NEW ZEALAND-HAWAII CONSERVATION EXCHANGE PROGRAMME 1997

TRAVEL REPORT

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Introduction

The New Zealand-Hawaii Conservation Exchange was established to enhance communication of approaches, techniques, and philosophies relevant to the common natural resource management issues of the two countries. Like New Zealand, Hawaii has no native land-based mammals (except for one species of bat). Introductions of deer, goats, pigs, cats, rats, and mongooses have either modified bird habitat or preyed upon birds or their eggs. Hawaii also has two introduced avian diseases (avian pox and avian malaria) that cause high mortality of birds. Of the approximately 70 known Hawaiian forest bird species, about half are now considered extinct, including all the flightless species, and 20 of the known surviving species are classified as endangered. Hawaiian birds comprise more than half of the birds listed in the "Red Book of Rare and Endangered Species".

I spent about 4 weeks in July-August 1997 attending the Hawaii Conservation Conference and visiting conservation research organisations in Hawaii as part of the Exchange programme (Appendix 1).

Hawaii Conservation Conference

The Hawaii Conservation Conference this year was held on the island of Maui and was attended by about 375 people. It was a good venue to meet a large number of people from many different places in a short space of time. It was also a good opportunity to gain an overview of conservation research and management in Hawaii.

The first day of the conference was a series of showcases of conservation efforts on Maui. The most interesting paper for me was by Paul Krushelnycky, from the USGS Biological Resources Division, Maui, on monitoring and control of the Argentine ant (*Linepitherma humile*) in Haleakala National Park. This ant is a threat to native invertebrates. In July 1995, an attempt was made to eradicate ants in the Park using helicopter application of Maxforce granules containing hydramethylnon. Hyramethylnon is one of the alternatives to 1080 that I tested for wasp control in New Zealand (and published the results in the Proceedings of the New Zealand Weed and Pest Control Conference 1991). The eradication attempt failed. Treatment resulted in an initial 97% reduction but ant numbers increased again after 3 weeks. The research objective now is to prevent further spread of the ant. In August 1996 test plots at the expanding edge of the ant invasion were treated aerially with Maxforce granules. This appears to have halted further spread of the ants. A management plan proposes annual treatment to contain the ant population.

The second day of the conference comprised a series of papers on biodiversity conservation, four concurrent panels on protection and restoration activities, and a series of papers on bird biology (recovery, predation, and disease). The most interesting paper for me was presented by Catherine Swift, a student at the University of Hawaii. She was co-author of a paper on research on the broadcast application of diphacinone for rodent control. Diphacinone is currently registered with the Environment Protection Agency (EPA) for field use only in bait

stations. The bait is manufactured by J.T. Eaton & Co. Inc., and contains 0.005% diphacinone in a bait block flavoured with molasses and peanut butter. Some researchers have found that although this bait is highly palatable to *Rattus rattus* it is not so palatable to *R. exulans*. Thus, there is a demand for a different flavoured bait. There is also a demand for a bait that can be broadcast either from the ground or the air because use of bait stations is not practical in many areas. Catherine has been testing a fish-flavoured pellet bait (Ramik® Green) containing 0.005% diphacinone. From laboratory trials, she has found that *R. rattus* needs to eat about 35 g of bait per day for 7 consecutive days and *R. exulans* needs to eat about 30 g per day for 7 consecutive days to receive a lethal dose. From her literature search she has concluded that broadcast use of these baits would present no risk to humans or aquatic species, and only a very low risk to birds (known LD_{50}s are more than 1500 mg/kg). She is planning field trials with non-toxic Ramik® Green bait containing a bait marker to determine broadcast application rates.

In the evening, we visited the Hawaii Nature Centre in the 'Iao Valley. This is a private, non-profit, organisation that teaches children about the out-of-doors. It has an interactive science arcade with more than 30 hands-on exhibits, experiences, and live animal displays that interpret Hawaii's unique natural history. The centre also offers weekend hikes, nature excursions, week-long summer adventures, and many other community programmes.

Haleakala National Park, Maui

I went on the post-conference field trip to Haleakala National Park on the slopes of Haleakala Volcano in eastern Maui. Ron Nagata from the National Park Service explained problems with goats, cattle, pigs, and recently axis deer in the Park. Since 1987, much of the Park has been fenced to keep out these pests. We walked around a nature trail and were shown some native (and alien) plants and birds. We were then shown a cluster of silversword (*Argyroxiphium sandwicense*), a striking globe-shaped rosette plant with succulent silver-haired leaves. This plant was near extinction in the 1920s, having been decimated by human collectors and browsed by feral goats and cattle. Although the silversword still has threatened status, protection and fencing have allowed its numbers to recover. The greatest current threat to its survival is the potential loss of endemic pollinators following the invasion of the Argentine ant into the Park. Paul Krushelnycky, from the USGS Biological Resources Division, who gave a paper at the conference, showed us the area where the Argentine ant occurs the Park and talked about plans for future control to prevent its spread. Lloyd Loope, from the USGS Biological Resources Division, talked about the western yellowjacket (*Vespula pensylvanica*), a wasp related to the two species we have in New Zealand. There were large numbers of these yellowjackets present in the Park in 1983-1986, but numbers have subsequently declined. The National Park Service operates a yellowjacket monitoring programme using Wasp Inn traps baited with tuna cat-food and heptyl butyrate. When the trap catch reaches a certain level they instigate a poison-baiting programme using micro-encapsulated diazinon (Knox-Out) mixed into a minced chicken bait. I tested Knox-Out for wasp control in New Zealand two summers ago. Cathleen Hodges, from the National Park Service, talked about rodent, cat, and mongoose control in the Park, to protect ua'u (dark-rumped or Hawaiian petrel) and other birds. She showed us the bait stations (Protecta®), which are baited with Eaton's Bait Block® rodenticide containing 0.005% diphacinone and molasses and peanut butter flavorizer for rodent control. Live-traps are set for cats and mongooses. Because of lack of resources, traps are checked only every 5 days. Any cats caught are taken to the Humane Society for potential adoption, although to date all have subsequently been euthanased. Since pest control started in 1979, the breeding success of ua'u has increased.

Benefits of predator control

After the Hawaii Conservation Conference, I visited conservation research organisations on the islands of Hawaii ("Big Island") and Oahu. I saw three studies using different methods to measure the benefits of predator control for native birds.

(a) Hakalau Forest National Wildlife Refuge, Hawaii

Steve Fancy, from the USGS Biological Resources Division, Kilauea Field Station, took me to his study site in Hakalau Forest National Wildlife Refuge, at an altitude of 5400 feet on the slopes of Mauna Kea volcano, Hawaii ("Big Island"). The refuge was established in 1985 to protect rare native birds and is managed by the US Fish & Wildlife Service. Three endangered bird species in the refuge are the 'akepa, the Hawaii creeper, and the 'akiapola'au, all insectivores. The main canopy is ohia (*Metrosideros polymorpha*) with some koa (*Acacia koa*), most of which has been logged out. The refuge has been fenced to exclude pigs and about 200,000 koa have been planted to restore the forest. Steve's research is attempting to answer managers' questions about what can be done to improve the refuge for birds. He is conducting a large experimental manipulation of predator populations to (a) determine the cost and effort needed to control predators in a Hawaiian rainforest, and (b) determine whether predator control results in increased numbers and productivity of native forest birds. He has two 48 ha study sites, one a managed site and the other a non-managed site, separated by a 200-m buffer zone. In 1994 and 1995, Steve obtained data on rodent numbers, bird density, and bird productivity before any treatment. Rodent densities were measured from 192 Census™ wax blocks left out for 3 nights, 300 tracking tunnels, and 100 live-traps, bird densities from 25 variable circular plot (VCP) counts every 3 months, and bird productivity from the proportion of juveniles to total number of birds caught in 24-48 mist nets operated for 9 days every fortnight. The density of rats in the two sites is about 60 rats/ha, 10 times the density recorded in New Zealand and one of the highest densities of rats in the world for a forest habitat. Predator control began in the managed site in 1996, and was repeated in 1997. Cats and mongooses were live-trapped. A total of 15 cats has been caught to date, and 16 mongooses were caught in the first year but few since. Rats (*R. rattus* and *R. exulans*) and mice were caught in 192 snap-traps or poisoned with Eaton's molasses and peanut butter flavoured bait blocks containing 0.005% diphacinone placed in 204 bait stations on a 50-m grid between January and April when birds were breeding. Populations of *R. rattus* were reduced to low numbers (almost 100% reduction) within 2 weeks of poisoning, but many *R. exulans* were not attracted to the bait and their numbers were reduced primarily by snap-trapping. Rodent numbers returned to pre-poison levels by the following January. Predator control has resulted in an increase in the productivity (ratio of the number of juveniles to the total number of birds captured in mist nets) for three species of native forest birds (the 'elepaio, apapane, and i'iwi) for which there are adequate sample sizes. Continued monitoring in 1998 will provide a larger sample size so that the effect on other less common bird species can be examined. The bird count data (of bird densities) have not yet been analysed. This project has an annual budget of ca. US$300,000 (NZ$500,000) and employs 12 people in the field (eight of them volunteers). The experimental manipulation is unreplicated (there is only one treatment and one non-treatment site) so the results will apply only to this refuge.

(b) Keauhou Ranch, Hawaii

Tonnie Casey, a wildlife biologist employed by the Kamehameha Schools Bishop Estate, showed me her study area on the Keauhou Ranch, at about 6000 feet on the slopes of Mauna Loa volcano, Hawaii. The area has been lightly logged for *Acacia koa*. The main canopy tree now is *Metrosideros polymorpha*. There are three endangered bird species in the area; the 'akepa, Hawaii creeper, and 'akiapola'au. Tonnie's objectives are to (a) increase the abundance of

native birds in the area, and (b) to ensure that the 'io (Hawaiian hawk) and pueo (short-eared owl) were not at risk from secondary poisoning. Tonnie has a similar study design to Steve Fancy's. She has two 27 ha study areas (treatment and non-treatment areas) separated by 1 km. Rat density is estimated from 60 tracking tunnels and Haruma live traps, both baited with coconut, on a 50 x 150 m grid, and set for 3 consecutive nights. The rat density is about 2.3 rats/ha (much lower than in Steve Fancy's study). Control of rats and mongooses started in 1994 and has continued for 4 years. There are no pre-treatment data. Protecta® bait stations were placed in the treatment area on a 50 x 150 m grid and baited with Eaton's Bait Blocks containing 0.005% diphacinone. Both rodents and mongooses eat these baits. In 1994, activity indices in tracking tunnels in the treatment area were reduced by 84% for rats and by 66% for mice. Rodent densities have remained low in the treatment area in subsequent years (unlike in Steve Fancy's management area where rodent densities returned to pre-poison levels within 6 months). Radio-transmitters attached to rats indicated that the majority died underground, and the remainder in dense cover, indicating little risk to 'io or pueo from scavenging carcasses. However, the risk of these birds capturing poisoned live rats has not been investigated. Birds are monitored from variable circular plot counts at 20 stations on a 150 m x 150 m grid in each area. Two people do the counts, one in each area, for 2 days (minimum). Observers do not change between areas but their abilities are calibrated beforehand. Graphs of results for the first 3 years (1994-1996) do not show any trends in counts of birds that can be attributed to the rodent poisoning. In 1994 and 1996, Steve Fancy's team mist-netted birds in Tonnie's study areas. Again, the results do not show any trends in the ratio of juveniles to total birds caught for any species that can be attributed to the rodent poisoning. Perhaps the initial low density of rats in the treatment area means that little benefit could be expected from rat control. Alternatively, juveniles produced in the treatment area may move into adjacent non-treatment areas.

(c) Pia Valley, Oahu

Eric Vanderwerf, a PhD student at the University of Hawaii at Manoa, Oahu, talked to me about his study on the impact of predator control on 'elepaio (an insectivorous bird that looks a little like our fantail). This species is strongly territorial and has delayed juvenile plumage. Eric has two study areas, one in the Pia Valley and another in the Kuli'ou'ou Valley, on the island of Oahu. He measured reproductive success by recording the number of juveniles (fledglings) produced per territorial pair. In 1996, 'elepaio produced 0.30 fledglings per pair in the Pia Valley and 0.25 fledglings per pair in the Kuli'ou'ou Valley. In 1997, predator control was carried out in the Pia Valley from January to June, using snap traps and diphacinone poison in bait stations to control rats and live traps to catch cats and mongooses. The trap catch of rats was reduced from 40% to 0% in about 5 weeks. Six cats and 15 mongooses were caught in the 6 months. Reproductive success of 'elepaio in the treatment area (n=14) increased from 0.30 to 0.80 fledglings per pair, and in the non-treatment area (n=10) from 0.25 to 0.44 fledglings per pair. That is an 82% increase as a result of treatment. He is planning to expand the study next year.

Baits for predator control

During my visit I saw a number of baits being used or trialed for predator control.

(a) JT Eaton Bait Block®

The only bait that is currently registered in the USA for field use for rodent control is the JT Eaton Bait Block® rodenticide with molasses and peanut butter flavorizer™ containing 0.005% diphacinone for killing Norway rats, roof rats (black or ship rats), and house mice (JT Eaton &

Co. Inc., 1393 East Highland Road, Twinsburg, OH 44087, USA). This bait is a 2 oz (approx. 50 g) wax block for use in bait stations.

(b) Ramik® Green
A bait that is being trialed for rodent control by Tonnie Casey, Catherine Swift, and others is Ramik® Green, a fish flavoured, weather-resistant rodenticide containing 0.005% diphacinone (HACO Inc., PO Box 7190, Madison, WI 53707, USA). This is a rounded pellet about a 1-g in weight. It could be used in bait stations or broadcast.

(c) PestOff™ mongoose bait
A bait that is being trialed for mongoose control by Tonnie Casey is PestOff™ mongoose bait (Animal Control Products Ltd, Wanganui, New Zealand). This is an extruded pellet about a 2-g in weight, made from fishmeal and chickenmeal, and containing 0.005% diphacinone. The directions for use state "apply in bait stations, by hand laying, hand broadcasting or aerial sowing as dictated by circumstances". I did not know that this bait existed and would be interested in testing it for palatability to stoats and ferrets in New Zealand.

(d) Ferrovex Predator Paste
This bait, containing 0.03% diphacinone, made by Animal Control Products Ltd, Wanganui, New Zealand, is the bait we have been testing in New Zealand for ferret control. Tonnie Casey has samples for testing its palatability to mongooses in Hawaii.

(e) Multi-species baits
Gerald Lindsey, from the USGS Biological Resources Division, Kilauea Field Station, has submitted a proposal for developing a fish-flavoured bait for control of rats, cats, and mongooses. I suggested he contact Dave Morgan.

Toxicants for predator control
The only toxicant that is currently registered in the USA for field use for rodent or mongoose control is 0.005% diphacinone. At this concentration of diphacinone, Catherine Swift, from the University of Hawaii, has found that *R. rattus* needs to eat about 35 g of bait per day for 7 consecutive days and *R. exulans* needs to eat about 30 g per day for 7 consecutive days to receive a lethal dose. This seems a demanding requirement that could be reduced if the concentration of the toxicant was increased. Gerald Lindsey, from the USGS Biological Resources Division, Kilauea Field Station, is planning field trials to evaluate the use of brodifacoum for rodent control.

Rodent control techniques for macadamia nut orchards
Earl Campbell, from the National Wildlife Research Centre, Hilo Field Station, took me to the largest macadamia nut orchard in Hawaii (Mauna Loa). These orchards support high populations of black rats and mongooses. The rats nest underground but climb trees to eat the nuts. The rats will not eat baits on the ground. The NWRC (c/- Kathy Fagerstone) is submitting a package to the EPA for registration of diphacinone in bait stations placed in trees (one bait station per 20 trees). Registration will be sought for Eatons and Ramik Green fish-flavoured baits containing 0.005% diphacinone. The proposed management practice is to bait initially with non-toxic indicator baits (Census blocks), check monthly, and replace with toxic baits when rats start eating the baits. Earl expects the EPA may ask for studies of non-target secondary poisoning risks to raptors. Although good data already exist from trials in native forest (from research by Gerald Lindsey), Earl may do trials in macadamia nut orchards using

photography to identify scavengers of rat carcasses and using radio-telemetry to determine whether rats die on the ground or underground. Mongooses are not a problem in macadamia nut orchards but Earl is collecting stomachs from animals caught in rat traps to determine diet. The macadamia nut orchards appear to be ideal field laboratories for developing methods for rat and mongoose control because of the large area they cover (1000s of hectares), their uniformity, easy access, and high pest densities. Techniques could be developed here initially then adapted for use in conservation areas.

Tuberculosis in wild animals
Earl Campbell told me that Tb has recently been identified in cattle on the island of Molokai. It has previously been identified only in wild animals. The NWRC is considering a large-scale epidemiological study of wild animals that may interact with cattle (e.g., wild cattle, deer, pigs, and mongooses). Tb has been identified in mongooses in the past. If Tb in mongooses is identified as a problem, this will give added support for research on developing a bait for mongoose control. I gave Earl the names of some people he should contact in New Zealand re Tb issues (Phil Cowan, Peter Caley, Jim Coleman).

Non-target species risks from diphacinone-poisoning for rodent control
Gerald Lindsey, from the USGS Biological Resources Division, Kilauea Field Station, described his research on the safety of diphacinone in bait stations for rodent control in native forest. In one experiment, rat carcasses were tied to a trigger mechanism attached to cameras. The photographs showed that the carcasses were scavenged by pigs, mongooses, cats, and other rats. None were scavenged by ‘io (Hawaiian hawks). In another experiment, most radio-tagged rats (*R. rattus* and *R. exulans*) that had consumed bait containing diphacinone were found to stay in their nest sites during the day and only become active, moving above ground, at night. When they died, the rats died either underground or in dense cover. This suggests that there would be minimal risk of diurnal ‘io (hawks) catching live rats that had ingested diphacinone or scavenging dead rats. This finding contrasts with another study that found that anticoagulant-intoxicated Norway rats (*R. norvegicus*) became more active during the day, and died in the open, increasing the risk of their being predated and scavenged by diurnal predators (Cox, P. & Smith, R.H. 1992: Rodenticide ecotoxicology: Pre-lethal effects of anticoagulants on rat behaviour. *Proceedings of the Vertebrate Pest Conference 15:* 165-170). The risk to nocturnal predators, such as the pueo (native short-eared owl) has not been investigated.

Secondary poisoning of crows
I talked to Greg Massey, a veterinarian with the State Forestry and Wildlife Division, Maui, about a study he recently participated in with John Marzluff, a raptor biologist from the University of Washington, to determine whether alala (Hawaiian crows) were at risk of secondary poisoning from diphacinone used for rodent control. They fed diphacinone-poisoned rats to American crows. All of the birds survived for at least 1 month after dosing. Crows that consumed diphacinone-poisoned rats daily for 6 days had elevated prothrombin times and some clinical signs of clotting abnormalities. Those that ate only one diphacinone-poisoned rat had slightly elevated prothrombin times but no clinical abnormalities. This is good news for ‘alala, and probably means that diphacinone can now be used for rodent control in the ‘alala area.

Avian malaria
I talked to Carter Atkinson, from the USGS Biological Resources Division, Kilauea Field Station, about the impact of avian malaria (*Plasmodium relictum*) on native bird populations. This

disease is transmitted by introduced *Culex* mosquitoes. Malaria is believed to be restricting endangered native bird populations to high altitude habitats where disease transmission is limited by cool temperatures. Feral pigs are believed to be playing a major role in the spread and maintenance of the disease by creating water hollows that are subsequently used by mosquitoes as breeding sites. Carter is co-author of a proposal to induce persistent immunity to avian malaria in Hawaiian birds by inoculating them with the parasite and then pharmacologically controlling the clinical signs associated with the initial malarial infection. It is hypothesised that birds surviving the initial infection will be protected against future malarial attacks. By combining this strategy with methods to reduce the number of mosquito vectors, these "naturally vaccinated" birds, and potentially their offspring, would be available for release in malaria endemic areas. This could greatly expand the low and mid-elevation habitat that is suitable and available for forest bird repopulation. Tonnie Casey is attempting to reduce mosquito numbers in her Keauhou study area by spreading Mosquito Dunks®, a floating sustained-release larvacide containing 10% *Bacillus thuringiensis*, in water hollows.

Captive breeding of birds for release into the wild

Alan Lieberman, from the Peregrine Fund, showed me around the captive breeding facility at the Keauhou Bird Conservation Centre on Hawaii. The centre is dedicated to the restoration of Hawaiian birds and conservation education. It has a captive breeding programme involving 10 species of native birds, including six endangered species. The facility has a bank of time-lapse video cameras to monitor the behaviour of breeding birds. An experimental release of the common 'amakihi into forest containing predators (rats, cats, and mongooses) and mosquito-transmitted avian diseases (avian pox and avian malaria) in 1995 resulted in the death of almost all birds. This illustrates that re-introductions may only be possible in predator and mosquito-controlled sites. Releases of 'alala and 'oma'o into predator-controlled and disease-free habitat have been more successful. The centre is still developing its education programme, and is going to incorporate some features from the Hawaii Nature Centre that I visited on Maui.

Variable Circular Plot (VCP) bird counts

I talked to Steve Fancy from the USGS Biological Resources Division, Kilauea Field Station, about the use of VCP counts to monitor forest bird populations. Sampling locations (stations) are systematically spaced along a transect, and the distance to each bird heard or seen by an observer at each station is recorded during a 5- to 8-minute sampling period. This method differs to the 5-minute count used in New Zealand, where distances to birds are not recorded. Steve has developed a new approach for analysing bird densities from these counts (Fancy, S.G. 1997: A new approach for analyzing bird densities from variable circular-plot counts. *Pacific Science 51:* 107-114). He has validated the technique in two field tests where reasonably accurate estimates of density were derived by independent methods (one where the majority of 'oma'o were banded and another where a known number of palila were translocated into an isolated stand of forest).

Endangered bird research

(a) Po'ouli

I talked to Mark Collins and Vern Duvall, from the DLNR Forestry and Wildlife Division, Jim Jacobi and Thane Pratt from the USGS Biological Resources Division, Tonnie Casey from the Kamehameha Schools Bishop Estate, and a number of other people about the po'ouli, a small honeycreeper found only on Maui, and probably the most endangered bird species in Hawaii and perhaps the world. It was first discovered by modern science in 1973 and thought to number 200 birds. The population has since plummeted and now there are only three

individuals known (though there could be a few more because they live in thick forest on a very steep mountainside that gets even more rain than our West Coast). However, even the most optimistic estimate is 10 individuals. All historic records of po'ouli have been within the Hanawi Natural Area Reserve, which provides habitat for the highest number and density of endangered forest birds in Hawaii. Protection and restoration of po'ouli and other endangered birds will require the continued control of pigs and goats that degrade the habitat and continued control of rats, cats, and mongoose that prey on eggs, chicks, and adult birds. A recovery plan has been developed by at least 11 organisations; the U.S. Fish and Wildlife Service, Hawaii Department of Land and Natural Resources, Biological Resources Division of U.S. Geological Survey, Peregrine Fund, Haleakala National Park, Kamehameha Schools Bishop Estate, Nature Conservancy of Hawaii, Hawaii Forest Bird Recovery Team, Avian Disease Recovery Working Group, Toxicant Registration Working Group, East Maui Watershed Working Group, and independent researchers. The following steps are proposed; locate all remaining po'ouli, develop and implement a public outreach and funding campaign, control predators, ungulates, and other threats, accelerate research into life history and demography of po'ouli, increase the number of po'ouli in the wild through nest protection, captive propagation and release, and other management options, and assess the impacts of research and management efforts on po'ouli and other components of the ecosystem. Some people I spoke to thought the recovery efforts were moving too slowly, others thought they were moving too rapidly. With the large number of organisations involved, it will be difficult to please everyone. There is a very real chance that the species will become extinct.

(b) 'Alala (Hawaiian crow)

I talked to Donna Ball, a biologist with the US Fish & Wildlife Service working on re-introduction of the 'alala (Hawaiian crow) to a block of ohia-koa forest on the McCandless Ranch, private land on the slopes of Mauna Loa, south Kona. In 1992, there were only 12 crows left in the wild. Disease, loss of habitat, illegal shooting, and predation by introduced mongooses, cats, and rats contributed to their decline. Since then 16 birds reared from eggs by the Peregrine Fund have been re-introduced into the area. At least 10 are known to have survived. The known population in the wild is now 15, making the species still one of the world's most endangered. Another nine chicks are currently being held in captivity awaiting release. Mongooses, cats, and rats are being live-trapped. Poisons have not been used so far for fear of secondary poisoning ('alala are known to feed on carrion).

(c) Palila

I talked to Paul Banco from the USGS Biological Resources Division, Kilauea Field Station, who is working on the palila, an endangered finch-billed honeycreeper, restricted to the mamane (*Sophora*)-naio (*Myoporum*) forest on the western slopes of Mauna Kea, Hawaii. There are perhaps 3000-4000 of these birds left but their habitat has been degraded by sheep. Sheep have been removed for 16 years but palila numbers have not yet increased. I also talked to Greg Brenner, an entomologist working with Paul on the palila project. Although palila feed largely on immature seeds of mamane (*Sophora*), Greg has discovered that the chicks are fed tortricid and geometrid (moth) caterpillars. Many of the caterpillars are parasitised by a parasitic wasp, and this may be reducing the food supply for palila chicks.

(d) Oma'o (Hawaiian thrush)

I talked to Steve Fancy from the USGS Biological Resources Division, Kilauea Field Station, about the oma'o (Hawaiian thrush), which is restricted to the island of Hawaii. The species occupies only a fraction of its former range. Steve monitored an experiment in which 25 young

birds reared from eggs at the Keauhou Bird Conservation Centre and 16 wild-caught birds were released in the Puuwaawaa Wildlife Sanctuary in September 1996. More than 90% of the captive-reared birds but only about 40% of the wild-caught birds remained within 2 km of the release site. At least one pair is known to have bred.

(e) Laysan duck

I talked to Michelle Reynolds from the USGS Biological Resources Division, Kilauea Field Station, who described a study she is starting on the endangered Laysan duck, which is currently restricted to Laysan Island in the northwestern Hawaiian chain. Five years ago the population was about 500, but today it is about 125 birds. The cause of decline is unknown. There are no introduced predators on the island. The ducks feed on insect larvae and brine flies in a saline lagoon. Michelle plans to determine the habitat requirements of the ducks as a prelude to translocating birds to other islands for safety.

(f) Nightingale reed warbler

I talked to Stephen Mosher from the USGS Biological Resources Division, Kilauea Field Station, who is part-way through a 20-month study of the Nightingale reed warbler on Saipan in the west Pacific Ocean, near Guam. This warbler is restricted to Saipan??? and the population numbers about 3000-4000 birds. Recent proposals to develop large parts of the island for tourism, especially clearing vegetation for golf courses, pose a risk for the species. Stephen is trying to identify prime reed warbler habitat so that it can be excluded from any development activities.

(g) Nene and ‘ua’u

I talked to Darcy Hu, from the Hawaii Volcanoes National Park (Resources Management section), who is responsible for management of nene (Hawaiian goose) and ‘ua’u (dark-rumped or Hawaiian petrel), the two endangered bird species in the Park. Although research has officially been separated from management, Darcy is collecting data on distribution and abundance of these birds as part of her management duties. In conjunction with staff from the University of California, she is conducting population viability analyses of the two species. Nene used to number in the thousands, ranging from coast to mountains, but loss of habitat, hunting, and the introduction of predators such as mongooses, cats, and dogs have reduced their number to only a few hundred. The current population of nene in the Park is just under 200 and is relatively discrete, but is probably not self-sustaining. Trapping (for mongooses and cats) and diphacinone-poisoning (for mongooses) has been undertaken for 2 years in selected nesting and brooding habitats. This has resulted in a greater production of goslings. Radio-transmitters have been fitted to goslings to determine causes of mortality. Last year none of the goslings died from predation, but all died from an unknown cause, possibly a nutritional deficiency. A trial with supplementary feeding significantly increased survival. It is possible that the birds may be occupying marginal habitat and a key species of grass may be missing. A trial planting of grasses is planned.

Dark-rumped petrels nest in the Park above about 8000 feet. They used to nest down to sea level. The population size is unknown but probably numbers several hundred birds. Darcy is still surveying nesting distribution in the Park. She is also monitoring breeding success at nests in three areas. The population is thought to be declining. The main threat is cat predation. Cats have been trapped for the last 2 years. A post-doctoral student from the University of California

is going to research cat control methods. I suggested that Darcy or the student contact Landcare Research regarding baits for cat control.

Kaho'olawe Island restoration
I talked to a number of people including Gerald Lindsey and Rick Warshamer, from the USGS Biological Resources Division, Kilauea Field Station, about the restoration of Kaho'olawe Island (11700 ha) which has been used as a military training ground. The Kaho'olawe Island Reserve Commission (KIRC) has been appointed to handle the transition of ownership of the island from the military to the State of Hawaii. The Biological Resources Division was contracted to produce a plan for the restoration of flora and fauna. Pests include cats and mice (and possibly rats). The plan recommends eradication of these pests to allow translocation of endangered bird species. The problem is how to do this over such a large area.

Wildlife management in Forestry and Wildlife Division
I talked to Tod Lum, Forestry and Wildlife Division, Waimea, about management of sustained-yield hunting areas (for pigs and sheep) and wildlife refuges. Under the Wildlife Restoration Act, there is an 11.5% excise tax on firearms and ammunition which goes to wildlife management, much to the chagrin of hunters. The Forestry and Wildlife Division uses volunteers for wildlife management under a scheme supported by the Federal Government. The Forestry and Wildlife Division also contracts wildlife research from the University of Hawaii. One project that Tod is currently managing is the Puuwaawaa Wildlife Sanctuary, 2000 acres on Mt Hualalai, which is currently being fenced to exclude ungulates (cows, sheep, and pigs). Control of mongooses, cats, and rats is also underway. This is the site where Steve Fancy released oma'o (Hawaiian thrush). It is also a site proposed for the release of 'alala (Hawaiian crow).

Yellowjacket research
David Foote, from the USGS Biological Resources Division, Kilauea Field Station, took me to his study areas in Hawaii Volcanoes National Park. In 1996, he started a study on the control of yellowjackets (*Vespula pensylvanica*) to protect native invertebrates. Yellowjackets invaded the island of Hawaii in 1978, and irrupted in Hawaii Volcanoes National Park in 1982. Within a year, anecdotal observations indicated that several species of invertebrates had declined. Two species commonly eaten by yellowjackets are the endemic picture-wing flies, *Drosophila hawaiiensis*, which is relatively widespread, and *Drosophila engyochracea*, which is restricted to two kipukas (Kipuka Puaulu and Kipuka Ki) about a mile apart, on the lower slopes of Mauna Loa. Kipukas are "islands" of dense ohia-koa forest that survived lava flows. *Drosophila engyochracea* breeds in the bark of the a'e or soapberry (*Sapindus saponaria*) which also has a very restricted distribution. These two picture-wings are larger than the more common *Drosophila* known as yellowflies. David is attempting to determine whether reduction of yellowjacket numbers by poison-baiting will increase the abundance of invertebrates, using picture-wings as indicator species.

One kipuka has been selected as a treatment area and the other as a non-treatment area. The two kipukas have similar vegetation and are similar in size (about 50 ha). David is using micro-encapsulated diazinon (Knox Out 2FM) mixed into canned white chicken meat (expensive) to reduce yellowjacket numbers in one kipuka (Kipuka Puaulu). About 3 g of bait is placed in each bait station. Yellowjacket nests are usually not completely destroyed, but yellowjacket numbers are severely reduced. Apart from yellowjackets, the two species of endemic picture-wings, an endemic calliphorid fly, and two species of native solitary wasps are attracted to the baits. The

picture-wings and calliphorid flies die on the baits within a few hours whereas yellowjacket workers take about 2 days to die. To reduce the impact on picture-wings, the bait stations are hoisted at least 3 m above ground on a string and pulley system to where picture-wings are less abundant and yellowjackets are more abundant (at least in wet forest). The baits are also replaced about every 3rd day (Monday, Wednesday, and Friday) to keep them relatively fresh and so less attractive to the scavenging flies.

Yellowjacket numbers are monitored using Wasp Inn traps baited with heptyl butyrate (placed inside the traps). The traps are spaced 50 m apart and are hoisted 3-6 m above ground to keep trapping results comparable with those in wet forest (because yellowjackets are most abundant at that height in wet forest). The traps are emptied weekly and the heptyl butyrate replaced every second week. Apart from yellowjackets, the traps also catch large numbers of a species of cerapagonid fly. David is not monitoring yellowjacket traffic rates at nest entrances. In 1996, yellowjacket numbers in the non-treatment area peaked in August-September. Knox-Out reduced yellowjacket numbers in the treatment area to zero about 2 months earlier than in the non-treatment area. This year (1997) yellowjacket numbers are currently very low following heavy rain in June-July.

Drosophila populations in the two areas are monitored by counting (instantaneous) numbers attracted to pieces of sponge (approx. 10 x 5 x 2 cm thick) soaked with yeast-fermented mushroom extract (as a long-distance attractant) and yeast-fermented banana (as a food source) nailed to trees 20-m apart (n = 25). The bait sponges are inspected early in the morning (starting 6 am) because that is when *Drosophila* numbers on them are highest. I asked about correlation between numbers on bait sponges and true population density. David said he has funding to do a capture-recapture study to estimate population numbers and compare with numbers counted on bait sponges. The reduction in yellowjacket numbers in the treatment area in 1996 did not result in an increase in picture-wing numbers recorded on bait sponges. One reason for this may be that the poison-baiting may be directly reducing picture-wing numbers. David is considering doing some bait preference trials to find an alternative to white chicken meat that is still attractive to yellowjackets but less attractive to the picture-wings.

Public relations

I talked to a number of people about the issues facing Hawaiian conservation. Probably the greatest issue is the lack of both public and Federal recognition of the problems of introduced pests. With this in mind, an inter-departmental Public Relations Working Group has been set up and has drafted a public relations plan to raise public support to save Hawaii's threatened and endangered forest birds. Its objectives include public acceptance of the use of rodenticides as the most effective means of predator control and increased financial support for protection programmes. The plan is to use the po'ouli as a "spokesbird", to provide a "face" for the public to relate forest birds with themselves. After the po'ouli is introduced to the public statewide, a different rare bird will be identified for each of the islands. In the end, of course, Federal recognition of Hawaii's conservation problems will be necessary to ensure adequate funding of both research and management.

Summary

Some of the impressions I gained from my visit were:

1. The large number of endangered species in Hawaii. Before my visit I knew Hawaii had a large number of endangered species but I didn't realise just how many nor how

serious their plight was (e.g., there are only three known po'ouli and 15 known 'alala in the wild).

2. The large number of organisations involved in conservation research. I was over-awed by the large number of organisations involved in conservation research (Federal, State, local government, and private). I have attached an appendix listing some of the organisations I made contact with.
3. The large amount of research done by partnerships and teams. I was impressed by the amount of research being done by partnerships and teams (both multi-disciplinary and inter-departmental). This has been fostered to a large extent by the Secretariat for Conservation Biology.
4. The large-scale use of volunteers in conservation research and management. Volunteers are indispensable in many projects in the USGS Biological Resources Division, the US National Park Service, and the State Forestry and Wildlife Division. They give a 3 month commitment to a project and in return are provided with accommodation and paid between $7 and $20 per day.
5. The large area of conservation-zoned land in private ownership. I was surprised at how much conservation-zoned land was in private ownership. These private owners are legally responsible for the preservation of natural resources on their lands. This results in private land-owners contributing to both research and management of wildlife.

I feel I gained an enormous amount from talking with conservation researchers in Hawaii and this should be of benefit to Landcare Research in New Zealand. I was exposed to some different techniques to those we use in New Zealand (e.g., use of large-scale banding of birds and measuring distances to birds when counting bird numbers for estimating population density). In return, I hope I was able to share with Hawaiians the results of some of my research in New Zealand on conservation problems common to the two countries.

Acknowledgements

I would like to thank the Secretariat for Conservation Biology for funding this exchange, and Nancy Glover for making logistic arrangements for me in Hawaii. I would also like to thank Tonnie Casey for hosting me during my stay on Big Island, and staff at the various research institutes and management agencies that I visited for sharing their research with me. I hope I have accurately summarised the research that I was privileged to learn about.

Appendix 1. Itinerary

Sunday 20 July
Arrived at hotel (Outrigger Hobron) in Waikiki about midnight.

Monday 21 July - Tuesday 22 July
In Waikiki. Spent most of the time completing uncompleted work from home. Met Nancy Glover (Administrative Officer for the Secretariat for Conservation Biology) and Michael Buck (Administrator for the Hawaii State Division of Forestry and Wildlife). Discussed plans for my visit and collected tickets for flight to the Hawaii Conservation Conference on Maui. Read conference abstracts. Telephoned people to make arrangements to visit them. Had dinner on Tuesday night with Martin Kaye and Walter Hobgood, both Managing Directors for the Asia-Pacific Division of Griffin Corporation in Honolulu. Discussed my wasp control research. They told me that Elliott Chemicals Ltd had just that day applied to the New Zealand Pesticides Board for a registration for a 20% sulfluramid granule for mixing into sardine cat-food for wasp control. They are hopeful that the product would be registered in time for the next New Zealand summer. They did not know what the price of the product will be but it will be a major cost-saving to the customer. This is a direct result of my research on a sulfluramid concentrate for wasp control (published in the Proceedings of the New Zealand Plant Protection Conference 1996). Interestingly, Martin and Walter were not aware that Hawaii had a wasp (yellowjacket) problem.

Wednesday 23 July
Flew to Kahului airport on Maui and caught a shuttle to the Aston Wailea resort, the venue for the Hawaii Conservation Conference. At the conference reception in the evening, met Colin and Anne Bassett. Colin was the previous Administrative Officer for the Secretariat for Conservation Biology.

Thursday 24 July - Friday 25 July
Hawaii Conservation Conference.

Saturday 26 July
Early (6.30 am) start. All-day post-conference field trip to Haleakala National Park. Then caught late flight to Hilo on Hawaii (Big Island) via Honolulu. Arrived about 7.30 pm, met by Tonnie Casey's sister and brother-in-law, and driven 45 minutes to Tonnie's house in Volcano.

Sunday 27 July
Early (7.15 am) start. Driven by Tonnie Casey's sister to Steve Fancy's house in Hilo. Steve then took me to his study site in Hakalau Forest National Wildlife Refuge, at an altitude of 5400 feet on the slopes of Mauna Kea volcano. Returned to Hilo about 6 pm, picked up by Tonnie Casey and taken back to her house.

Monday 28 July - Tuesday 29 July
Tonnie Casey showed me her study area at Keauhou Ranch on the Kamehameha Schools Bishop Estate, at about 6000 feet on the slopes of Mauna Loa volcano.

Wednesday 30 July
Raining (14 inches in 24 hours). Visited the Peregrine Fund's Keauhou Bird Conservation Centre, and met Alan Lieberman and Cyndi Kuehler, resident biologists.

Thursday 31 July
Visited the Biological Resources Division of the US Geological Survey, Kilauea Field Station. Met and talked to a number of people about their research. Gave a seminar on my research on development of toxic baits for stoat and ferret control.

Friday 1 August
Visited BRD again. David Foote took me to his study areas in Volcanoes National Park, where he is attempting to determine whether reduction of yellowjacket (wasp) numbers by poison-baiting will increase the abundance of invertebrates. On return from the field, I gave a seminar on my research on poison-baiting for wasp control.

Monday 4 August - Thursday 7 August
At BRD again. Continued to meet staff and discuss their research. Early (6 am) start on Wednesday when I went with David Foote to visit his yellowjacket study area again. Gave two seminars (on "Impacts of mammalian pest control operations on non-target species" and on "Bird repellents for baits for mammalian pest control"). Also visited Hawaii Volcanoes National Park offices, and met Darcy Hu, from the Resources Management section. Darcy is responsible for management of nene (Hawaiian goose) and ʻua'u (dark-rumped or Hawaiian petrel), the two endangered bird species in the Park. Also met Dick Rasp and Jay Robinson from the Interpretation section, and discussed use of volunteers for wildlife work. Rang Tod Lum, Forestry and Wildlife Division, Waimea, who is responsible for management of sustained-yield hunting areas (for pigs and sheep) and wildlife refuges. Also rang Greg Massey, a veterinarian with the Forestry and Wildlife Division, Maui, who has recently participated in a study with John Marzluff, a raptor biologist from the University of Washington, to determine whether alala (Hawaiian crows) may be at risk of secondary poisoning from diphacinone used for rodent control. Met Mike Fall and Kathy Fagerstone from the National Wildlife Research Centre, Fort Collins, who were visiting Earl Campbell at the Hilo Field Station.

Friday 8 August
Spent most of the day with Earl Campbell, from the National Wildlife Research Centre, Hilo Field Station. Earl has a staff of three in Hilo involved in rodent population monitoring, damage, and control research. Earl is also involved with brown tree snake research in Guam, and supporting research by Catherine Swift, an MSc student from University of Hawaii, on the broadcast application of Ramik Green for rat control.

Monday 11 August
At BRD again, talking to staff about their research. Also met Bill Steiner, Director of the BRD, Pacific Islands Ecosystems Research Center, based in Honolulu, who was visiting the Hawaii Field Station.

Tuesday 12 August - Friday 15 August
On leave.

Monday 18 August
Visited BRD to check E-mail and say farewells. Flew from Big Island to Oahu, and checked into accommodation at the East-West Center.

Tuesday 19 August - Wednesday 20 August
On leave but telephoned to make appointments to visit people.

Thursday 21 August
Visited the University of Hawaii, Zoology Department, and met Sheila Conant, a member of faculty specialising in ecology, life history, and reproductive behaviour of birds, and Eric Vanderwerf, a graduate student doing a PhD on the breeding biology of 'elepaio. Telephoned Colin Bassett and spoke with him about the work of the Secretariat for Conservation Biology.

Friday 22 August
Visited Department of Land and Natural Resources, Division of Forestry and Wildlife, in Honolulu and met with Paul Conry, wildlife biologist, and Karen Rosa, U.S. Fish and Wildlife Service, to discuss registration of diphacinone for vertebrate pest control. Both are on the Toxicant Registration Working Group. Also met Fern Duvall, Carol Terry, and Sharon Reilly. Telephoned Cliff Smith, Unit Leader of the Cooperative Parks Studies Unit, University of Hawaii, and spoke with him about the work of the unit.

Monday 25 August - Thursday 28 August
On leave

Friday 29 August
Left Hawaii for the UK.

Appendix 2. Organisations undertaking conservation research and management in Hawaii

US Department of Agriculture, National Wildlife Research Center
A Federal organisation, the National Wildlife Research Center (NWRC) is the research arm of the Animal Damage Control (ADC) program of the U.S. Department of Agriculture (USDA) Animal Plant and Health Inspection Service (APHIS). The main office is in Fort Collins (previously Denver), Colorado. The Hawaii field station is in Hilo. Primary responsibility for conducting research on wildlife management problems, particularly vertebrate pests and the reduction of damage these species cause to agriculture, human health, and natural resources.

US Geological Survey, Biological Resources Division
A Federal organisation conducting government and contract research on problems of environmental concern relating to conservation of indigenous biological resources. Established in 1994, it combines research elements of the US Fish and Wildlife Service and National Park Service. The main field station in Hawaii is in Volcanoes National Park.

US Fish and Wildlife Service
A Federal organisation responsible for the conservation, protection, and enhancement of wildlife (e.g., responsible for the management of National Wildlife Refuges). The Hawaii headquarters is in Honolulu.

US National Park Service
Responsible for management of National Parks, including endangered wildlife (e.g., Haleakala National Park on Maui and Volcanoes National Park on Hawaii).

State of Hawaii Department of Land and Natural Resources, Forestry and Wildlife Division
Responsible for endangered species protection, administration of forest reserves, natural area reserves, wilderness reserves, plant enclosures, and wildlife sanctuaries, and regulatory control over other conservation lands. The Division does not conduct its own formal research but depends upon cooperative projects with partners to obtain research needs.

University of Hawaii Center for Conservation Research and Training
Operates an Ecology, Evolution, and Conservation Biology graduate programme that has grown from three students in 1991 to more than 50 students in 1997.

Cooperative Parks Studies Unit, University of Hawaii and USGS Biological Resources Division
Administers a cooperative research program between the University of Hawaii and the USGS Biological Resources Division in the Pacific Islands. The unit's primary focus is on conservation of natural resources in protected habitats, such as national parks, wildlife refuges, and natural area reserves.

Nature Conservancy
An international non-profit conservation organisation dedicated to biodiversity conservation through direct protection of key habitats. It invests heavily in three science strategies; (a) advocating conservation science needs to Congress and the legislature, (b) funding selected priority research programmes, and (c) maintaining the Hawaii Natural Heritage Program databases.

The Peregrine Fund, Hawaii Bird Conservation Program
A non-profit conservation organisation operating two captive propagation facilities (the Keauhou Bird Conservation Center on Hawaii and the Maui Bird Conservation Center).

Kamehameha Schools Bishop Estate
A private, large landowner in Hawaii that employs a wildlife biologist to undertake research on ecosystem restoration and pest control for protection of endangered animal and plant species on its lands.

Maui Pineapple Company Ltd
A private company, actively managing privately-owned conservation-zoned lands in West Maui to protect and preserve rare and endangered natural resources including the Hawaiian bat and endemic bird and snail species.

Secretariat for Conservation Biology
Established in 1993, the Secretariat promotes effective, long-term management of Hawaii's native ecosystems through a collaborative research and training effort among land managers, scientists, and educators. Partner organisations include: University of Hawaii Center for Conservation Research and Training, US Fish and Wildlife Service, US Forest Service, US National Park Service, US Geological Survey Biological Resources Division, State Division of Forestry and Wildlife, Nature Conservancy of Hawaii, Department of Defence, and Bishop Museum. The secretariat organises the annual Hawaii Conservation Conference, administers the New Zealand–Hawaii Conservation Exchange Programme, and helps co-ordinate conservation working groups established at the Conservation Forum.