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Traditional gathering of native *hula* plants in alien-invaded Hawaiian forests: adaptive practices, impacts on alien invasive species and conservation implications

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SUMMARY

Traditional resource management (TRM) systems in tropical forests can provide insights on sustainable resource use, but despite the growing prevalence of degraded tropical forest habitats, few studies have assessed the relationships between TRM and conservation in these environments. In Hawaii, the traditional gathering of native wild plants used for *hula* (chants and dance) and *lei* (garlands) is carried out in forests increasingly dominated by alien invasive species. Ethnographic methods and exploratory experimental harvests were employed to examine: gathering of *hula* plants in the past and present, ecological impacts of contemporary gathering practices of three important native hula species in alien-dominated forests, and relationships between traditional practices and past and modern conservation. Past gathering traditions included practices to increase and conserve hula plant populations. Harvest of *Microlepia strigosa* fern fronds significantly decreased *M. strigosa* cover over the short term. Cover of alien species significantly increased after frond-harvest of *Sphenomeris chinensis*. Regeneration of the fruit-harvested shrub, *Melicope anisata,* was significantly negatively correlated with the level of understorey invasive species. These results suggest that in Hawaiʻi's alien-dominated forests, gathering of some species may increase spread of alien invasive species or exacerbate regeneration problems caused by invasive species. However, some expert cultural practitioners have adapted traditional practices to ensure hula plant conservation by incorporating weeding of alien invasive species into their protocols. The re-strengthening and adaptation of traditional Hawaiian knowledge and social institutions to the modern context can provide opportunities to improve conservation of Hawaiʻi's culturally-important native plants and their habitats.

Keywords: Hawaii, *Melicope anisata*, *Microlepia strigosa*, non-timber forest products, *Sphenomeris chinensis*, sustainable harvest

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INTRODUCTION

Traditional resource management (TRM) systems in tropical forests have received attention recently because they can provide insight into sustainable resource use (Redford & Padoch 1992; Gadgil *et al.* 1993; Berkes 1999; Cunningham 2001). For example, various studies have demonstrated that traditional methods for harvesting wild plant resources can effectively maintain and increase population sizes (Velasquez-Runk 1998; Martinez-Ballesté *et al.* 2002; Ticktin & Johns 2002). Little research however has assessed the dynamics or impacts of TRM practices in rapidly changing or deteriorating tropical forest ecosystems.

Most tropical forests are subject to unprecedented rates of degradation, due to deforestation, fragmentation (Whitmore 1997) and alien-species invasion (Cox 1999). The effects of TRM in these changing forest ecosystems may differ from those in intact forests (Cunningham 2001; Ticktin & Nantel 2004) because of changing ecological and social conditions. For instance, the impacts of harvesting native forest plants may be exacerbated in alien-invaded forests, where native species are regenerated with difficulty, and where gathering practices may affect the spread of competing alien species. At the same time, TRM is highly dynamic and can be expected to adapt to the changing forest contexts (Berkes & Folke 2001). Nonetheless, resilience of TRM practices is also affected by the socioeconomic and cultural changes that often accompany forest degradation, including changes in world views and customary institutions that govern resource use and common property rights (Berkes 1999).

Here we explore some of dynamics and ecological impacts of traditional Hawaiian gathering of wild plants used for *hula* (chants and dance) and *lei* (garlands) in forests that are increasingly dominated by alien invasive species. Hula and lei are ancient Hawaiian traditions that continue to hold great significance in contemporary Hawaiʻi. Hula is a sacred and ceremonial art composed of chants and dance that carries with it much of the oral history of the Hawaiian people. It plays an important role in the lives of tens of thousands of people of all ages living in Hawaiʻi today (Josephson 1998). Lei used in hula have great cultural and spiritual significance as they represent physical manifestations of the Hawaiian deities. Apart from their use in hula, lei are also used to celebrate a plethora of occasions, including birthdays, graduations and political speeches, and are widely used by all sectors of Hawaiʻi's multicultural society.

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Like many of Hawai'i's native plants, native hula plants are declining or have already disappeared from most forest areas on some islands, and gatherers report that they are increasingly difficult to find (Timmons 1996). Over the past two centuries, Hawai'i has lost almost half of its native forests as a result of habitat destruction, and most of the remaining forests have been heavily invaded by alien plants and animals (Buck 2003). The gathering of native plants from Hawai'i's alien-dominated forests is perceived by many to be an added pressure on the already-declining populations and has therefore raised conservation concerns. Nonetheless, many Hawaiian cultural practitioners maintain that, if carried out according to traditional protocols, their gathering is not damaging to the forest.

In this paper we address three questions. (1) How were hula plants gathered in the past and how are they gathered today by cultural practitioners? (2) What are some of the ecological impacts of contemporary gathering practices on three important native hula plants growing in alien-dominated forests? To address this, we focus on the ferns, *Microlepia strigosa* (Thunb.) C. Presl (Dennstaedtiaceae) and *Sphenomeris chinensis* (L.) Maxon (Lindsaeaceae) on the island of O'ahu, and the shrub, *Melicope anisata* (H.Mann) T.G. Hartley & B.C. Stone (Rutaceae) on Kauai. (3) Based on the above, what are the relationships between Hawaiian gathering practices and resource conservation in the past and in today's alien-invaded forests?

METHODS

Documenting past and present harvesting practices and impacts

To assess how native plants are gathered today by cultural practitioners, during 2002–2003 we carried out semi-structured interviews and participant observation with seven of Hawai'i's expert cultural practitioners, including hula teachers (*kumu hula*), lei makers and elders (*kūpuna*). These expert cultural practitioners were chosen because they all maintain traditional gathering practices, are the teachers of generations of hula and lei-making students, and agreed to be interviewed. We also spoke informally with many other students of hula about their collection practices and their views on gathering, and accompanied several groups on gathering trips.

To assess how native plants were gathered for hula in the past, we searched through written records of traditional Hawaiian chants (*oli*), songs (*mele*) and sayings (*'ōlelo no'eau*), as well as any other historical references to gathering forest plants. We also interviewed the cultural practitioners about the ways in which gathering was done in the past. Note that traditionally lei used for hula were gathered according to protocols which involved chants or prayers to ask permission to enter the forest and to collect the plants (Abbott 1992; McDonald & Weissach 2003). While many examples of these chants and prayers have been recorded (Gutmanis 1983), our aim here was to obtain information about the specific methods used for harvesting hula and lei species.

We selected three native hula species for exploratory, quantitative studies to investigate some of the ecological impacts of contemporary gathering practices for native hula plants growing in alien-dominated forests (Table 1). These species, *Microlepia strigosa*, *Sphenomeris chinensis* and *Melicope anisata*, were among a list of five native hula species identified to us by cultural practitioners as most important to them today. All are reported to be declining, though they are not listed as endangered or threatened.

M. strigosa and *S. chinensis*, known locally as *palapalai* and *pala'ā* respectively, are terrestrial forest ferns, indigenous to all the main Hawaiian Islands (Palmer 2003). In Hawaiian culture, *M. strigosa* is a physical manifestation of Laka, the principal goddess of hula, and its fronds are harvested to decorate the hula altar and make lei for adorning *hula* dancers. It is reported to be among the most commonly collected lei plants (Rhonda Loh, personal communication 2003). The lacy delicate fronds of *S. chinensis* also make it one of the most popular lei plants and it is a physical manifestation of the goddess Hi'iaka.

M. anisata, known locally as *mokihana*, is a shrub or small tree. It produces highly aromatic, anise-scented fruits, which are squarish yellow-green capsules, about 1.5 cm wide, which are harvested and strung in lei. It is endemic to the semi-dry to wet forests of Kaua'i (Wagner *et al.* 1999) and is the favourite lei plant of that island.

Experimental harvests

We carried out experimental frond harvests to assess effects on cover of both the ferns and alien invasive species with which they grow. Since our interviews revealed that some cultural practitioners now weed alien invasive species as they gather plants, we tested the effects of frond-harvest alone, as well as frond-harvest and weeding.

In August 2002, we established 16 1×1 m^2 plots within a large stand of *S. chinensis* in the 'Ewa Forest Reserve, central O'ahu (Table 1). The location of the lower left corner of each plot was randomly selected within the stand, with the condition that plots had to be at least 0.5 m apart. Each plot was then laid out in the same orientation. Distance between adjacent plots ranged from 0.5 to about 2 m. In each of the 16 plots, we recorded per cent cover of understorey vegetation by establishing two random transect lines using the pole-intercept method (Barbour *et al.* 2002). A thin pole was dropped every 10 cm, the number of fronds touching the pole and number of times each frond touched the pole being recorded. Plots differed in alien cover and were therefore grouped into four blocks according to increasing levels of alien cover. Four plots, one from each block, were then randomly subject to each of the following treatments for a total of four plots per treatment: (1) control (no harvest or weeding); (2) frond harvest only; (3) frond harvest plus weeding; and (4) weeding only.

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Table 1 Description of study sites and experiments. [1]Alien invasive species. [2]Quantification of fruit-harvest rates requires following harvesters while picking, which was not possible. High and uncontrolled harvest pressure also made experimental harvests impossible. Therefore trail accessibility was used as a proxy for harvest pressure. [3]Populations not easily accessible and showed no signs of harvest by others before or during experiment. N/A = not applicable.

Study species	*Sphenomeris chinensis (Dennstaedtiaceae)*	*Microlepia strigosa (Lindsaeaceae)*	*Melicope anisata (Rutaceae)*
Experiment	Effects of harvest treatments on *S. chiensis* and alien cover	Effects of harvest treatments on *M. strigosa* and alien cover	Effects of trail accessibility[2] and understorey alien cover on population structure
Study site	Mānana-Waimano tract of the ‘Ewa Forest Reserve, O‘ahu	Kahanahāiki tract of the Mākua Military Reserve, O‘ahu	Koke’e Park, Kauai
Elevation	520 m	550 m	1050–1200 m
Public access	Yes[3]	No	Yes
Dominant overstorey species	*Eucalyptus spp*[1]	*Psidium cattleianum*[1], *Schinus terebinthifolius*[1] *Aleurites moluccana*[1]	*Metrosideros polymorpha, Acacia koa, A.meansii*[1], *Grevillea robusta*[1], *Eucalyptus robusta*[1]
Dominant understorey species	*S. chinensis*, *P. cattleianum*[1], *Clidemia hirta*[1], alien grasses	Mix of alien grasses, and native and alien ferns	Variety of native species with *Hedychium garnerianum*[1] and *Rubus argutus*[1] increasingly forming thick, monospecific stands
Treatments	Control; frond-harvest; frond-harvest and weeding; weeding	Control; frond-harvest; frond-harvest and weeding	Accessibility (3 levels); understorey alien cover (2 levels)
Plot size	1 m × 1 m	Variable: 1–2.25 m^2 (see text)	5 × 20 m^2
Replicate plots per treatment	4 (blocked according to increasing alien cover)	4 (equal alien cover)	10 per level of trail accessibility; each rated according to understorey alien cover
Harvest rate	72 fronds harvested; ∼ 9 per plot	53 fronds harvested; ∼6–8 per plot	N/A[2]

In August 2002, we also established an experimental harvest of *M. strigosa* in the Kahanahāiki management unit of the Mākua Military Reserve, Oahu (Table 1). In one extended *M. strigosa* stand, we established four large square plots that ranged in size from 4 to 9 m^2, each plot containing a similar number of fronds. Note that for the *S. chinensis* experiments, we were able to use equal-sized plots since they contained similar frond densities. Plot locations were randomly established as described above. Distance between adjacent plots ranged between 2 and 4 m. We divided each plot into four equal-sized subplots. One subplot from each plot was randomly assigned to each of three treatments: (1) control; (2) frond-harvest; and (3) frond-harvest with alien weeding (Table 1). We were unable to use the fourth subplots in two of the plots owing to large differences in frond density, and were therefore unable to include a fourth treatment of weeding alone in this experiment as we had for *S. chinensis*. Cover was measured using the described pole-intercept method. We also measured the number of fronds per plant. This was not possible for *S. chinensis*, fronds of which grow so densely that it is impossible to identify individual plants.

For both species, harvest and weeding treatments were carried out immediately after the first census in August 2002 by an experienced gatherer and hula dancer. All harvestable fronds were gathered (Table 1). For both species, cover was measured every three months over a period of one year (except that one month, namely May 2003, was missed for *M. strigosa* cover measurements). No plots were re-harvested over this period owing to the absence of harvestable fronds.

Note that for both species we had only four replicates per treatment. We were unable to increase the number of replicates because of the limited size of the stands we were able to work in, and were unable to replicate the experiments elsewhere owing to the great difficulty of finding stands that were large enough for experimental manipulation and free from uncontrolled gathering pressure.

Assessing *Melicope anisata* population structure

As a result of high and uncontrolled harvesting pressure, we were unable to carry out a controlled experimental harvest of *M. anisata* as we did for ferns. Instead, we documented population structure along trails that differed in their accessibility to harvesters (as a proxy for harvest pressure) and level of understorey invasive species (Table 1). In May 2003, we carried out surveys of the structure of *M. anisata* populations along six trails in Koke’e State Park (Kauai), where most *M. anisata* is gathered (Table 1). The six trails differed in accessibility to gatherers, with two trails each defined as low, medium and high accessibility. Accessibility was determined by ease of getting to the trailhead (i.e. was a four-wheel drive vehicle required?) and how far away from the trailhead the populations were. For each trail, we identified the first 20 *M. anisata* patches that were visible from the trail, and then randomly selected five of these to census. For each patch,

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Table 2 Protocols for traditional gathering of *hula* plants reported by expert Hawaiian cultural practitioners, and their potential conservation implications.

Traditional gathering protocol	*Potential conservation implications*
Only gather on your way out of the forest (i.e. back from where you are going)	Allows for assessment of resources stocks before making a decision of how much to gather
Only gather in your own ahupua'a	Restricts number of people able to gather in an area
Gather only what you need and always leave for the next gatherer	Allows for, and recognizes, multi-use of common resources
Don't gather fruit from branches higher than those you can reach	Allows for dispersal of higher fruits and therefore future propagation
Don't take all you need from one plant	Spreads pressure over multiple individuals
Gather so that when you finish, it looks like no one has gathered	Restricts amount of gathering
Return used lei (garlands) to forest floor	Allows for decomposition and re-absorption of harvested materials
Gather only from the edges of populations, as far as you can reach in	Prevents trampling, allows for non-harvested individuals that are too far from reach; may prevent spread of invasive species today
Ferns: Remove fronds by cutting the stem (stipe), do not pull from the ground	Allows for regeneration through rhizomes which remain intact
Ferns: Gather only fronds with pointy tips	Restricts harvest only to mature fully unfurled fronds, which will not live much longer
Ferns: Don't gather any fronds that are light green or have light green parts	Restricts harvest only to mature fully unfurled fronds, which will not live much longer
Ferns: Gather a few weeks after rain	Ensures gathering only when fronds are growing and prevents when subject to additional (drought) stress

we laid out one 5-m × 20-m transect that ran perpendicular to the trail, forming a total of 30 transects encompassing an area of 3000 m^2. In each transect, the basal diameters of all the *M. anisata* stems were recorded and the heights of seedlings and saplings were measured. Suckers, which we defined as shoots that split from the main branch at less than 10 cm above ground level, were also measured and counted, and the presence or absence of fruit or flowers were recorded. All species of plants found in the understorey and overstorey were recorded, and the level of invasiveness of the understorey was rated on a scale of 1–2, where 1 = low level of invasiveness and 2 = high level of invasiveness.

Data analysis

To test the effects of harvest treatments on *S. chinensis, M. strigosa* and alien cover, MANOVAs were used. Student-Newman-Kuels (SNK) tests were used to test for differences in variables among treatments at the end of one year. For alien cover in *M. strigosa* plots, the data were not normally distributed, so a Kruskal-Wallis test was used. For neither species were there significant differences in cover among treatments at the start of the experiment. For *M. strigosa*, we also tested whether the number of fronds per plant was dependent on treatment (harvest versus harvest and weeding versus control) using log linear analyses (Sokal & Rolf 1995).

M. anisata population structure (size classes based on basal diameter) was calculated for each of the six trail areas by combining the data from the five transects per trail. Population structure of all stems, including all suckers, was calculated. A canonical correspondence analysis (CCA) (Legendre & Legendre 1998) was carried out to assess relationships between population structure, trail accessibility and level of understorey invasive species. The forward selection procedure indicated that after invasiveness had been selected, accessibility did not significantly explain any additional variation, and it was therefore excluded from the analysis. Analyses were carried out using the program CANOCO (ter Braak & Smilauer 1998). In addition, the Pearson correlation coefficient was used to assess correlations between the level of understorey invasiveness and the proportion of seedlings (number of seedlings per reproductive adult) regenerating.

RESULTS

Gathering practices in the past

All the cultural practitioners we interviewed told us of the traditional and customary protocols for gathering that had been passed down to them through the generations, relating to when, where, what and how to gather (Table 2). Some protocols have a strong conservation rationale, as stressed by all the cultural practitioners, including controls on the amount and means of gathering the desired part and a concept of always leaving enough for the next gatherer.

Other rules also reflected larger cultural beliefs. For instance, returning lei to where the plants were gathered is sometimes carried out for spiritual reasons, as an act of reverence and thanks. Two of the practitioners we interviewed make a lei with the first fronds they gather and offer it back to the forest before they continue.

The importance of gathering only on the way out of the forest was passed down to almost all of the cultural practitioners we interviewed. For example the traditional saying '*E nihi ka helena i uka . . . , mai pūlale i ka 'ike a ka maka'* (Pukui 1983) can be interpreted in differing ways and on different levels, one of which is that you should watch your

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step and not let the things you see lead you into trouble; to leave the picking until the return trip (Pukui 1983). Other traditional sayings also emphasize a conservation ethic when gathering, though they have significance on many other levels. For instance, '*I ulu no ka lālā i ke kumu*' means that the branches grow because of the trunk of the tree (Pukui 1983).

Restrictions on gathering were an important part of the protocols. All practitioners noted that in the past it was only possible to gather in your own *ahupua'a* (Hawaiian political unit of land division, which often approximated a watershed).

In the past, there were strong repercussions if gathering was not carried out according to protocol. For instance, if a hula dancer gathered too much, or in a destructive way, they could expect punishment. One cultural practitioner provided the example that when gathering fern fronds, if a hula dancer pulled the rhizome out of the ground instead of just the frond, they could have been expelled from the hula school. Wild plants were not just gathered, but actively managed for increased propagation. For example, one of the people we interviewed had recorded a *mele* (song) from the late Tūtū Ho'ohila Kawelo that was used for entering the forest and gathering the greenery of the goddess Laka, who takes the form of *maile* (*Alyxia oliviformis*), a highly fragrant and important hula and lei plant (McDonald 1978). The song was used to invoke the goddess, and to ask her permission for gathering and to honour her, and talks about scattering the seeds of maile during gathering (H. Kawelo & M. Lake, A collection of traditional chants, unpublished manuscript). Similarly, one of the elders we interviewed told us they used to propagate *M. anisata* by planting cuttings in the forest.

Traditional gathering practices today

All the cultural practitioners interviewed maintained that they continue to gather according to traditional protocols. One exception was 'gathering in your own ahupua'a', which, they said, was simply impossible in many regions, as the necessary plants could no longer be found in the accessible forests of most ahupua'a on O'ahu.

Other changes included the adaptation of traditional gathering protocols to meet Hawai'i's current forest conditions. For instance, three of the cultural practitioners we interviewed weeded invasive alien plants from the desired populations each time they gathered, and we estimate that on O'ahu possibly 25% or more of hula teachers and students may have adopted this practice. One gatherer commented that she and her peers were taught to gather in the old ways, but needed help adapting their traditions by learning how to recognize and remove invasive species. Hula schools also incorporate other activities, including picking up trash when gathering, or arranging or participating in weeding or other service trips with natural resource managers to 'give back' to the forest. In addition, one expert gatherer told us that he did not return lei to the forest anymore for fear of introducing lowland alien, and potentially invasive, organisms (insects, fungi and other pathogens) to the more isolated upland forests. Instead he returned them to his garden.

Spatial patterns of harvest may have also been adapted or maintained to address the problem of invasive species. For instance, one expert lei maker did not weed aliens when gathering ferns, but maintained gathering could only take place at the edges of the population, as opposed to throughout the population as most people do. While this may prevent trampling and limit the quantity harvested, it may also prevent the spread of invasive species by maintaining a dense ground cover through most of the patch, so that light-loving alien seeds do not have open spaces in which to germinate and grow.

While the cultural practitioners all felt strongly that gathering was not harmful if traditional protocols were followed, they all also commented that many gatherers did not know how to gather correctly and that this could cause damage. Participant observation of gathering by hula students and other collectors illustrated a wide range of variation in care when gathering, with hula teachers gathering very selectively, but inexperienced students trampling plants, gathering large quantities, or gathering intensively or destructively over a small area. Many instances of destructive harvesting were reported to us in our informal interviews with cultural practitioners, hula dancers and other forests users.

Effects of experimental harvests on *S. chinensis*, *M. strigosa* and alien cover

S. chinensis cover was not significantly affected by frond-harvest or alien weeding over the one-year period (Fig. 1*a*). However, the block × harvest interaction was significant (MANOVA, $df_{12,45}$; F = 1.36; p = 0.05) indicating that plots with higher levels of aliens show a greater decrease in *S. chinensis* after harvest than those with lower levels of aliens. The time × block × weeding × harvest interaction was also significant ($df_{12,45}$; F = 3.01; p = 0.003), indicating that this relationship differed over time, as would be expected since harvest and weeding were only carried out at specific times.

Weeding of alien plants significantly decreased alien cover in *S. chinensis* plots over time (Fig. 1*a*; $df_{4,13}$; F = 4.68; p = 0.015). Frond harvest did not affect alien cover over the one-year period, however harvest did significantly increase aliens immediately after harvest (second census; Fig. 1*b*; $df_{1,3}$; F = 38.2; p = 0.008). By the end of the experiment, weeding alone had significantly reduced alien cover, but plots that were both harvested and weeded did not differ significantly from control plots (Fig. 1*b*).

In contrast to *S. chinensis*, frond-harvest reduced *M. strigosa* cover over time ($df_{6,16}$; F = 3.36; p = 0.024). However, by the last census cover levels of harvested plots did not differ significantly from the control (Fig. 2*a*). The number of *M. strigosa* fronds per plant was also independent of treatment (n = 244, df_6; χ^2 = 3.47; p = 0.7480). Harvest treatment had no significant effects on alien cover in *M. strigosa* plots (Fig. 2*b*).

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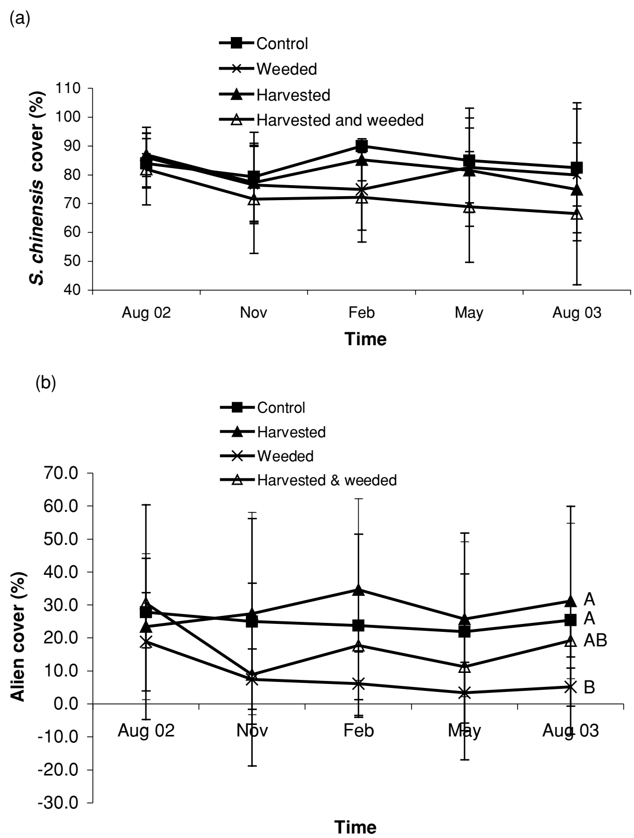

Figure 1 Effects of *Sphenomeris chinensis* frond-harvest and alien weeding treatments on (*a*) *S. chinensis* cover and (*b*) alien cover, over a one-year period. Harvest and weeding was performed after the first census in August 2002, and weeding was repeated in March 2003. Error bars represent ± 1 SD. There were no significant differences in *S. chinensis* cover among plots subject to different treatments at the end of one year. Different letters represent significant differences ($p < 0.05$) in alien cover among plots subject to different treatments, at the end of one year.

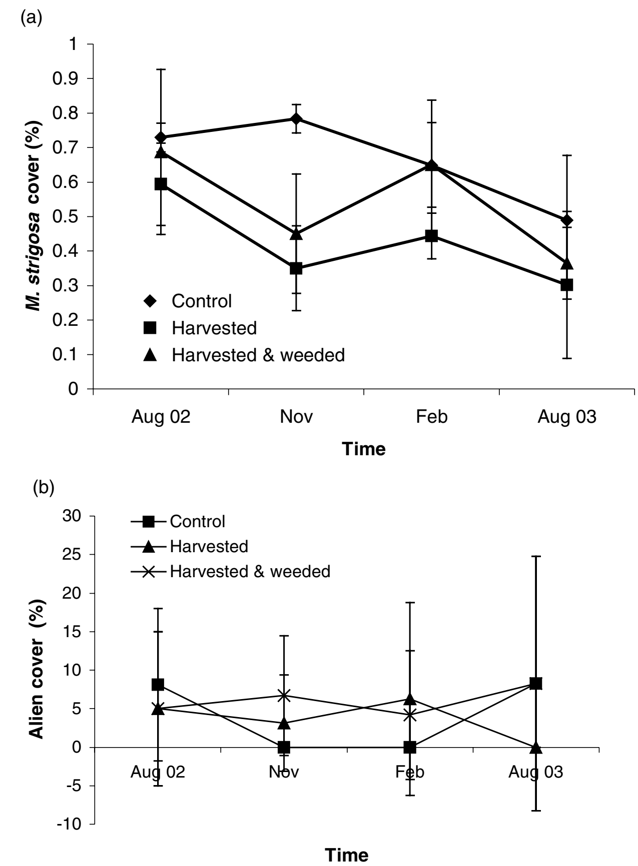

Figure 2 Change in (*a*) *Microlepia strigosa* cover and (*b*) alien cover in plots subject to three different management treatments over a one-year period. Error bars represent ± 1 SD. Harvest of *M. strigosa* fronds and alien weeding was performed after the first census in August 2002. There were no significant differences in *M. strigosa* cover or in alien cover among plots subject to different treatments at the end of one year.

Melicope anisata regeneration and population structure

A total of 496 *M. anisata* stems growing in the 30 transects across the six sites were recorded. For all sites, the structure of *M. anisata* populations was dominated by stems in the smaller size-classes, with few stems that had a basal diameter > 4 cm (Fig. 3). The great majority of the small stems were suckers however, and there were few seedlings (Fig. 3). In addition, there was a significant correlation between proportion of new seedlings (number of seedlings/total number of reproductive-sized stems) and the level of understorey invasiveness ($n = 6$, $r = 0.822$, $p = 0.0127$).

CCA showed that population structure did not vary according to trail accessibility, however, the relationship between population structure and level of invasiveness of the understorey was marginally significant ($p = 0.079$, 9999 permutations), and explained 47.8% of variation in structure among trails. The first eigenvalue was 0.134 and the first axis represented increasing understorey invasiveness, so that the positive end of the axis was associated with sites with a higher level of understorey invasiveness. The smaller size-classes had more of their variation explained by invasiveness than did the larger size classes (Table 3). Seedlings were

Table 3 Results of canoncial correspondence analysis (CCA) to assess relationships between *M. anisata* population structure and level of invasive species in the understorey.

Size-class category (basal diameter, cm)	*Score along 1st CCA axis*	*Variance*	*% Variance explained by level of understorey invasiveness*
Seedlings	−0.49	0.37	64.0
Suckers (<1 cm)	−0.29	0.12	71.4
1–1.9	0.63	0.69	57.7
2–3.9	0.10	0.11	10.0
4–5.9	−0.14	0.23	8.4
6–7.9	−0.21	0.71	6.5
8 or >	−0.06	0.64	0.6

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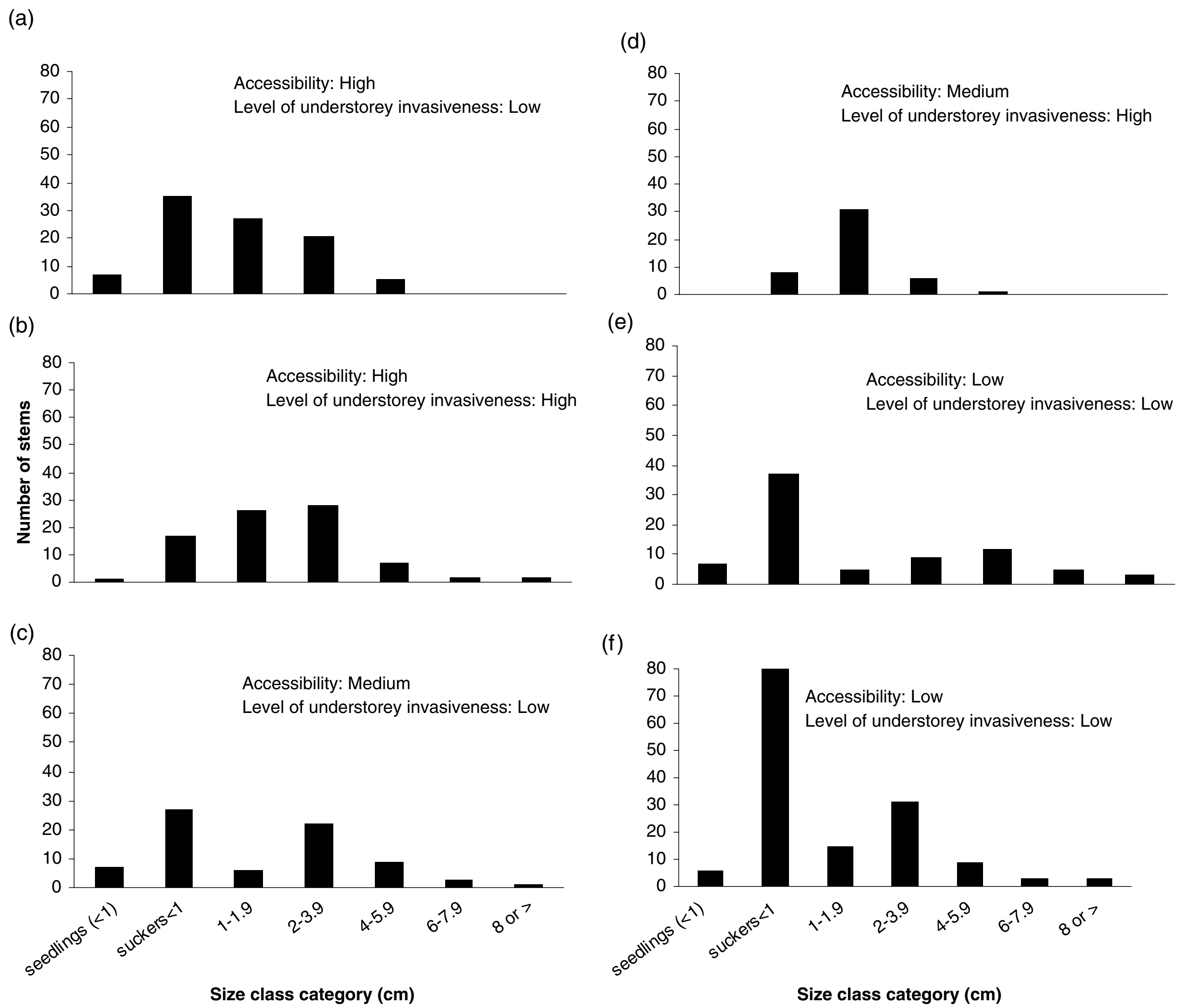

Figure 3 Size-class structure of *Melicope anisata* populations along six trails in Koke'e Park, Kaua'i, that differ in accessibility (low, medium or high) to harvesters and level of invasive species (low or high) in the understorey. Population structure was measured in five, 10 × 20 m transects on each trail. Size-classes are based on basal diameter (cm). (*a*) Nu'alolo Trail, (*b*) Awa'awapuhi Trail, (*c*) Kaluapuhi Trail, (*d*) Honopū Trail, (*e*) Waininiua Trail, and (*f*) Pu'u Ka 'Ōhelo Trail.

associated with the negative end of the axis, indicating that they were more abundant in sites of lower invasiveness, while the reverse was true for stems in the 1–2 cm size-class category (Table 3).

DISCUSSION

Plant gathering practices: past and present

The traditional protocols passed down to Hawaiian hula teachers and lei makers today suggest that in the past, plant gathering for lei used in hula was carried out according to strict protocols that honoured the gods and appear to have promoted resource conservation (Table 1). Our interviews also provide evidence that wild plants such as *A. oliviformis* and *M. anisata* may have been actively manipulated to maintain and increase populations. Similar examples of wild plant management are reported elsewhere (Turner *et al.* 2000; Anderson 2005; Deur & Turner 2005).

Today, some expert cultural practitioners have adapted traditional gathering protocols to meet the changing ecological conditions of Hawai'i's forests, the most widespread adaptation being the concurrent weeding of alien invasive species when gathering. However, many non-expert gatherers do not gather according to traditional protocol. This is likely a consequence of the loss of traditional ecological knowledge and disintegration of the two main social institutions that governed resource use in the past. The system of regulatory laws called the kapu system, which governed all aspects of social behaviour and carried heavy sanctions for

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non-compliance, was abolished in 1819. The ahupua'a system of political and land division, in which commoners lived on and had the right to gather and use the communal resources within their ahupua'a, began to fall apart in 1848. Today, the communal property arrangement of the ahupua'a system has been transformed to a type of open-access system where rules and regulations are not enforced.

Ecological impacts of contemporary gathering in alien-dominated forests

Our ecological studies indicate that the harvest of *S. chinensis* fronds, without weeding, may facilitate the spread of alien invasive species with which it grows. They also show that *S. chinensis* may have more difficulty recovering from harvest when growing in areas with high alien cover. Frond harvest could act to open up space for light-loving alien seedlings to germinate and thereby facilitate their spread. Weeding, as adopted by some cultural practitioners, appears to be an important adaptive practice.

In contrast to *S. chinensis*, decreases in *M. strigosa* frond cover did not affect alien cover. However this may be because alien cover in the *M. strigosa* plots was much lower than in *S. chinensis* plots (Figs 1*b*, 2*b*). However, harvest did significantly decrease *M. strigosa* cover over the short term, and other research has demonstrated that gathering without weeding can lead to decreases in rates of *M. strigosa* frond production (Ticktin *et al.* 2006)

The interpretation of our results is limited by the low number of replicates in our study, lack of significance in some tests possibly resulting from the low power of our statistical analyses. We were unable to increase the number of replicates given the constraints of finding stands that were both large enough for experimental manipulation and free from uncontrolled gathering pressure.

Effects of gathering M. anisata fruit

M. anisata populations did not appear to be affected by fruit harvest. Floyd (1977) found similar results, and other tree species also tolerate high levels of fruit harvest when, as with *A. anisata*, harvest does not involve branch cutting (Peters 1990; Ratsirarson *et al.* 1996).

In contrast to fruit harvest, *M. anisata* populations appear to be much less tolerant of understorey alien invasive cover. This is probably explained by the fact that aliens such as kalihi ginger (*Hedychium garnerianum*) and blackberry *(Rubus argutus*) form dense cover over the soil, blocking the light and space necessary for seedling germination.

In addition, overall densities of *M. anisata* appear to have decreased greatly over time, especially those of seedling and saplings. Densities of *M. anisata* stems that were sampled on the same trails in 1976, were 35–65% lower in 2003 (Floyd 1977). This suggests that *M. anisata* is having more difficulty regenerating from seed than in the past, and this is most probably because of the higher levels of invasive species across all transects. This could also be exacerbated by increased gathering pressure across all trails, or variation in climatic conditions. The concurrent weeding of alien invasive species from the understorey while gathering could also help increase *M. anisata* regeneration.

Challenges and opportunities for conservation

Our ethnographic and ecological data suggest that Hawaiian hula plant gathering practices incorporate conservation measures, but in Hawai'i's increasingly alien-species dominated forests gathering of some species may increase potential for spread of alien invasive species or exacerbate regeneration problems caused primarily by invasive species. While expert cultural practitioners have adapted traditional protocols to foster conservation by incorporating weeding and other practices, other gatherers who do not harvest according to traditional protocols may be contributing to increased forest degradation. In this context, three main factors present opportunities and challenges for native hula plant gathering to better foster conservation.

One issue relates to strengthening the transmission and adaptation of traditional ecological knowledge in the modern context. Expert cultural practitioners have much traditional ecological knowledge that could inform better practices among younger harvesters and that could be combined with scientific information on the ecology of alien invasive species.

A second issue relates to land tenure and land rights, and to the social institutions that govern resource use. Some hula teachers maintain that they need access to, and control over land to reinstate proper gathering protocols and teach their students traditional Hawaiian concepts of *mālama 'āina* (land stewardship) and *kuleana* (responsibility). Several suggested that this could occur in the context of stewardship or co-management agreements, where gathering in parts of state forests is restricted to certain hula schools or other cultural groups, who enforce gathering protocols and are responsible for maintaining populations While open access regimes can lead to resource degradation, some communal property regimes with enforced rules and regulations can foster a strong conservation ethic (Berkes 1999).

Thirdly, there is a need to re-establish the connections between forests and culture in increasingly urbanized environments. Despite Hawai'i's reputation as the endangered species capital of the world, recent surveys indicate that conservation remains a low priority among Hawai'i's citizens (Mālama Hawai'i 2001). In this context, hula is one of the very few remaining activities that tie people to the disappearing native forests. Thus, these species may be critically situated for providing the motivation to foster more interest in, and action towards, forest conservation (Garibaldi & Turner 2004; Ticktin *et al.* 2002). In the case of Hawai'i, the success will depend on the willingness of the forest landowners, gatherers, conservationists and others to take on the challenges and opportunities described above.

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