rare bird sightings and offer tips on where to best observe native flora and fauna. Please leave your questions and messages on his answering machine.

Hawaii Audubon Society

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The *'Elepaio* is printed on recycled paper.

T-shirts for Sale

The Hawaii Audubon Society has a stock of T-shirts designed to spread the Audubon message. Not only are they attractive personal apparel, but they make excellent presents as well.

T-shirts bearing the Society's 'Elepaio logo are available in ash (gray) with a black design. We also have a few in aqua, navy, white, and beige. In addition, the "hot" Kolea (Pacific Golden Plover) T-shirts are also available. This T-shirt is white with a three-color design of the Kolea and native hibiscus. Proceeds from the Kolea T-shirt go to help HAS fund research on shorebirds in Hawai'i and elsewhere in the Pacific region.

T-shirts are $12 each, plus $2.00 per shirt for postage. They are available in medium, large, and extra large adult sizes only. When ordering T-shirts, be sure to list size and first, second, and third choice of color. To order T-shirts send your check, payable to the Hawaii Audubon Society, to Yvonne Izu, 2069 California Avenue, #20B, Wahiawa, HI 96786. Don't forget to add $2.00 per shirt for postage. Insufficient postage will delay your order until the proper amount is remitted. T-shirts are not available at the HAS office.

HAS Dues for 1992

All amounts are in U.S. dollars.
Includes delivery of *'Elepaio*.

Life Membership	**$300.00**
Payable in full or three equal installments. (The Board of Directors recently increased the amount of life dues. Those life members who are currently on the installment plan will be billed for their remaining payments at the old rate.)	
Delivery to U.S. zip code addresses	
Via bulk mail	**6.00**
(Not forwardable to new address)	
Via first class mail	**12.00**
(Hawai'i residents: there is no significant time difference between bulk and first class mail to addresses within the state of Hawai'i.)	
Junior Membership (18 and under)	**3.00**
Delivery to non-U.S. addresses:	
Mexico (airmail only)	**12.00**
Canada (airmail only)	**13.00**
All other countries (surface mail)	**14.00**
All other countries (airmail)	**24.00**
Introductory dues for National and Hawaii Societies:	**20.00**
(Includes delivery of *'Elepaio* and *Audubon Magazine* as bulk or 2nd class mail to U.S. zip codes. Renewal, $30 annually.)	

Board Welcomes Joyce Stanney

In September the board of directors appointed Joyce Stanney to fill a vacancy on the board. Her term expires in December 1993. Joyce, a tax consultant with Deloitte and Touche, has practiced public accounting for six years. She brings to Hawaii Audubon financial expertise which will help us both in long-term planning and the day to day operations of the Society.

Also in September the board accepted the resignation of Luciana Honigman.

Publications Available

The Hawaii Audubon Society publishes books, checklists, and field cards relating to birds of Hawai'i and the Pacific. For a complete price list send a self-addressed stamped envelope to Publications List, Hawaii Audubon Society, 212 Merchant Street, Suite 320, Honolulu, HI 96813.

Mahalo Donors!

The Hawaii Audubon Society thanks the following members and friends for their continued support:

Dr. Jeff Black, Elizabeth Castro, Gara Adams Hudson, Rita Jennings, Audrey Newman, Jim Snyder, and Louise Thomas.

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walking, mostly from the parking lot to the sinkholes. Meet at the State Library at Punchbowl and King Streets at 8:00 a.m. for carpooling or the entrance gate to CIP at 9:00 a.m. We will drive into CIP as a group. We should be pau by noon. Suggested donation: $2.00. For more information call Casey Jarman, 956-7489 (W).

December, TBA
Christmas Bird Counts. For information or to sign up call Lance Tanino, 247-5965 (H), 247-7878 (W).

Calendar of Events

First Monday of Every Month
Monthly meeting of the Conservation Committee, 6:00 p.m., HAS office. To join or for more information call David Hill, 943-2784 (H).

October 10, Saturday
Beach Clean-up, Waimanalo Beach Park. Millions of seabirds are killed each year from either ingesting or becoming entangled in beach debris, including nets, plastic, and styrofoam. As our service project for this year, it is fitting that we take part in the nationwide beach debris clean-up program, concentrating our efforts on Waimanalo Beach Park. Meet at 7:45 a.m. at the State Library on Punchbowl and King Streets for car pooling or at 8:30 a.m. at the sign up table at the baseball backstop at Waimanalo Beach Park. Bring gloves, shorts/t-shirt or swimming attire, sunscreen, hat, and water. For those interested, bring lunch to celebrate our morning's work. The state litter office gives each volunteer free passes to Sea Life Park and Waimea Falls Park. Please join us as we clean up the beach and help protect the birds, even if you have only an hour to spare. We will finish at noon. For more information call Casey Jarman, 956-7489 (W).

October 12, Monday
Board meeting, 7:00 p.m., HAS office. Call Reggie David on Hawai'i, 329-9141 (W), for details.

October 19, Monday
General meeting, 7:30 p.m., Paki Conference Room, Bishop Museum. Ken Redman, assistant director of the Honolulu Zoo, will give a slide presentation on the wildlife of East Africa. Refreshments will be served.

November 8, Sunday
Join Alan Ziegler as he takes us excavating for extinct bird fossils and bones at the sinkholes at Campbell Industrial Park (CIP). Long pants, shoes, and gloves are recommended attire. Be sure to bring water. The trip requires about 10 minutes of

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