WĒKIU BUG MITIGATION REPORT

Prepared for the Keck Outrigger Telescopes Project Jet Propulsion Laboratory California Institute of Technology Pasadena, California 91109



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I. EXECUTIVE SUMMARY

The Mauna Kea Science Reserve is located on the summit of the tallest mountain in Hawai'i, (13,796 feet). Within the reserve are the world's two largest optical telescopes, constituting the W. M. Keck Observatory (WMKO), operated by the California Association for Research in Astronomy (CARA). Also found within the Mauna Kea Science Reserve is a unique natural environment that supports the Wēkiu bug, a rare insect found only in this extreme habitat. Some of this habitat is found directly adjacent to and below the WMKO.

Outrigger telescopes have been proposed as an addition that will greatly enhance the scientific capability of the WMKO. It is possible that construction and operation of the Outrigger Telescopes could have a deleterious impact on the Wēkiu bug population. This Wēkiu Bug Mitigation Report was developed to provide guidance for protecting and enhancing the Wēkiu bug population and habitat during construction and operation of the proposed Outrigger Telescopes. This Report is consistent with the CARA goal of good stewardship of the natural environment on the summit of Mauna Kea.

This Wēkiu Bug Mitigation Report addresses five major concerns related to the on-site construction, installation, and operation of the Outrigger Telescopes at the WMKO site that have the potential to impact Wēkiu bug populations: (1) Habitat Restoration and Protection, (2) Dust, (3) Hazardous Materials, (4) Trash, and (5) Alien Arthropods. In each section of this Report we provide an analysis of the potential impacts, and make specific recommendations to mitigate those impacts. These include guidelines, procedures, and actions for protection and enhancement that architects, designers, contractors, builders, and operators of the Outrigger Telescopes should take to prevent impact to the habitat and population of the Wēkiu bug. A compilation of these recommendations can be found in Section X.

The National Aeronautics and Space Administration (NASA), through a contract with the Jet Propulsion Laboratory (JPL)/California Institute of Technology (Caltech), is the sponsor of this Mitigation Report. The University of Hawai'i (UH), the Institute for Astronomy (IfA), and CARA have provided significant assistance and collaboration.

II. INTRODUCTION

The summit of Mauna Kea, on the Big Island of Hawai'i, is home to the largest observatory complex in the world. The summit is also home to unique plants and animals, including the Wēkiu bug. One of the principal habitats of this rare insect is directly adjacent to and below the Pu'u Hau 'Oki crater rim site of the W. M. Keck Observatory (WMKO).

Outrigger telescopes have been proposed as an addition to the WMKO. It is possible that construction and operation of the Outrigger Telescopes could have a deleterious impact on the Wēkiu bug population within the crater. This Mitigation Report was developed to provide recommendations for protecting and enhancing the Wēkiu bug population. This Report is consistent with the California Association for Research in Astronomy (CARA) goal of good stewardship of the natural environment on the summit of Mauna Kea.



Figure II-1. Mauna Kea summit in winter. Photo by D.A. Swanson, courtesy US Geological Survey.

Astronomy on Mauna Kea

Mauna Kea is a dormant shield volcano. It is the largest mountain on earth, rising 32,000 feet from the ocean floor to its summit, 13,796 feet above sea level. At the summit the night sky is dark and transparent, providing what is considered to be among the best astronomical observation conditions in the world (Parker 1994).

The Mauna Kea Science Reserve, an 11,288-acre area at the summit of Mauna Kea, is the site of the world's two largest optical telescopes, Keck I and Keck II, together constituting the WMKO. The Mauna Kea Science Reserve is leased by the State of Hawai'i to the University of Hawai'i (UH), which in turn subleased certain areas to various observatories including the WMKO, operated by CARA. Astronomy institutes worldwide make use of the unparalleled astronomical capabilities on Mauna Kea.

The National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL) of the California Institute of Technology have collaborated with CARA in the development of new astronomy techniques for detecting distant planets. This collaboration includes the proposed Outrigger Telescopes project at the WMKO site that will combine the light from the two existing Keck telescopes using a technique known as optical interferometry. This project is an important part of NASA's Origins Program. The Keck Telescopes and their Interferometer will provide essential elements for this project, including testing of optics and other companion investigations. The current plans call for adding four to six Outrigger Telescopes on the existing graded areas of the WKMO site.

The Wēkiu Bug

Mauna Kea is the site of one of the most unusual natural habitats in the world. The Hawaiian Islands are isolated in the mid-Pacific Ocean, over 2,000 miles from the nearest continent. This isolation has led, over millions of years, to the development of unique species. Plants and animals occur on or near the summit of Mauna Kea that are found nowhere else. Over 95% of native Hawaiian plants and animals are found only in Hawai'i (Carlquist 1980). These include the Wēkiu bug, *Nysius wekiuicola*, a true bug found only above 12,800 feet on Mauna Kea.

The summit of Mauna Kea is an island within an island, separated from other ecosystems by high elevations as well as vast oceans. The species found on Mauna Kea are not only

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unique; they are rare and limited in population and area of distribution. One of the principal habitats of the Wēkiu bug is the northwest-facing inner slope of Pu'u Hau 'Oki, directly adjacent to and below the crater rim site of the existing WMKO and proposed Outrigger Telescopes (Howarth et al. 1999).



Figure II-2. Wēkiu bug, *Nysius wekiuicola*, native to the summit area of Mauna Kea. *Photo courtesy W.P. Mull.*

The Wēkiu bug is a "true bug" of the order Heteroptera. Wēkiu is the Hawaiian word for top or summit (Pukui and Elbert 1971). This small insect, (3.5 to 5 mm long), has made a remarkable adaptation in feeding behavior. Many true bugs, including most of those found elsewhere in Hawai'i, are herbivores and feed on seeds and plant juices. The Wēkiu bug is a predator. It has presumably made this evolutionary adaptation because of the lack of suitable plants at the summit. Wēkiu bugs use their straw-like mouthparts to feed on wind-carried insects blown up the mountain from the surrounding lowlands. These aeolian insects accumulate in protected pockets on the high-elevation cinder cones and are not adapted to the cold temperatures at the summit. They quickly become moribund and are thus easy prey for foraging Wēkiu bugs.

Insects are generally considered to be cold-blooded. That is, their body temperatures rise and fall with the environmental temperature. Insect enzymes function efficiently only with a limited range of temperatures that varies among species. The temperature at which an insect dies depends on the species, duration of exposure, and interaction with other factors including blood chemistry. At temperatures below the preferred range, insects become increasingly less active until they are finally unable to move. They may remain alive under these conditions for a considerable time, but will ultimately die.

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Wēkiu bugs are known to forage for their prey (moribund due to cold) near the edges of the snow pack. The blood, or haemolymph, of many insects that live in cold environments contains glycerol compounds that discourage the formation of ice crystals (Chapman 1969). Wēkiu bugs may have glycerol or similar substances in their blood that allow them to continue normal activities in sub-freezing temperatures while their prey do not.

Wēkiu bugs may also be dependent on slowly melting snow for moisture. The Mauna Kea summit area is extremely dry, but snow does accumulate in winter. The area of snow accumulation and the distribution of Wēkiu bugs are highly correlated. This is suggestive observational evidence that Wēkiu bugs are dependent, for some reason, on snow.

The areas of the summit most densely populated by Wēkiu bugs are the inner slopes of the pu'u craters. Those slopes are composed of loose, volcanic cinder. The porous structure of the surface rubble is thought to provide hiding spaces for Wēkiu bugs, and thermal protection from the warm, mid-day sun. Wēkiu bugs have been observed foraging at night on compacted areas, but they spend most of their lives below the surface. Frost heaving and snowmelt contribute to the loose, porous structure of the surface habitat.

The Wēkiu bug population apparently experienced a significant decline in activity between 1982 and 1996 (Howarth et al. 1999). The causes of this population decline are not known. Hypotheses include climate change, a possible long-term downward trend in winter snowpack depth and persistence, introduction of predatory alien arthropods, mechanical habitat disturbance from observatory construction, recreationalist impacts, vehicle impacts, and the possible presence of environmental contaminants from human activities. These hypotheses have not been well studied. More information, gathered through long-term monitoring and research programs, is needed to establish the actual causes of the Wēkiu bug population decline.

There is concern that construction of the Outrigger Telescopes could have a deleterious effect on the Wēkiu bug population within the crater. Wēkiu bug habitat consists of special conditions: at high-elevations on Mauna Kea, in ice- and gravity-sorted volcanic cinder of optimal depth and porosity, in limited locations subject to snow accumulation and aeolian insect deposition (Howarth et al. 1999). Outrigger Telescope construction will be limited almost entirely to the previously graded site of the WMKO. No Wēkiu

bugs have been found on this graded area, nor is it considered to be suitable habitat. The slopes below the WKMO site, however, are considered to be excellent Wēkiu bug habitat. Side-cast materials, dust, trash, chemical spills, and other construction-related externalities, should they occur on slopes within the Pu'u Hau 'Oki crater, could possibly impact the resident Wēkiu bug population. Any such habitat disturbance should be mitigated.

Environmental Mitigation

Environmental mitigation is the protection and enhancement (restoration) of natural resources from activities that could have potential negative impacts to those resources. This Mitigation Report provides recommendations for protection and enhancement of the Wēkiu bug habitat and population adjacent to the Outrigger Telescope construction site.

The National Aeronautics and Space Administration (NASA), through a contract with the Jet Propulsion Laboratory (JPL)/California Institute of Technology (Caltech), is the sponsor of this Mitigation Report. Over the last twenty years NASA and JPL have made major contributions to the study of natural environments on Earth. Sponsored by NASA's Office of Earth Sciences, JPL engineers and scientists have developed a series of Earthorbiting missions that have advanced ecology, geology, hydrology, oceanography, climatology, forestry and other earth science disciplines. These include the Seasat satellite, multiple Shuttle Imaging Radar systems, the Topex/Poseidon satellite, the Jason-1 satellite, the Advanced Earth Observing satellite, the Quicksat satellite, and the Upper Atmosphere Research satellite. Future missions in various stages of design and construction include the Multi-angle Imaging Spectro Radiometer, the Atmospheric Infrared Sounder, the Tropospheric Emission Spectrometer, the Active Cavity Radiometer, and the Gravity Recovery and Climate Experiment's twin satellites (JPL 1999). Data from the satellites and the space shuttle have been combined with land-, air-, and sea-based measurements for calibration and verification (JPL 1999). A wealth of environmental information has resulted.

Protection and enhancement of our natural environments is an important goal of our nation's civil space program. All the JPL missions cited above, and many others not mentioned, were designed to increase our knowledge about environments here on Earth. Past missions, and those currently in operation, have contributed substantially to our understanding and stewardship of ecosystems. In addition, both NASA and JPL have

instituted extensive environmental controls at their facilities, and have demonstrated a fundamental concern for our natural resources.

Astronomy organizations worldwide have been privileged to establish and operate observatories on Mauna Kea. It is their concurrent responsibility to be good stewards of the special natural environment there. Appropriately, CARA, JPL, and NASA have made a commitment to protect and enhance the Wēkiu bug population and habitat during the proposed on-site construction and operation of the Outrigger Telescopes.

In order to achieve the goal of protecting Wēkiu bug habitat, JPL contracted with Pacific Analytics to develop this Wēkiu Bug Mitigation Report and a Wēkiu Bug Monitoring Plan. This report presents our mitigation recommendations.

In developing this Mitigation Report, we have held comprehensive discussions with the managers, designers, and potential operators of the proposed Outrigger Telescopes regarding the cost or feasibility of implementing different mitigation actions. We have inspected and evaluated the proposed building site. Construction plans, grading plans, and other documents were examined. Options and alterations were evaluated in a collaborative manner, and modifications were made based on those discussions. Entomologists with special knowledge of the Wēkiu bug were consulted. Dr. Gregory Brenner of Pacific Analytics was one of the principal investigators of the 1996-97 Mauna Kea Science Reserve Arthropod Assessment (Howarth et al. 1999). Extensive discussions were held with other entomologists and natural resource experts.

III. OBJECTIVES

The general objectives of this Mitigation Report are to aid in the protection and enhancement of the Wēkiu bug population and habitat adjacent to the WMKO, during construction and operation of the proposed Outrigger Telescopes.

This Mitigation Report recommends guidelines, procedures, and actions for protection and enhancement that architects, designers, contractors, and operators of the proposed Outrigger Telescopes should take to prevent impact to the habitat and population of the Wēkiu bug. They are presented in the following Sections:

- Section IV Habitat Restoration and Protection
- Section V Dust Control
- Section VI Hazardous Material Control
- Section VII Trash Control
- Section VIII Alien Arthropod Control

Each Section begins with an analysis of potential impacts. Recommendations follow, each discussed in detail. In addition, Section IX of this Report discusses the compliance and effectiveness monitoring needed to insure that the adopted recommendations are implemented, and to measure any changes in the adjacent Wēkiu bug population.