

Conservation status of the Hawaiian endemic fern *Diplazium molokaiense* (Athuriaceae) in Honomanu, East Maui, Hawai'i

K. R. Wood*

National Tropical Botanical Garden, 3530 Papalina Rd, Kalaheo, Kaua'i, Hawai'i 96741, USA

ABSTRACT: *Diplazium molokaiense* W. J. Rob is one of Hawai'i's rare and endangered endemic fern species. This paper summarizes its conservation status with information concerning its historical and current distribution and its morphology, habitat, and ecology within the Honomanu region of the Nature Conservancy's Waikamoi Preserve, East Maui. With 303 of Hawai'i's plant taxa federally listed as endangered there is an urgent need to conduct rapid biological assessments of remote insular ecosystems and to make conservation collections of the endangered flora. Poorly known species such as *D. molokaiense* could easily become extinct without receiving special attention, while this biodiversity of many tropical areas is rapidly disappearing before having been adequately surveyed.

KEY WORDS: *Diplazium molokaiense* · Pteridophytes · Hawai'i · Endangered species · Conservation · IUCN Red List Category

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INTRODUCTION

Diplazium molokaiense W. J. Rob. (Fig. 1) is a member of the Athuriaceae family, which comprises some 23 genera (Jones 1998, Palmer 2003). Other authors (e.g. Kato & Kramer 1990) place Athuriaceae into the Dryopteridaceae subfamily Athurioideae, and recognize 15 genera. Athurioid ferns are usually terrestrial, but are occasionally epipetric with erect or creeping rhizomes and non-clathrate papery scales, which can be entire or toothed (Jones 1998). Their lower stipes consist of 2 vascular bundles and their sori are elongated along the veins. The indusium is linear, shaped similarly to the sorus, or occasionally cup-shaped or inflated (Kato 1984, Kato & Kramer 1990). *Diplazium*, *Cystopteris*, *Deparia*, and *Athyrium* compose the 4 Hawaiian genera, totaling 11 Hawaiian endemic species (Kato 2001, Palmer 2003).

The genus *Diplazium* consists of ca. 400 species, most of which are tropical (Kato & Kramer 1990, Jones 1998, Palmer 2003). Their scales are born on small

protuberances and their blades are 1 to 4-pinnate, occasionally simple and entire, thin to coriaceous, with the rachis occasionally bearing adventitious buds. Although their veins are mostly free, they can be anastomosing. Sori are elongate on the veins with the lowest pair of a group often united. In *Diplazium* the indusia are linear, attached along the vein, and the spores are bilateral, with winged perispores (Jones 1998). Hawaiian species of *Diplazium* usually occur in mesic to wet forest and other moist habitats.

Diplazium molokaiense is currently one of the most rare species of ferns in the Hawaiian Islands and is federally listed as endangered (USFWS 1998). It easily falls into the critically endangered IUCN Red List Category, which designates this species facing the highest risk of extinction. Recent surveys (e.g. Wood & Bily 2006, also H. Oppenheimer & R. Agurauja pers. comm.) estimate that there are approximately 61 individuals remaining at 2 separate sites on Haleakala Mountain, East Maui, including East Honomanu Stream and the Kula Forest Reserve (Fig. 2).

*Email: kenwood@pelea.org



Fig. 1. *Diplazium molokaiense* in Honomanu Stream, East Maui, Hawai'i

Historical distribution

Diplazium molokaiense was historically recorded from 5 of the main Hawaiian high islands, namely Kaua'i, O'ahu, Lana'i, Moloka'i, and Maui. I reviewed the natural diversity database of the Hawaii Biodiversity and Mapping Program (HBMP) and examined specimens in the Bishop Museum herbarium (BISH), both of which provided the following localities.

Kaua'i. Charles Forbes documented *Diplazium molokaiense* on Kaua'i in 1909, where he observed it at 1158 m (3800 ft) above Waimea Canyon, within the Kaholuamanu region: *Forbes 438.K* (BISH); *Forbes 338.K* (BISH).

O'ahu. *Diplazium molokaiense* was recorded from the Waianae Mountains of O'ahu, where Carl Skottsberg observed it in 1922 around Makaleha Valley at 450 m (1476 ft): *Skottsberg 396* (BISH); and

W. H. Wagner observed it around Schofield Military Reservation in 1945 (HBMP 2006).

Lana'i. On Lana'i, Joseph Rock observed this elusive fern in 1910 at Mahana Valley around 550 m (1800 ft): *Rock 8081* (BISH #16572, holotype); and in 1914 George Munro observed it around Kaiholena at 640 m (2100 ft): *Munro 316* (BISH).

Moloka'i. Wilhelm Hillebrand (1888) documented *Diplazium molokaiense* on Moloka'i some time between 1851 and 1871 when he observed it on the walls of a narrow gulch in Mapulehu Valley, at around 457 m (1500 ft), and mistook it for *Asplenium arboreum* Willd. Subsequently, in 1912, C. Forbes observed it in several other locations on Moloka'i including Wailau Trail at 152 m (500 ft): *Forbes 339.MO* (BISH); Kalua'aha Valley at 305 m (1000 ft): *Forbes 372.MO* (BISH); and in Kala'e at 442 m (1450 ft): *Forbes 38.MO* (MICH), (HBMP 2006).

Mau'i. In 1910, C. Forbes also noted this species in West Maui around Waikapu at 427 m (1400 ft): *Forbes 140.M* (BISH); as did E. Bailey in the 1800's at approx. 427 m (1400 ft) in Iao Valley: *Bailey s.n.* (BISH).

Diplazium molokaiense has been observed more recently, on the slopes of Haleakala, East Maui (Palmer 2003) where W. H. Wagner noted it in Maliko Gulch in 1947 at around 792 m (2600 ft):

Wagner 5162 (MICH), (HBMP 2006). Wagner also documented it around the Ainahou region of Koolau Gap in 1965 at 1707 m (5600 ft), where he noted that ca. 20 plants occurred under overhanging rocks and at the base of cliffs: *Wagner et al. 65 440* (MICH), (HBMP 2006).

Thereafter, *Diplazium molokaiense* was not recorded for 20 yr, until R. Hobdy made an observation of a single plant in 1985 at 1494 m (4900 ft) around the Wai'opai Gulch of Kahikinui, East Maui (R. Hobdy pers. comm.; HBMP 2006). Unfortunately, this individual, and all the other previous sightings, were never relocated.

Current distribution

In August 1997, I observed 17 *Diplazium molokaiense* on the northern face of Haleakala, in Honomanu, East Maui at 1615 m (5300 ft) (Wood 1997, Wood

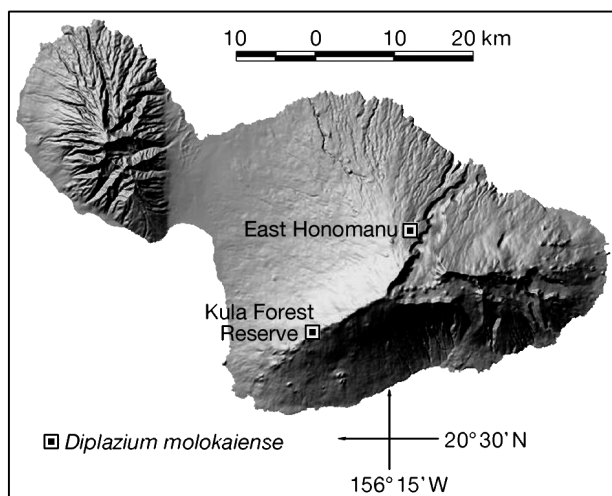


Fig. 2. *Diplazium molokaiense*. Current known distribution on East Maui, Hawai'i

& Perlman 1997). In August 1998, H. Oppenheimer discovered several colonies of *D. molokaiense* just outside Polipoli State Park and within the Kula Forest Reserve, East Maui. The Kula Forest population comprises ca. 46 plants occurring in 3 separate colonies between 1700 and 1737 m (5600 and 5700 ft) (H. Oppenheimer pers. comm.). Both the Honomanu and the Kula Forest populations have since remained in a relatively stable condition.

During recent research within The Nature Conservancy's Waikamoi Preserve (April 2006), *Diplazium molokaiense* was successfully relocated around East Honomanu Stream having not been seen there for 9 yr (Wood & Bily 2006). The following data reflect the status of this population and summarize the ecology of the region.

Habitat of *Diplazium molokaiense* in East Honomanu

The drainages of Honomanu lie just to the east of Waikamoi and flow around 13 km (8 miles) from its upper headwaters at 2500 m (8200 ft) in north central Haleakala down to the sea. The upper regions of its eastern branch, where *Diplazium molokaiense* occurs, are deeply carved and meandering. Botanically, the region represents one of the richer riparian habitats of northern Haleakala. During recent research within an area of ca. 7 ha (17.3 acres), I observed 135 species of vascular plants from 49 families. Of these species, 61 are native ferns or fern allies, 51 are native dicotyledons, and 8 are native monocotyledons. Thirteen of these taxa represent Maui single island endemics (SIE) and the balance consists of 15 non-native naturalized species. When compared to 7 other predominantly

native riparian regions of equal size on the slopes of Haleakala, this Honomanu site records the greatest level of pteridophyte diversity (Wood & Bily 2006).

In the regions between 1400 and 1600 m (4600 and 5300 ft), the walls of the East Honomanu Stream can exceed 60 m (197 ft) in height and can be extremely difficult to traverse. The drainage width ranges between 7 and 20 m (23 and 66 ft) and is pervaded by large basalt chunks and boulders strewn along a smooth river-worn basalt bottom, with some sections thickly covered in lichens. Sections of the stream have impassable 5 to 15 m (16 to 50 ft) high waterfalls that plunge and form deep pools surrounded by amphitheatres of fern-dominated seeping walls. The forests above the riparian zone represent a *Metrosideros polymorpha* Gaudich. montane wet forest community with a 50 to 70% closed canopy reaching heights of 15 m (50 ft) which is dominated by understory trees of *Cheirodendron trigynum* (Gaudich) A. Heller, *Broussaisia arguta* Gaudich, *Ilex anomala* Hook. & Arnott, *Myrsine lessertiana* A. DC, *Melicope clusiifolia* A. Gray, *Kadua affinis* DC, *Kadua axillaris* (Wawra) W. L. Wagner & Lorence, *Coprosma ochracea* W. Oliver, along with *C. montana* Hillebr. and *C. foliosa* A. Gray. Dominant native shrubs include *Vaccinium calycinum* Sm., *V. dentatum* Sm., *Styphelia tameiameia* (Cham. & Schlechtend.) F.v. Muell., and *Rubus hawaiiensis* A. Gray. Common native herbs are *Astelia menziesiana* Sm., *Nertera granadensis* (Mutis) Druce, several *Peperomia* species including *P. cookiana* C. DC, *P. membranacea* Hook. & Arnott, *P. macraeana* C. DC, and the small terrestrial *Pilea peploides* (Gaud.) Hook. & Arnott. Native sedges and grasses densely cover the understory with *Carex alligata* Boott, *Deschampsia nubigena* Hillebr., *Uncinia uncinata* (L.fil.) Kükenth., and *Machaerina angustifolia* (Gaudich) T. Koyama. Common woody climbers and vines are *Freycinetia arborea* Gaudich, and *Smilax melastomifolia* Sm. Common native ferns, which can dominate the understory, include *Diplazium sandwichianum* (C. Presl) Diels, *Athyrium microphyllum* (Sm.) Atkinson, *Adenophorus tripinnatifidus* Gaudich, *Cibotium glaucum* (Sm.) Hook. & Arn., *Cibotium menziesii* Hook., *Elaphoglossum wawrae* (Luer) C. Chr., *Elaphoglossum paleaceum* (Hook. & Grev.) Sledge, *Pneumatopteris sandwicensis* (Brack.) Holttum, *Asplenium hobdyi* W.H. Wagner, *Sadleria pallida* Hook. & Arn., *Sadleriacyatheoides* Kaulf., *S. souleyetiana* (Gaudich) T. Moore, and *Marattia douglasii* (C. Presl) Baker, with many of the species epiphytic and epipetric in association with a rich bryophyte layer over ground, trees, boulders, and basaltic walls.

Below these forests and within the riparian zone where *Diplazium molokaiense* occurs, the forest canopy is around 70% open with occasional emer-

gent 15 m (50 ft) tall *Metrosideros polymorpha* trees, in addition to 8 to 10 m (25 to 33 ft) tall *Cheirodendron trigynum*. Common shrubs and tree species along the banks of the drainage include *Rubus hawaiiensis*, *Coprosma ochracea*, *C. foliosa*, *Broussaisia arguta*, and a well dispersed population of *Gunnera petaloïdea* Gaudich.

The micro-habitat of Honomanu's *Diplazium molokaiense* population is quite similar to that of the site observed and described in 1965 by W.H. Wagner in East Maui's Ainahou, where he also reported it to occur under overhanging rocks. In Honomanu, the ferns occur along the stream on a concave wall vertically carpeted in a fine light-green species of moss. This site stretches around 10 to 12 m (33 to 39 ft) along the eastern bank of the stream. Approximately 12 healthy plants can be seen sparsely distributed along this cool, moist, shaded wall and growing up as high as 5 m above the stream bed. Associated pteridophytes at this site include *Pteris cretica* L., *P. excelsa* Gaudich, *Polystichum haleakalense* Brack., *Pneumatopteris sandwicensis* (Brack.) Holttum, *Selaginella arbuscula* (Kaulf.) Spring, *Diplazium sandwichianum* (C. Presl) Diels, *Coniogramme pilosa* (Brack.) Hieron., *Dryopteris fusco-atra* (Hillebr.) W. J. Rob., *Asplenium hobdyi* W.H. Wagner, *A. excisum* C. Presl, and *A. normale* D. Don.

Threats to this rich natural ecosystem include habitat degradation and destruction by feral pigs, predation by seed-eating rats, mongoose, catastrophic extinction through environmental events, especially flash floods, and competition with non-native plant taxa. During research in April 2006 invasive plant species were represented by only a few scattered individuals and did not dominate any of the ecotones. The invasive species include *Acacia melanoxylon* R. Br. ex Aiton, *Ageratina adenophora* (Spreng.) R. M. King & H. Rob., *Anthoxanthum odoratum* L., *Cerastium fontanum* Baumg. subsp. *triviale* (Link) Jalas, *Epilobium ciliatum* Raf., which represents a new island weed record for Maui, *Epilobium billardierianum* Ser. subsp. *cinereum* (A. Rich.) P.H. Raven & Engelhorn, *Holcus lanatus* L., *Hypochoeris radicata* L., *Juncus planifolius* R. Br., *Lapsana communis* L., *Prunella vulgaris* L., *Rubus argutus* Link, *Rumex acetosella* L., and *Youngia japonica* (L.) DC.

Cortaderia jubata (Lemoine ex Carrière) Stapf, which can be highly invasive, was first reported in the general region at 1540 m (5050 ft) (Wood 1997) and since then, in spite of removal efforts, has spread into several adjacent regions of Haleakala's northern slopes.

Although this population of *Diplazium molokaiense* is predominantly well protected under concave stream bank walls, it would seem that some plants near ground level are affected by flash flood waters. During this recent survey, it was observed that several individ-

uals near the base of the overhanging stream walls had been dislodged by recent storms of heavy rain. Record amounts of rainfall in the early months of 2006 exceeded normal levels by far. Of the 17 individuals observed in 1997, 15 remain. Considering the rarity of this species, this represents a significant loss of 11.7% for the Honomanu population and an overall loss of 3.3% for the entire species. Of those 15 remaining individuals in Honomanu, only 12 appear to be in a stable condition, with an additional 3 mature plants barely clinging onto the lower wall where the stream bed meets the concave bank. I also observed and collected 1 individual that had become completely dislodged from the wall. This rhizome was submitted for cultivation at the National Tropical Botanical Garden (NTBG), along with spores from 3 separate individuals. In addition, fronds from this dislodged plant were submitted for scientific study as herbarium specimens and leaf material was preserved in silica for DNA sequence studies.

Morphology of the Honomanu population

The following list describes the characteristics of individuals within the East Honomanu population of *Diplazium molokaiense*:

Rhizome: brown, short, decumbent, somewhat twisted
Stipes: green, grooved, up to 14 cm, lower third black-brown densely covered with brown scales, scales at the base of the stipe up to 1 cm long, 1 mm wide at base, attenuate, upper stipe sparsely covered with light brown to gray-brown narrow scales up to 4 mm long

Blades: dark green and glossy, 5 to 7 arching pendent, lanceolate-oblong up to 19 cm long, chartaceous, 1-pinnate to 1-pinnate-pinnatifid, frond tips pinnatifid acuminate, rachis green and grooved

Pinnae: up to 12 pairs, stalked up to 4 mm long, oblong-lanceolate to subfalcate up to 5.2 cm long, 1.7 cm wide, margins shallowly crenate, acroscopic lobe truncate overlapping rachis, pinnae tip acute or short acuminate, pinnae base cuneate, veins pinnately branched and free ending

Sori: along lower half of pinnae, elongate, slightly curved outward up to 11 mm long.

Material examined

East Maui. Honomanu east branch, lower TNC Waikamoi Preserve, near boundary of East Maui Irrigation property, in deeply carved drainage, 27 Aug 1997, K. R. Wood & Perlman 6642 (BISH, PTBG), loc. id., 12 Apr 2006, K. R. Wood & Bily 11824 (BISH, PTBG, US).

Conservation status. IUCN Red List Category: critically endangered.

When evaluated using the IUCN endangerment criteria (IUCN 2001, see also www.iucnredlist.org/info/categories_criteria2001), *Diplazium molokaiense* falls into the Critically Endangered (CR) category, which designates this species facing the highest risk of extinction. *D. molokaiense* meets the IUCN criteria in that it has an extent of occurrence of less than 100 km², a severely fragmented distribution, a continuing decline in the number of mature individuals, an area of occupancy of less than 10 km², a continuing decline in quality of habitat, a population size of fewer than 250 mature individuals (i.e. 61), and no subpopulation containing more than 50 mature individuals. My formal evaluation can be summarized by the following IUCN hierarchical alphanumeric numbering system IUCN (2001) IUCN Red List Categories and Criteria Version 3.1. of criteria and subcriteria: **CR B1ab(v) + 2ab(iii,v); C2a(i)**.

SUMMARY

Monitoring and propagating rare outlying populations of endangered species such as *Diplazium molokaiense* can be challenging on many levels. The physical difficulties and logistical costs of accessing remote isolated locations can be extreme. Acquiring permits for conducting applied conservation research can, at times, be excessively time consuming, and with limited funds, a paucity of trained field biologists, and an overabundance of federally listed endangered plant taxa in Hawai'i (i.e. 303), it may be many years before conservation efforts can be continued.

Having biologically rich ecosystems rapidly assessed and creating conservation collections of Hawai'i's endangered flora has been a prime directive of the NTBG and the local conservation community. Currently, the NTBG is growing gametophytes from the April 2006 spore collection of *Diplazium molokaiense* and is cultivating the single rhizome recovered from recent storm damage (NTBG Acc. # 060327).

There are currently calls for an additional biotic inventory to be scheduled by The Nature Conservancy of Hawai'i in order to further evaluate potential habitat for *Diplazium molokaiense* within their Waikamoi Preserve property along the East Honomanu Stream, particularly above the 1650 m (5400 ft) falls of that region.

In addition, the collection and sowing of spores from other wild individuals should continue in order to help prevent the extinction of this species by conserving an adequate number of individuals for *inter situ* propagation and eventual re-introduction back into their natural ecosystems.

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