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THE DISTRIBUTION OF *MYRICA FAYA* AIT. IN THE STATE OF HAWAI'I

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ABSTRACT

The objective of this study was to map the distribution and abundance of *Myrica faya* (firetree) in the State of Hawai'i. Reconnaissance data were used to map 34,365 total hectares (85,912 acres) of infestation, categorized into three density classes, throughout the state. Infestations of 28,906 hectares (72,265 acres) occur on the island of Hawai'i, 1908 hectares (4770 acres) on Maui, 1007 hectares (2518 acres) on Lāna'i, 174 hectares (435 acres) on O'ahu, and 2370 hectares (5925 acres) on Kaua'i. Distribution ranges in elevation from as low as 425 m (1400 feet) on Lāna'i to as high as 1940 m (6400 feet) on the slopes of Haleakalā on Maui. *Myrica faya* occurs on recent, thin ash over pāhoehoe lava as well as on deep, well developed silty clay loam soil. It is found in montane rain forest habitats and in dry scrub marginal to submontane seasonal forest. Examination of the distribution patterns of *M. faya* implies that this species has not yet reached the limits of its potential distribution in Hawai'i.

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INTRODUCTION

Myrica faya Ait. (Myricaceae), commonly called faya or fire tree in Hawai'i, is a native of the Azores, Madeira, and Canary Islands in the Atlantic Ocean. From there it was introduced to Hawai'i in the late 1800s by Portuguese immigrants presumably as an ornamental (Neal 1965, Hasselwood and Motter 1983, Smathers and Gardner 1979, Fosberg 1937, Gardner and Kageler 1982). Because of its habit of forming multiple branches near the base of the main stem (Smathers and Gardner 1979), it has often been described as a shrub or small tree reaching heights of only 4 to 6 meters (13 to 20 feet) (Neal 1965, Hasselwood and Motter 1983, Fosberg 1937). However, in the Hāmākua region of the island of Hawai'i, M. faya grows to over 16 meters (50 feet) high, forming dense canopies with an understory devoid of other plant life (Smathers and Gardner 1979). The plant has narrow, pointed, smooth, shiny, dark green leaves with entire or toothed margins (Neal 1965, Hasselwood and Motter 1983). Although M. faya has a strong tendency toward dioecism, a few staminate flowers are found on pistillate plants and a few pistillate flowers are found on staminate plants (Gardner 1985). Staminate flowers with four stamens each are borne on small catkins near branch tips. Three pistillate flowers that may be joined and accompanied by one bract are grouped in small catkins further back from the branch tip (Fosberg 1937, Neal 1965). Fruits are small, edible drupes that form dense clusters changing from green through red to purple when ripe (Neal 1965, Fosberg 1937, Lawrence 1951).

The purpose of this study was to map the distribution and abundance of M. faya in the State of Hawai'i. These results will serve as a data base for location of all M. faya infestations for implementation of a biological control program should an appropriate agent be found, and for future studies of the spread of this species in Hawai'i.

LITERATURE REVIEW

The Hawaiian Sugar Planters' Association obtained seeds of M. faya from a Portuguese farmer on Hawai'i for use in reforestation attempts (Fosberg 1937). Planting of M. faya for reforestation purposes has been recorded for the islands of Kaua'i, O'ahu, and Hawai'i (Skolmen 1979). The majority of these plantings were in the 1920s, and by 1937 the aggressive, noxious character of this species had been noted along with its spread to Maui (Fosberg 1937). The continued spread of M. faya led the Territorial Board of Agriculture and Forestry to begin attempts to eradicate it in 1944 (Neal 1965). Also in the mid 1940s, M. faya was first observed by the management of Shipman Estate to be spreading in the Volcano area on the island of Hawai'i. An attempt was made by these personnel to control this species in that area (T. Lindsey, pers. comm.). Myrica faya was also declared noxious for state land leases since it spreads rapidly and

forms a dense cover that crowds out desirable species (Hosaka 1945, Haselwood and Motter 1983). Despite the state's efforts and those of the National Park Service to control this species, it has continued to spread and now occurs on all major Hawaiian Islands except Kaho'olawe, Moloka'i, and Ni'ihau. Estimates of the total infested area have varied over the years: 3280 hectares (8200 acres) (Yamayoshi 1954), 8550 hectares (21,375 acres) (Anonymous 1962), 16,000 hectares (40,000 acres) (Walters and Null 1970), but the most recent estimate showed 21,575 hectares (53,938 acres) to be supporting M. faya populations of various densities (Watanabe 1982): Hawai'i contained 20,000 hectares (50,000 acres); Maui, 1200 hectares (3000 acres); O'ahu, 40 hectares (100 acres); Kaua'i, 130 hectares (325 acres); and Lāna'i, 205 hectares (512 acres).

Myrica faya has been described as being distributed where average annual rainfall is 35 inches or more in vegetation zones C_1, C_2, D_1, and D_2 of Ripperton and Hosaka (1942) (Anonymous 1962, Hosaka and Thistle 1954). Within these broad limits, however, M. faya seems to be able to adapt to a wide range of habitats. Clarke (1978) has described the distribution of M. faya in Hawaii Volcanoes National Park (HAVO) as a horizontal band between 2200 feet (665 m) and 4000 feet (1210 m) elevation that includes 11 soil types and 15 of the vegetation units described for the park by Mueller-Dombois and Fosberg (1974). Average annual rainfall within the park distribution ranges from 1270 mm (50 inches) to over 2540 mm (100 inches) and average annual temperture ranges from 15°C (60°F) to 22°C (72°F) (Clarke 1978). This wide range of habitats where M. faya has been found may indicate that it has not yet occupied its full potential range.

Along the Hāmākua coast on the island of Hawai'i an estimated 6000 hectares (15,000 acres) of M. faya infestation has been classified as heavy (Watanabe 1982). In this region M. faya grows over 16 m (50 feet) tall and forms dense interlocking canopies with no understory (Smathers and Gardner 1979). The absence of other plant species under the M. faya canopy may be due partially to shading. However, allelopathic activity has been reported for a closely related species (M. cerifera L.) from the southeastern United States (Dunevitz and Ewel 1981). Thus it is possible that the lack of an understory in these stands may be due not only to canopy shading, but also to allelopathic activity (Smith 1985).

Current evidence suggests that the seeds of M. faya are dispersed primarily by birds (Smathers and Gardner 1979). The extensive, uniform distribution of M. faya in remote areas and the close spatial association of this species with other tree species, especially 'ōhi'a (Metrosideros polymorpha Gaud.), imply this means of dispersal. Species of birds commonly associated with dispersal of M. faya include

the Japanese White-Eye (Zosterops japonica Temminck & Schlegel), the Common Myna (Acridotheres tristis L.), the Red-Billed Leiothrix (Leiothrix lutea (Scopoli)), and the 'Ōma'o (Phaeornis obscurus (Gmelin)) (Gardner and Davis 1982, Smathers and Gardner 1979, Clarke 1978, LaRosa et al. in press). Low germination rates of M. faya seeds collected in the field contrasted with copious seed production and rapid dispersal of the species has led to the hypothesis that scarification from bird ingestion greatly improves germination rates for M. faya (Clarke 1978). This idea was supported by experiments that showed increased amount and speed of germination due to mechanical or chemical scarification of seeds of M. cerifera (Ewel et al. 1982). However, germination tests of M. faya in Hawai'i showed no significant difference in amount or rate of germination between seeds passed through birds and apparently mature, viable seeds collected in the field (LaRosa et al. in press). Feral pigs (Sus scrofa L.) have also been identified as dispersal agents for seeds of M. faya. Seedlings of this species have been observed growing directly from pig rooting areas in HAVO (Clarke 1978). Stomach content analysis of feral pigs in HAVO have shown significant percentages of M. faya seeds during certain times of the year (Stone and Taylor 1984).

Control efforts have been implemented primarily by the State of Hawai'i and HAVO. The effort by the state has been conducted over the last 25 years but variations in availability of funding and manpower have resulted in fluctuations in intensity of this effort. Herbicides are the primary method of control. Of the various herbicides tested by the state, Tordon 22K has been the most effective, producing a complete canopy kill and a 99 percent control of resprouting (Walters and Null 1970, Smathers and Gardner 1979, R. Kami, pers. comm.). In HAVO a basal bark application of a 4% Kuron in diesel oil solution was effective, and a method to introduce Roundup directly into the vascular tissue of M. faya through a cut branch was suggested for remote areas and less than ideal weather conditions (Gardner and Kageler 1982). In some areas, pasturelands have been cleared of invading M. faya trees with bulldozers by private landowners (R. Kami, pers. comm.).

In 1955 Mr. Fred Bianchi, an exploratory entomologist from Hawai'i, was sent to the native habitats of M. faya (the Azores, Madeira, and the Canary Islands) to search for potential biological control agents for this species. A fungus disease caused by Dothiorella berengeriana Sacc. initially appeared promising but was later rejected on the basis of tests conducted in Portugal that showed a lack of host specificity (Gardner and Davis 1982, Gardner 1984). Other disease-causing organisms were observed on this trip but none has been sufficiently tested for use as a control agent. Krauss (1964) has summarized his and others' previous observations of insects associated with M. faya and related

species. However, insects collected during these exploratory efforts either proved ineffective or failed to propagate. Krauss (1964) also discussed other apparently pathogenic organisms on Myrica spp., but no attempt has been made to test these as control agents in Hawai'i (Gardner and Davis 1982). Consequently, another exploratory trip to the native habitats of M. faya was made (Gardner 1984, Hodges and Gardner 1985). Observations from this trip indicate that M. faya is generally abundant and healthy in its native habitats and that biological agents in these areas are not important factors in limiting the growth, reproduction, or distribution of this species. However, at least two diseases and two insects were found that merit further investigation and are the subjects of current research in a biological control program for M. faya in Hawai'i.

METHODS

The maps of the distribution of M. faya in Hawai'i are based on reconnaissance data. Local persons familiar with the distribution of M. faya on a particular island or in a particular area were consulted to establish general areas that were infested with this species. The majority of these areas were visited, often in the company of the local person, and roads and trails in the area were driven or walked as completely as possible. Distributions in several areas were plotted from data provided by resource persons since access to these areas was limited by physical or political factors. Reconnaissance data collected included the limits of distribution, the form and structure of the infestation, and general density of the populations of M. faya observed. These data were collected with the aid of compass bearings to identifiable landmarks, altimeter readings of elevation, and U. S. G. S. topographic maps. Final drafts of the distribution maps were plotted on U. S. G. S. 1:24,000, 1:62,000, or 1:100,000 scale topographic maps. Distributions for each island were summarized on U. S. G. S. 1:62,500, 1:100,000, or 1:250,000 scale maps. Areas of M. faya distribution were determined by electronic planimeter on the largest scale maps that were used to plot the distribution for a particular area.

Heavy density areas were defined as containing extensive stands of M. faya with over 60% crown cover, frequently with interlocking crowns. In the Hamakua District of the island of Hawai'i, this density class is interspersed with pastureland that has been reclaimed by clearing with a bulldozer. Moderate density areas have large stands of M. faya with crown cover less than 60% but more than 25%, with some locally dense stands. Light density areas have less than 25% crown cover of M. faya but the species is usually common throughout the area. This classification includes areas where M. faya forms small stands in gullies or other protected sites, where it occurs in forest openings and along roads and trails, and where its range seems to be

expanding with scattered, mostly small individuals.

RESULTS

Hawai'i

In the Hāmākua District, M. faya is found between Laupāhoehoe and Honoka'a between 600 m (2000 feet) and 1335 m (4400 feet) elevation (Figs. 1-2). In this area 11,755 hectares (29,390 acres) are mapped as infested, of which 2860 hectares (7150 acres) are classified as heavy density and 2395 hectares (5990 acres) as moderate density. Much of this area is ranchland where M. faya has been cleared from pasture areas, but extensive areas are still covered with heavy or moderate density stands of large (20 m tall) M. faya trees.

Another major infestation is in the vicinity of Volcano Village, including a large portion of HAVO (Figs. 1, 3-6). The distribution in this area ranges between 545 m (1800 feet) and approximately 1210 m (4000 feet) elevation and covers 16,600 hectares (41,500 acres) of which 2915 hectares (7290 acres) are classified as moderate density and 4.3 hectares (10.8 acres) as heavy density. The exact upper elevation limit of M. faya on the Keauhou Ranch had to be plotted from estimates by the ranch manager, extrapolation from the surrounding limits of distribution, and from views available of Keauhou Ranch from the HAVO boundary since permission to survey this area was denied by the owner, the Bishop Estate. The Volcano area has a wide variety of habitats including montane 'ōhi'a rain forest near Volcano Village and the Kīlauea summit area, sub-montane seasonal forest near Āinahou Ranch and Hilina Pali Road, montane seasonal forest converted to pasture on Keauhou Ranch adjacent to the Mauna Loa Strip Road area of HAVO, and dry scrubland with scattered trees in the Ka'ū Desert. The vegetation, climate, and substrates of the wide variety of habitats in which M. faya is found within HAVO have been described in detail by Doty and Mueller-Dombois (1966) and Mueller-Dombois and Fosberg (1974).

In the Ka'ū District, a moderate density infestation of M. faya occurs on the Kapāpala Ranch adjacent to the Ainapō Cabin between 1060 m (3500 feet) and 1140 m (3760 feet) elevation (Figs. 1, 7). Total area of this population is 32 hectares (80 acres). This ranchland consists of pasture mixed with stands of alien shrubs and trees on steeper slopes. Myrica faya has also been reported in the Kiolaka'a-Kea'a Homesteads Addition portion of the Ka'ū Forest Reserve at 720 m (2380 feet) (Fig. 1). Data from a Hawai'i State Forestry survey of this area recorded observation of a single plant (L. Cuddihy, pers. comm.). A field trip to this area failed to locate the site, but a subsequent review of the State Forestry data resulted in a confident plot of the location (S. Anderson, pers. comm.).

In the North Kona District, M. faya occurs on the slopes of Hualālai between 1470 m (4850 feet) and 1830 m (6040 feet) elevation (Figs. 1, 8). The infestation covers 520 hectares (1300 acres) of which 14 hectares (35 acres) are classified as moderate density. This population is in a remote area on privately owned ranchland. Therefore, the distribution was mapped from data supplied by the State Department of Agriculture which is conducting a control program in the area (R. Kami, pers. comm.).

Total area of M. faya distribution on Hawai'i is 28,906 hectares (72,265 acres), of which 2864 hectares (7160 acres) are classified as heavy density and 5354 hectares (13,385 acres) are classified as moderate density (Fig. 1). This area includes 12,200 hectares (30,500 acres) within HAVO of which 4.3 hectares (10.8 acres) are classified as heavy density and 2857 hectares (7142 acres) as moderate density.

Maui

Myrica faya is found in the Kula area on the western slopes of Haleakalā between 970 m (3200 feet) and 1940 m (6400 feet) elevation (Fig. 9). The area consists of ranchland and small, private residential parcels of land. Total area of M. faya distribution on Maui is 1908 hectares (4770 acres) of which 152 hectares (380 acres) are classified as moderate density. The distribution in this area may be limited by the efforts of Haleakalā Ranch which maintains a crew that works only on weed control. Only one individual of M. faya along the Haleakalā Highway at 1290 m (4250 feet) elevation and a small stand in Hāpapa Gulch were noted within the boundaries of Haleakalā Ranch (Fig. 9). However, these individuals indicate that the ranch is suitable habitat for M. faya infestation. The State Department of Agriculture attempted to control M. faya on Maui in the mid-1970s, but logistical difficulties related to the large number of small, privately owned parcels of land led to abandonment of the effort (E. Tamura, pers. comm.).

Lāna'i

Myrica faya occurs in the mountainous portion, or Lāna'i Hale area, of the island (Fig. 10). The distribution ranges between 425 m (1400 feet) in protected gullies to the summit of the island at 1020 m (3370 feet) elevation. Total area occupied is 1007 hectares (2518 acres) of which 14 hectares (35 acres) are classified as moderate density and 58 hectares (145 acres) as heavy density. This area is rough, mountainous terrain consisting of narrow ridges and steep slopes. The heaviest densities of M. faya are on very steep slopes.

O'ahu

Myrica faya is found in the Waianae Mountains between

610 m (2000 feet) and 948 m (3127 feet) elevation (Fig. 11). The center of distribution is at the southern end of the Waianae Mountains between Mauna Kapu and Pu'u Kaua in the Honouliuli Forest Reserve where it was planted by the Territory of Hawaii for reforestation (Skolmen 1979). A smaller non-contiguous population occurs to the northwest at Pu'u Kawiwi (Fig. 12), and to the north at Pu'u Hāpapa (Fig. 13). Total area occupied is 174 hectares (435 acres) of which 34 hectares are classified as moderate density. This area is rough mountainous terrain with narrow ridges and steep slopes. Myrica faya was planted in several other areas on O'ahu, including sites in the Ko'olau Mountains (Skolmen 1979). However, populations of M. faya in these locations have not been observed by persons familiar with these areas (J. Obata, pers. comm.), and it is assumed that these plantings were at elevations not suited for reproduction of M. faya.

Kaua'i

The major infestation of M. faya is found just west and north of Waimea Canyon, mostly within Waimea Canyon State Park and Kōke'e State Park (Figs. 14-15). A separate population just east of Waimea Canyon is centered around Waialae Cabin on Waialae Stream in the Nā Pali-Kona Forest Reserve and is partially within the Alaka'i Wilderness Preserve (Figs. 14, 16). Myrica faya is also found on the northwest slopes of the island below the mesic native forest and/or forestry plantings (Figs. 14, 17). These populations occur between 545 m (1800 feet) on the northwest slopes to 1270 m (4200 feet) within Kōke'e State Park. Total area occupied is 2370 hectares (5925 acres) of which 55 hectares (138 acres) are classified as moderate density and 19 hectares (48 acres) as heavy density (Fig. 14). On Kaua'i M. faya occurs in a variety of habitats from montane rain forest with little topographic relief to sparsely vegetated, dry, eroded, steep slopes.

All Islands

Total area of M. faya distribution in Hawai'i is 34,365 hectares (85,912 acres) of which 2940 hectares (7350 acres) are classified as heavy density and 5610 hectares (14,025 acres) as moderate density.

DISCUSSION

The distribution of M. faya described here indicates that this alien species is adapted to a wide variety of habitats in Hawai'i. It occurs on recent, thin ash over pāhoehoe lava on Hawai'i and on soil classified by Foote et al. (1972) as deep, well developed silty clay loam on Kaua'i. It occurs in montane rain forest habitats on Hawai'i and Kaua'i and in dry scrub marginal to sub-montane seasonal forest on Kaua'i. It grows as low as 425 m (1400 feet)

elevation on Lāna'i and as high as 1940 m (6400 feet) on Maui. It is found on nearly vertical slopes on Lāna'i and in volcanic craters in HAVO, and on virtually level terrain or gentle slopes in Kōke'e State Park, Kaua'i. These extremes of several habitat factors in areas where M. faya occurs suggests that it may be able to occupy sites that are intermediate along these habitat factor gradients where it does not now occur. Therefore, the distribution of M. faya has not reached its potential extent in Hawai'i.

For example, the distribution mapped for HAVO in this report includes an area of 285 hectares (712 acres) that have been invaded by M. faya during the past two years. A helicopter reconnaissance related to another project in May, 1985, revealed that M. faya had expanded beyond the limits of distribution that had been mapped in the summer of 1983 for the Hilina Pali Road and Kīpuka Nēnē area. A subsequent ground reconnaissance of the area found trees up to 2.5 m tall where no trees had been found during the initial mapping.

Also to be considered are M. faya infestations in leeward areas such as Kula, Maui, and North Kona, Hawai'i, that extend up to 1940 m (6400 feet) and 1830 m (6040 feet) elevation, respectively. These records imply that infestations on Kapāpala Ranch and Keauhou Ranch in Ka'ū, Hawai'i, with upper limits of 1140 m (3760 feet) and 1210 m (4000 feet), respectively, have not yet reached their potential extent. Similarly, M. faya is found down to 600 m (2000 feet) and lower in protected sites in Hāmākua and HAVO, Hawai'i, on Lāna'i, and on Kaua'i. Therefore, infestations along Highway 11 near Volcano Village and on Kapāpala Ranch, Hawai'i may not have reached their potential lower extent.

The complex of environmental factors at a particular area may affect the potential elevational range of M. faya. In leeward areas such as North Kona, Hawai'i, and Kula, Maui, the distribution of M. faya is between 970 m (3200 feet) and 1940 m (6400 feet). However, in windward areas such as Hāmākua, Hawai'i, the distribution is between 600 m (2000 feet) and 1335 m (4400 feet) elevation. This implies that M. faya may be adapted to a lower elevational range in windward (wetter) areas than in leeward (drier) areas in Hawai'i. In regions that are intermediate along rainfall gradients, M. faya may have an intermediate potential elevational range.

The rate at which M. faya can spread into suitable habitats appears to be very rapid. A single individual was noted in HAVO between Kīlauea Military Camp and Hawai'i Volcano Observatory by F. R. Fosberg in 1961 (Doty and Mueller-Dombois 1966). By 1978, 609 hectares in HAVO were mapped as supporting M. faya infestations of various densities (Clarke 1978). Data from this study show 12,200 hectares as infested with M. faya in HAVO, including a 285

hectare increase during the two year course of the study. These records indicate a 20 fold increase in infested area within HAVO in approximately eight years. Thus it can be expected that M. faya will soon spread into suitable habitats that are currently not occupied.

The distribution of M. faya on Kaua'i (Fig. 14) includes infestations on the northwest slopes of the island that are non-contiguous with the center of distribution in the Kōke'e/Waimea Canyon area. Separating these areas of M. faya invasion is an area of closed canopy, mesic native forest. Similarly, in the vicinity of Volcano Village on Hawai'i (Figs. 1, 3-6), M. faya grows well on roadsides, in pastures, and on other disturbed sites, but few, if any, individuals are found in adjacent closed cover, relatively undisturbed forest. This pattern of invasion may indicate that M. faya in unable to invade intact, closed canopy native forests. If so, it is possible that M. faya is shade intolerant and its spread may be partially controlled by excluding disturbance factors, such as feral animals and industrial development, in areas that support a closed canopy forest.

In a broader sense, the distribution of M. faya throughout the state seems associated with disturbance. Major areas of infestation are pastures, roadsides, trails, secondary forest, and steep, unstable slopes. In fact, the aggressive nature of the species was first noted in pasture lands. Even the areas of its distribution that are within HAVO have been subjected to grazing by feral goats, feral pigs and cattle, fire, and volcanic activity. Additionally, M. faya has been identified as an actinorrhizal nitrogen-fixing species (P. Vitousek, pers. comm.). Thus the massive invasions of M. faya observed in Hawai'i may be due to a competitive advantage gained through nitrogen fixation on sites undergoing primary or secondary plant succession, especially on nitrogen-poor substrates such as those that occur in HAVO. This advantage may be lost on sites that have not been recently disturbed. However, in a landscape that is predominately influenced directly and/or indirectly by human activities, the further spread of M. faya seems inevitable.

MANAGEMENT CONSIDERATIONS

On a statewide basis, M. faya is controlled in local sites with herbicides and by mechanical removal. Managers of NPS areas in Hawai'i may choose one of the following courses of action:

1. Take no action.

2. Continue to pursue chemical and mechanical control efforts on a park-wide basis.

3. Pursue chemical and mechanical control efforts in smaller, particularly critical habitats for native species,

as designated by managers, within park areas, while emphasizing the need for research on biocontrol, a long range, less labor-intensive approach.

4. As a function of the parks' interpretation divisions, promote awareness among owners and managers of M. faya-infested lands adjacent to NPS areas of the threat of this species to park ecosystems and of the potential for spread from these lands to NPS areas. Solicit support of these personnel in controlling M. faya on the lands under their jurisdictions.

5. Through NPS interpretation, management, and administrative functions, encourage the State Departments of Agriculture and Land and Natural Resources to declare M. faya a noxious weed, and to increase efforts toward its control on a state-wide basis on state, as well as privately owned land. Bring the M. faya problem to the attention of the Interagency Steering Committee for Biocontrol of Forest Weeds, on which NPS and state agencies are currently represented, and encourage the state to support biocontrol research for M. faya by providing funds for foreign exploration and related work. Actively cooperate in any state-supported control program by providing biocontrol quarantine facilities, services of NPS personnel, etc. to the greatest extent possible.

Anticipated results:

1. If no action is taken, most ecologists familiar with the problem think that the present trend for rapid spread of M. faya into native habitats will continue, resulting eventually in formation of dense, closed canopy stands, beneath which native plant life will be excluded. This, in turn, will result in the destruction of habitats for native birds, including endangered species. To this extent, the NPS will have failed in its mission to control an aggressive and disruptive alien species, and thereby to preserve native ecosystems and the processes by which they were formed.

2. Considered realistically, sufficient funds and manpower are not available, nor is it anticipated that they will be provided in the future, for the park-wide control of M. faya through the labor-intensive chemical or mechanical removal approaches utilized in the past. Such continued efforts would serve only to divert and deplete limited funding and manpower away from efforts to control other alien plant species for which these approaches may still be feasible.

3. Whereas attempts at chemical and/or mechanical control of M. faya on a park-wide basis would be impractical, these approaches may be within the manpower and funding capability of management if limited to those comparatively small areas within HAVO which contain particularly valuable

resources, such as rare and endangered endemic species, and which have been designated special ecological areas by management. Myrica faya would therefore be eliminated from these areas. Biocontrol research would proceed and effective insects and/or diseases would be evaluated. Any successful, state-approved biocontrol agents eventually would be deployed in NPS areas, which would then better enable managers to consider direct control on a park-wide basis. Unsuccessful attempts at finding suitable biocontrol agents would result in the knowledge that this approach had, in fact, been considered and attempted and that M. faya indeed cannot be controlled by any practical means.

4. The support of the several owners and managers of M. faya-infested lands adjacent to NPS areas in controlling this species on their lands would aid in preventing M. faya from being reintroduced into park areas, principally by birds. This would further enable NPS managers to consider direct control on a park-wide basis, with the possibility of success in their control programs. Failure of the land owners to respond with positive support would not detract from the situation as it now exists.

5. A state-wide control program would enhance the ability of NPS management to control M. faya within HAVO, and to prevent this species from becoming established in Haleakala National Park and other NPS areas. The public awareness engendered by this program would be much more widespread than at present and public attitudes toward permitting the occurrence of apparently innocuous infestations of M. faya on private land would be altered, with an increase in understanding of the desirability for control. Consequently, the public would be less tolerant of M. faya infestations in state and federal public lands as well, including national parks.

Options 3, 4, and 5, considered together, are recommended.

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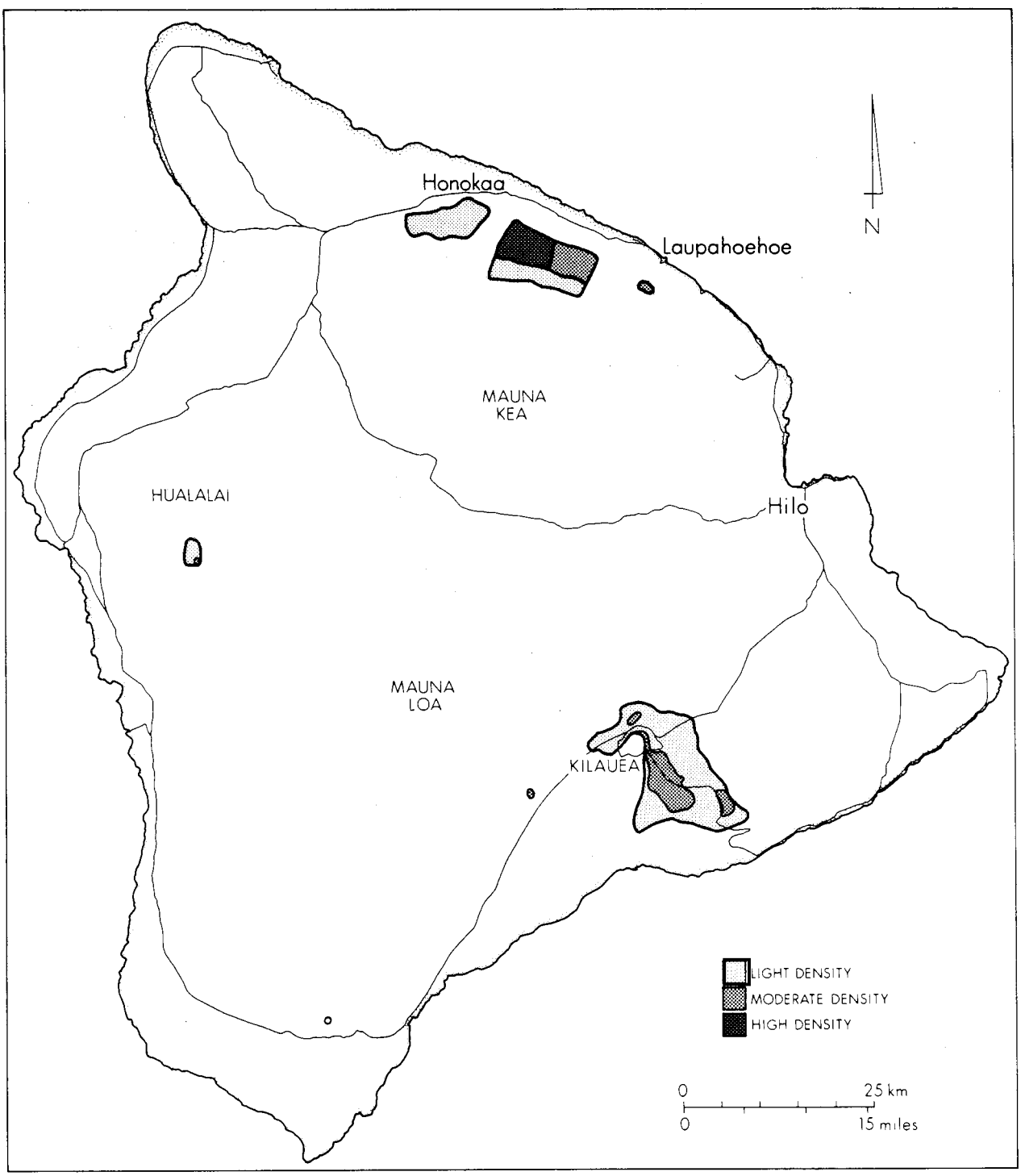

Figure 1. Distribution of Myrica faya on the island of Hawai'i.

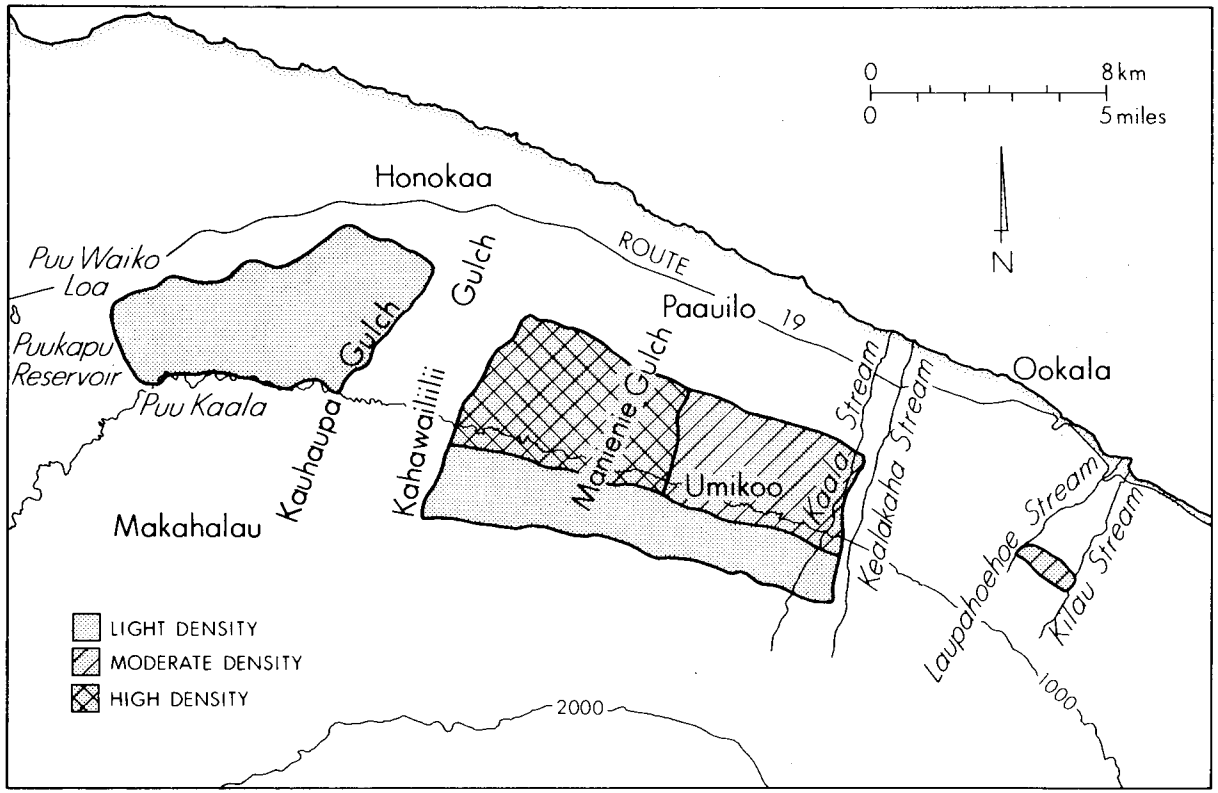

Figure 2. Distribution of Myrica faya in the Laupāhoehoe area on the Hāmākua Coast of the island of Hawai'i (quadrangle maps Kukuihaele, Hawaii; Honokaa, Hawaii; Kukaiau, Hawaii; and Papaaloa, Hawaii).

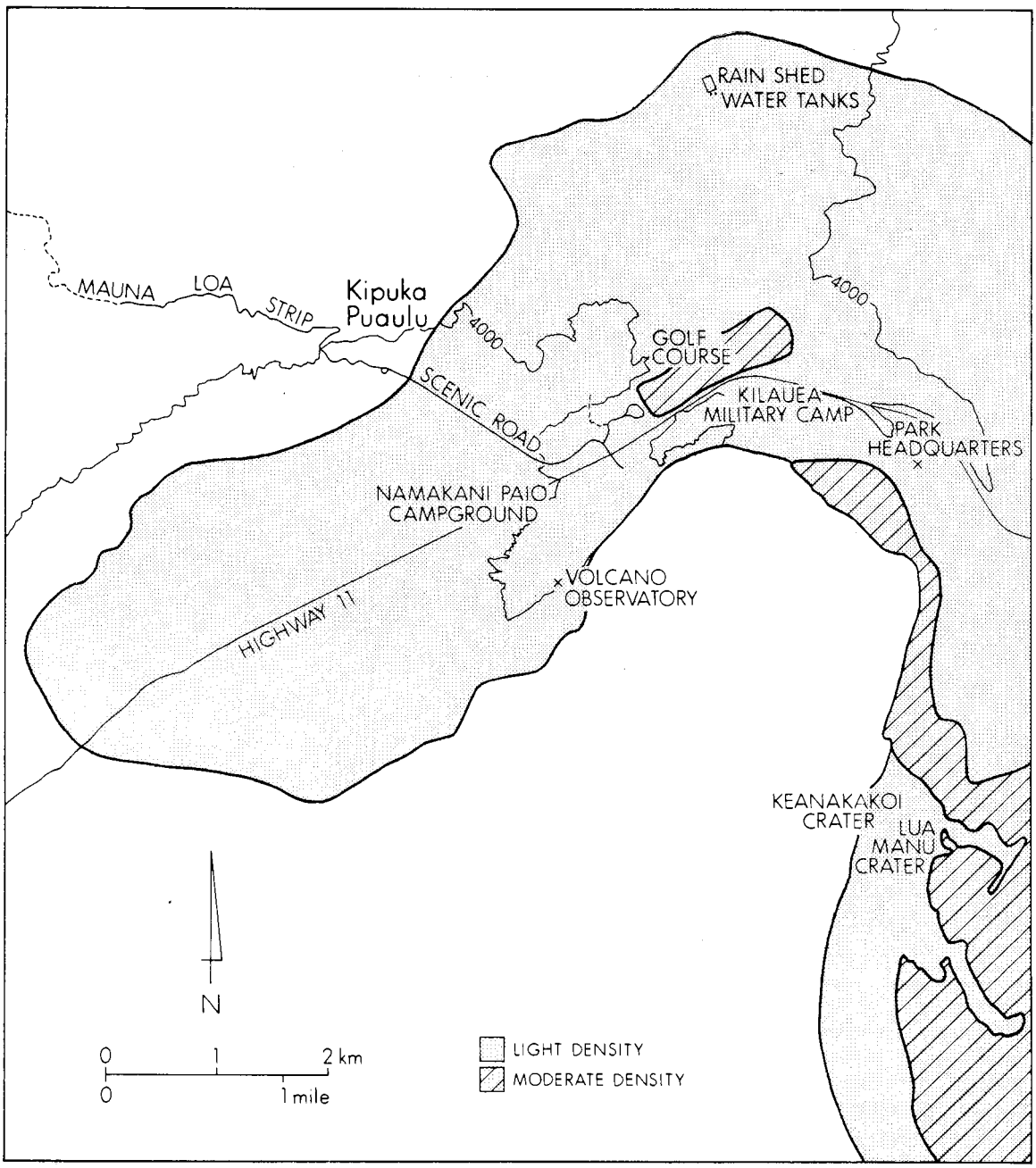

Figure 3. Distribution of Myrica faya around Kīlauea Caldera in and near Hawaii Volcanoes National Park, island of Hawai'i (quadrangle map Kilauea Crater, Hawaii).

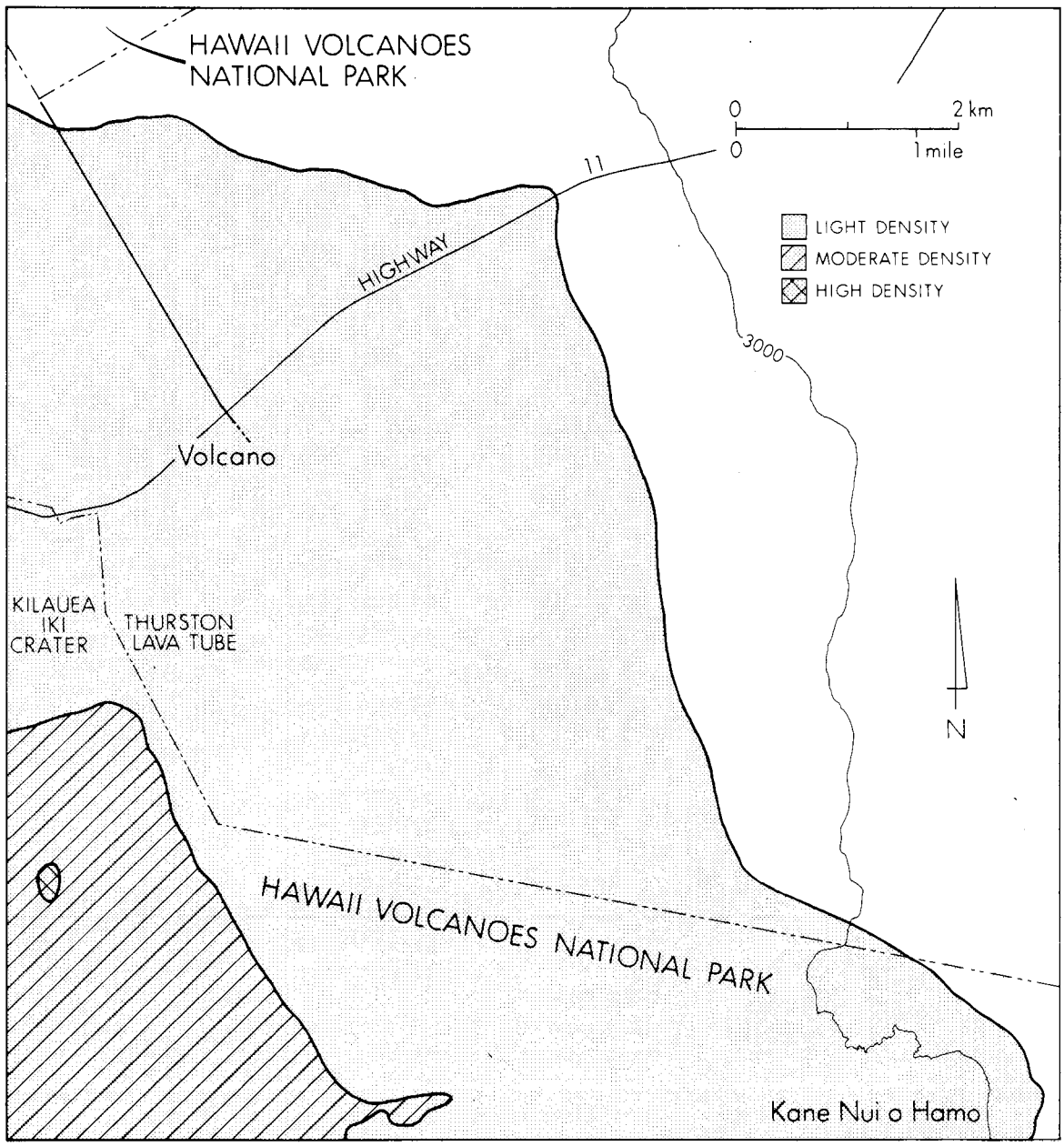

Figure 4. Distribution of Myrica faya to the east of Kīlauea Caldera in Hawaii Volcanoes National Park and in the Volcano Village areas, island of Hawai'i (quadrangle map Volcano, Hawaii).

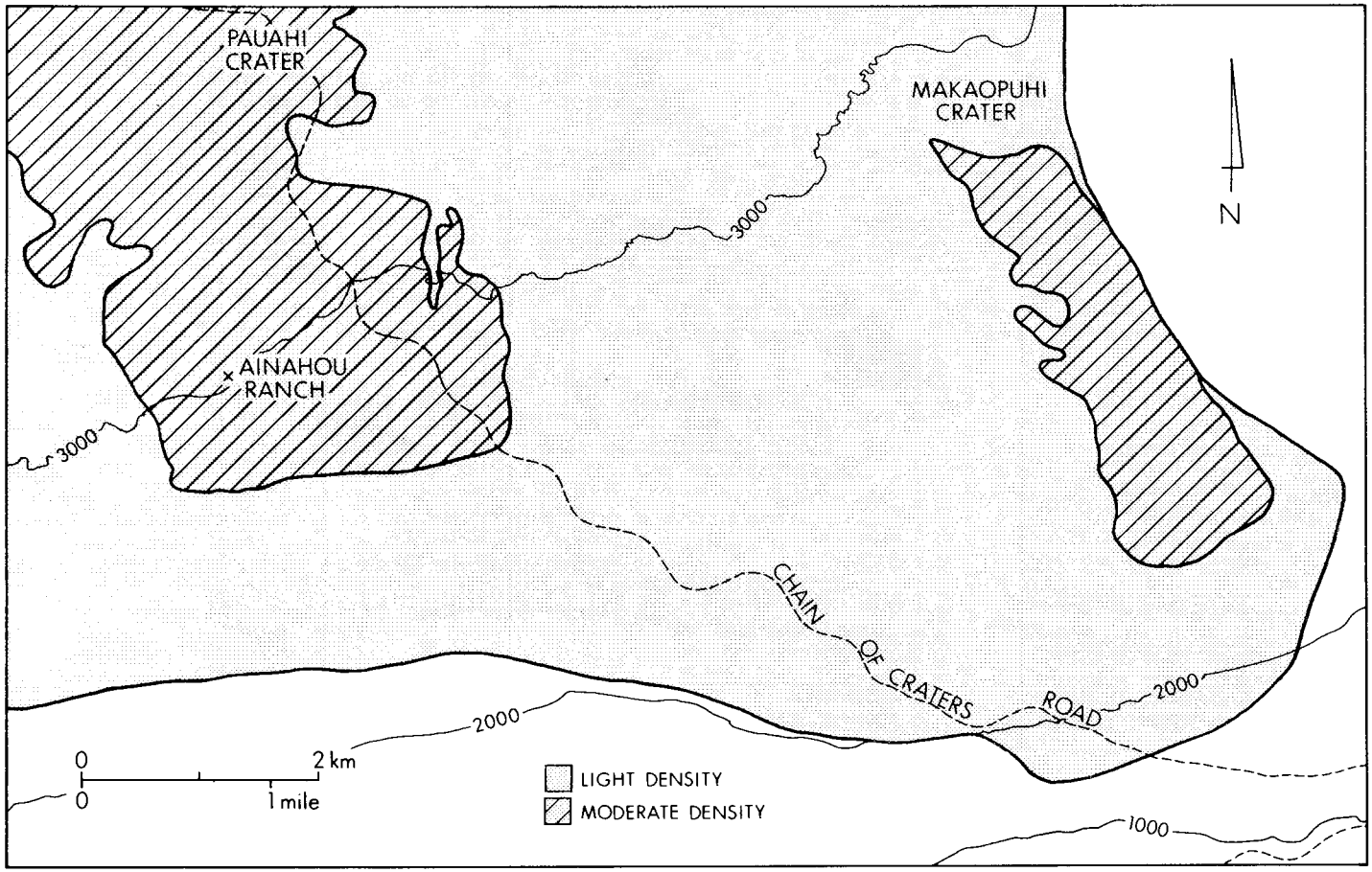

Figure 5. Distribution of Myrica faya southeast of Kīlauea Caldera in Hawaii Volcanoes National Park, island of Hawai'i (quadrangle map Makaopuhi, Hawaii).

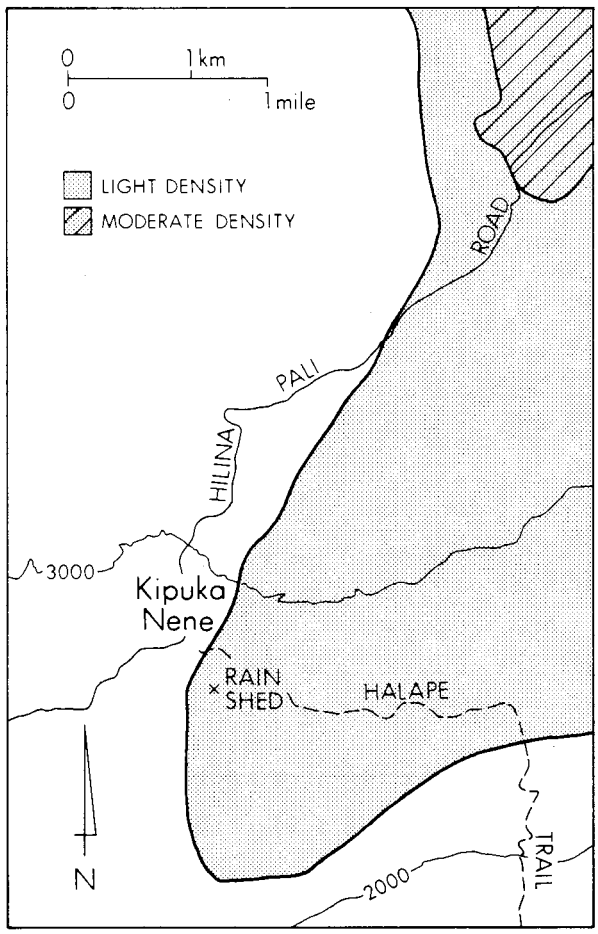

Figure 6. Distribution of Myrica faya in the Kīpuka Nēnē area of Hawaii Volcanoes National Park, island of Hawai'i (quadrangle map Kau Desert, Hawaii).

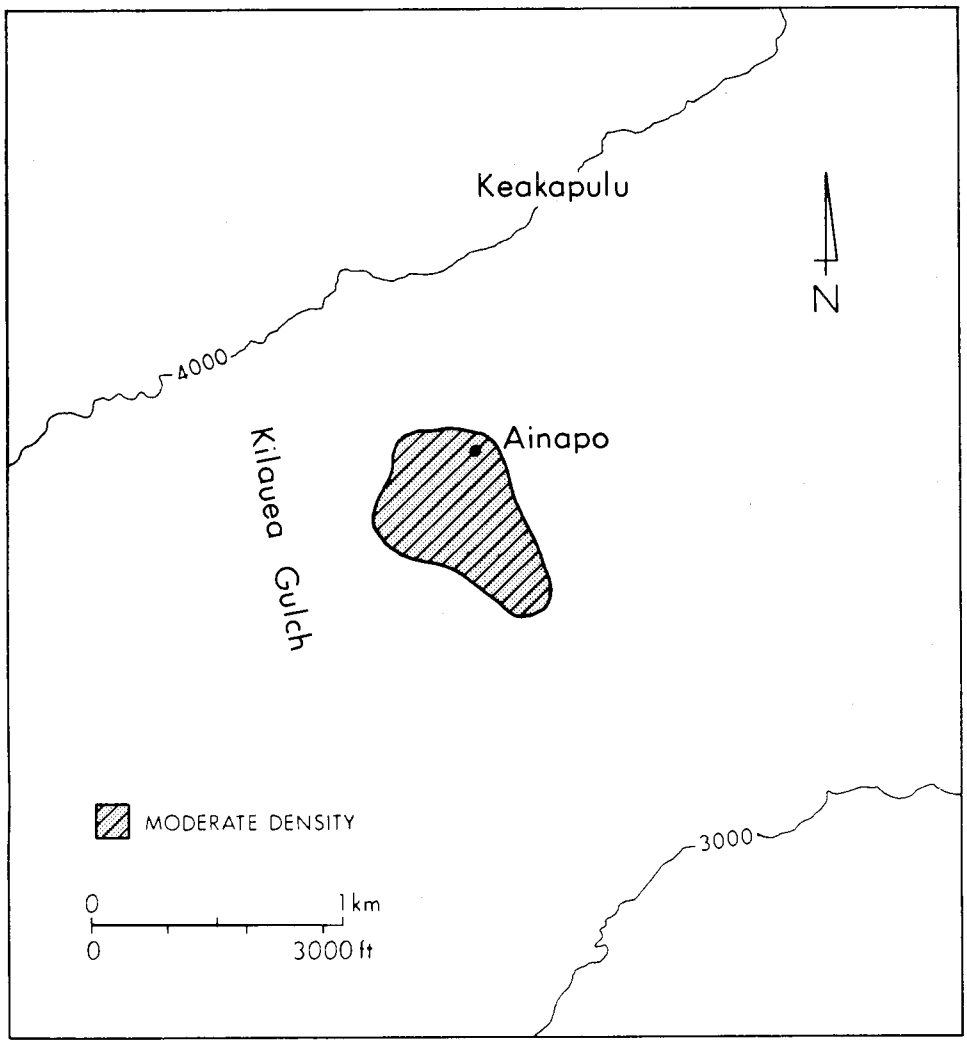

Figure 7. Distribution of Myrica faya in the vicinity of Ainapō Cabin on Kapāpala Ranch, Ka'ū District, island of Hawai'i (quadrangle map Wood Valley, Hawaii).

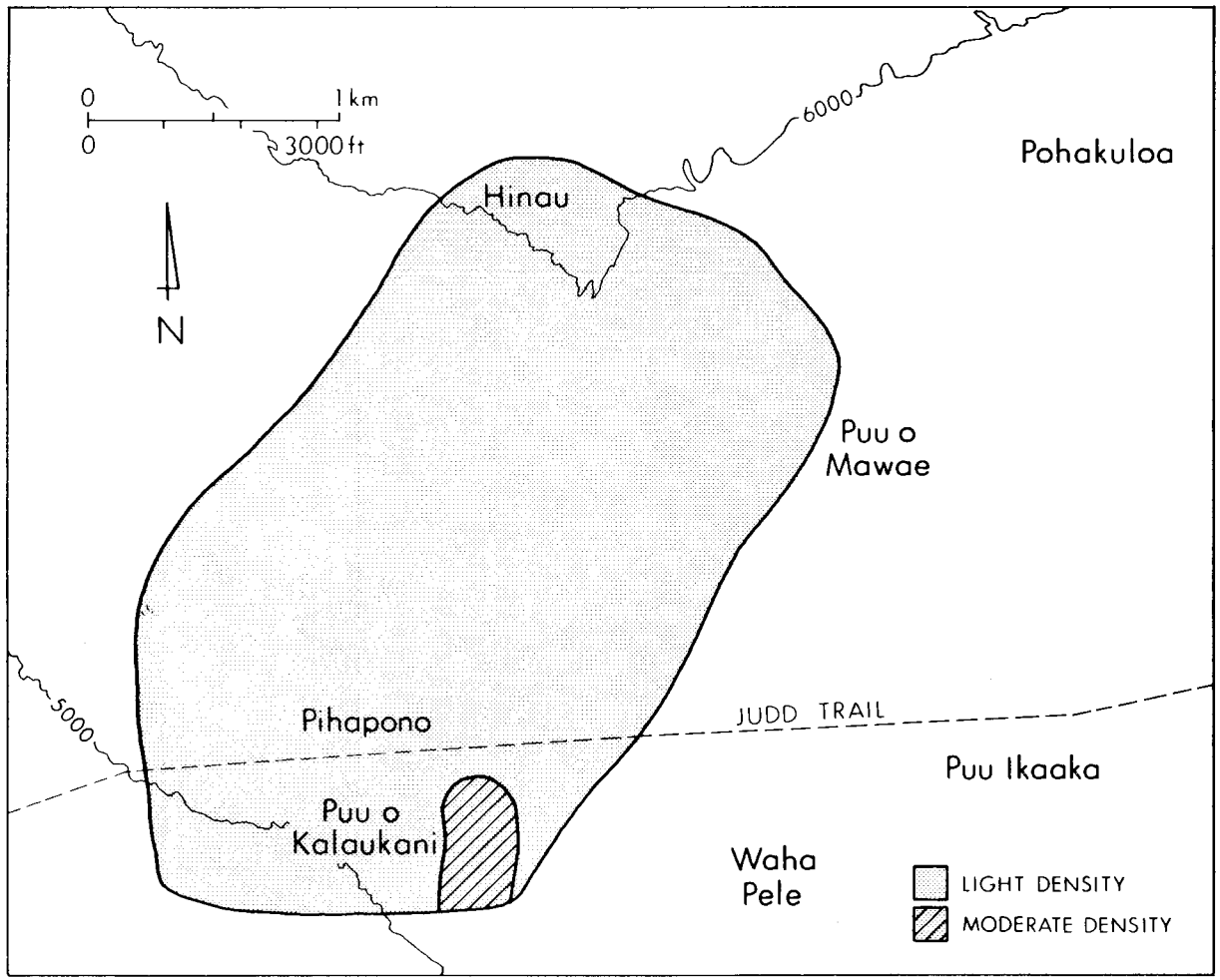

Figure 8. Distribution of Myrica faya on the slopes of Hualālai, North Kona District, island of Hawai'i (quadrangle map Hualalai, Hawaii).

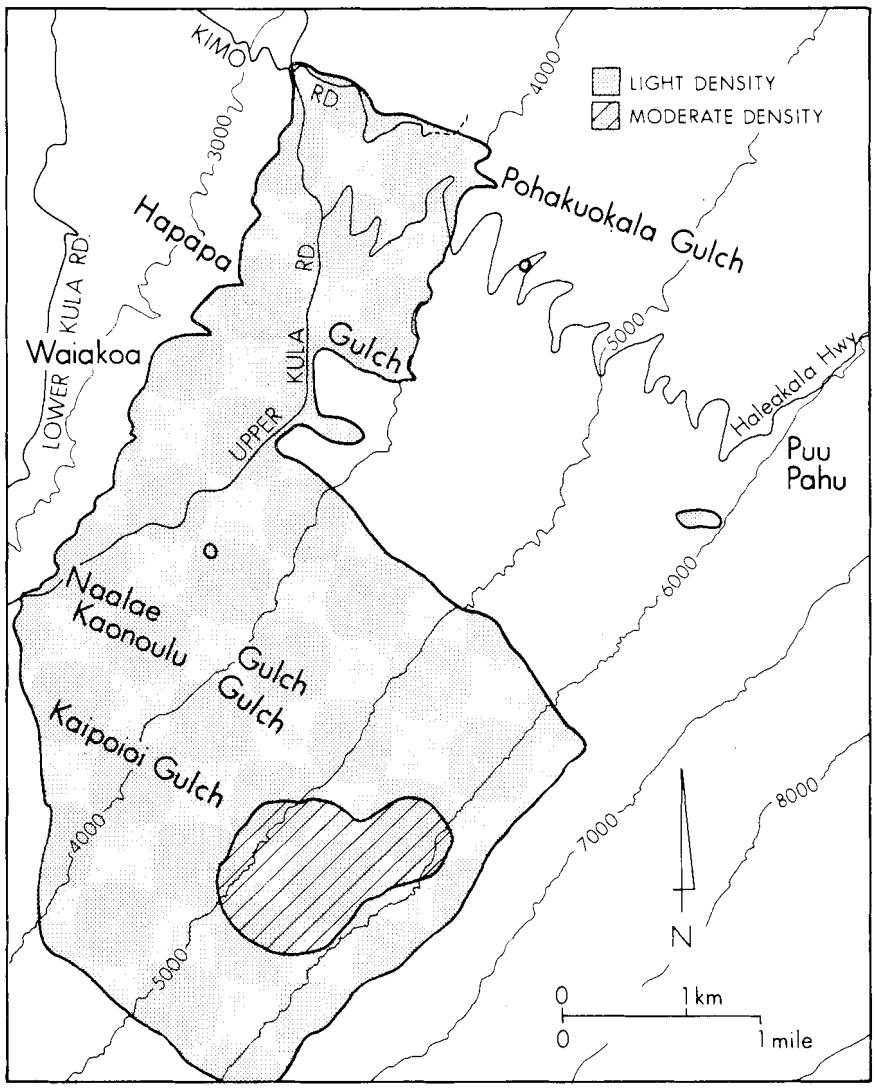

Figure 9. Distribution of Myrica faya in the Kula area on the western slopes of Haleakalā, island of Maui (quadrangle map Kilohana, Hawaii).

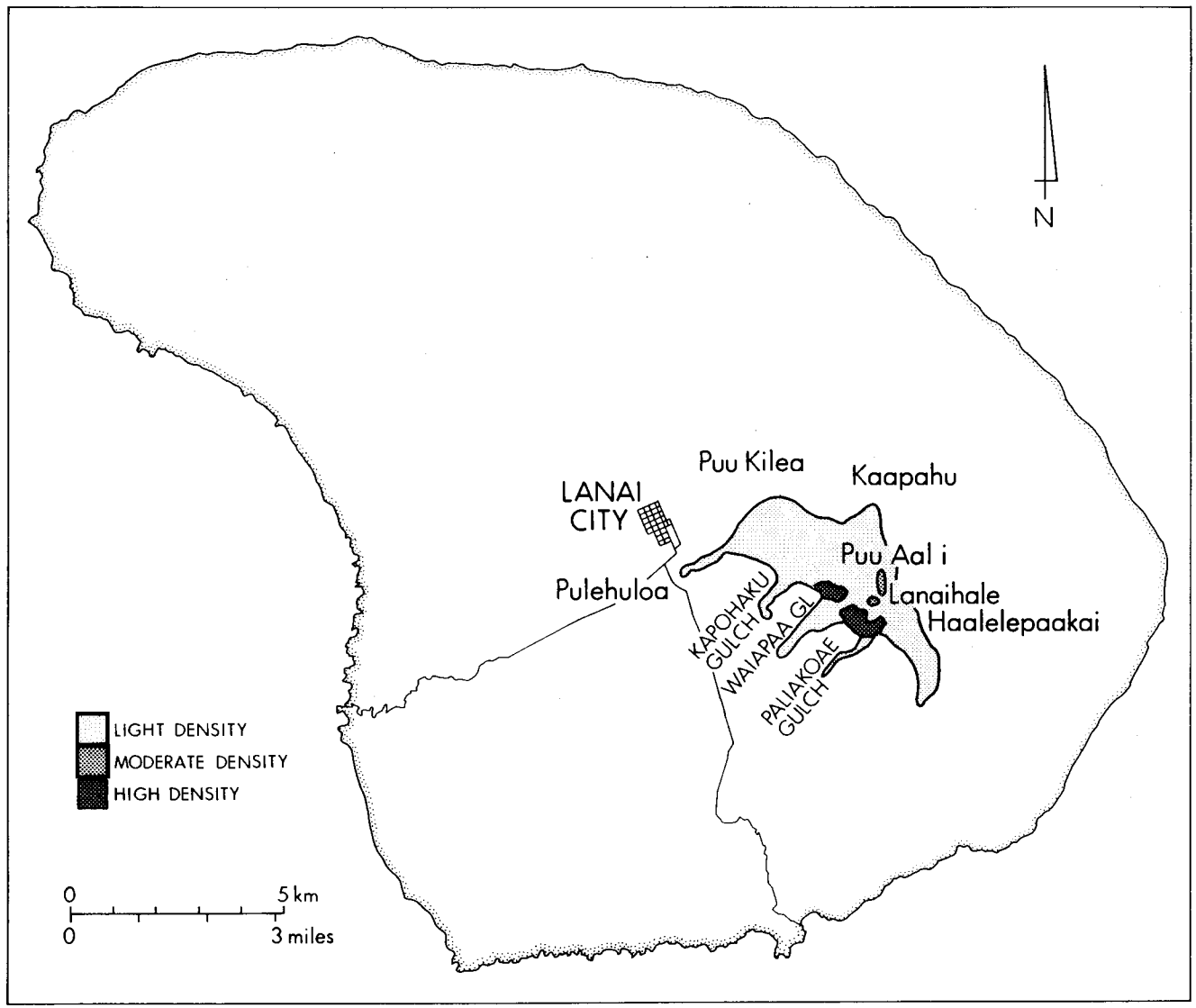

Figure 10. Distribution of Myrica faya on the island of Lāna'i.

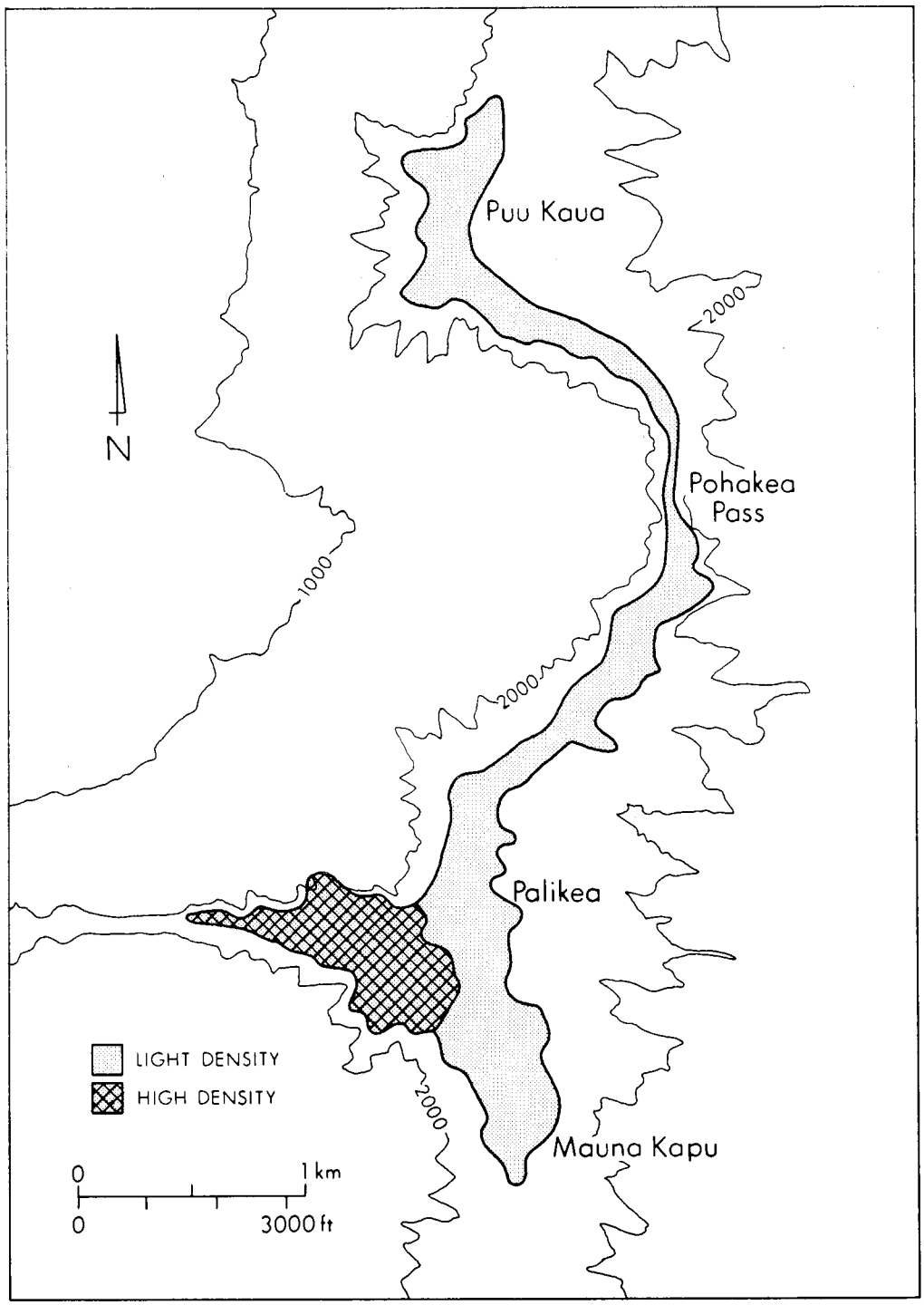

Figure 11. Distribution of Myrica faya in the Waianae Mountains, island of O'ahu (quadrangle map Schofield Barracks, Hawaii).

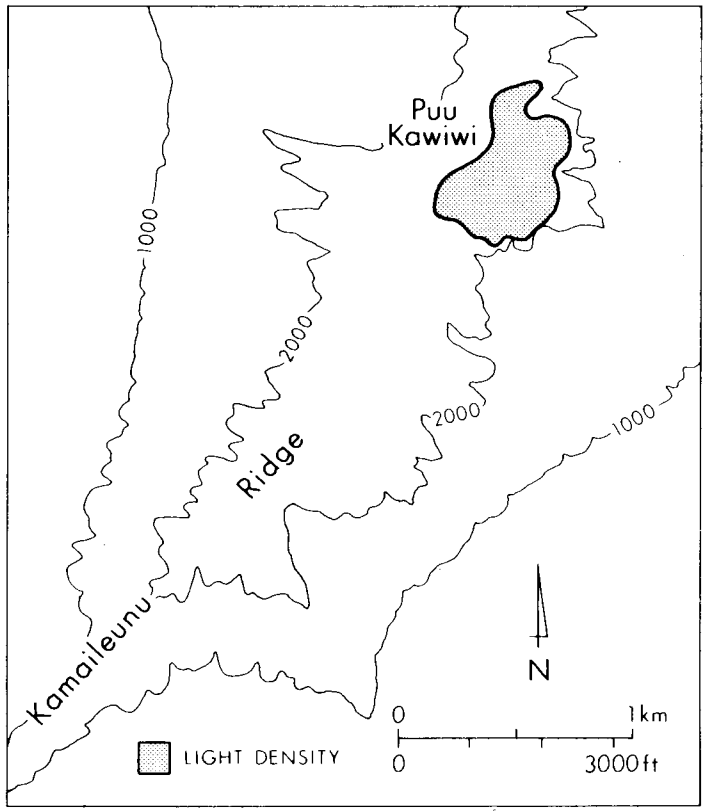

Figure 12. Distribution of Myrica faya at Pu'u Kawiwi, island of O'ahu (quadrangle map Waianae, Hawaii).

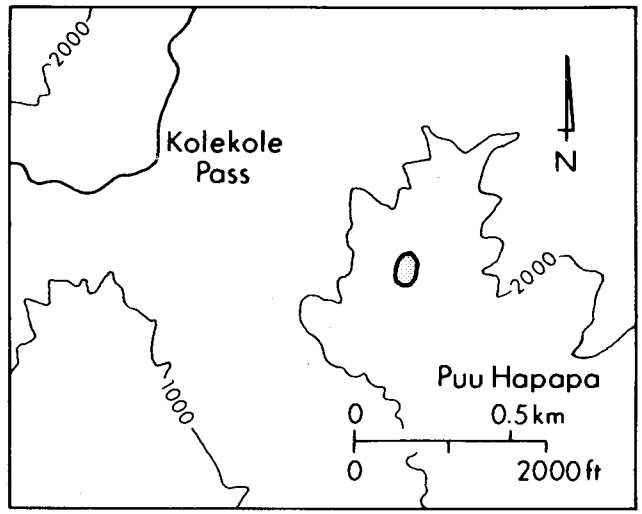

Figure 13. Distribution of Myrica faya at Pu'u Hāpapa, island of O'ahu (quadrangle map Schofield Barracks, Hawaii).

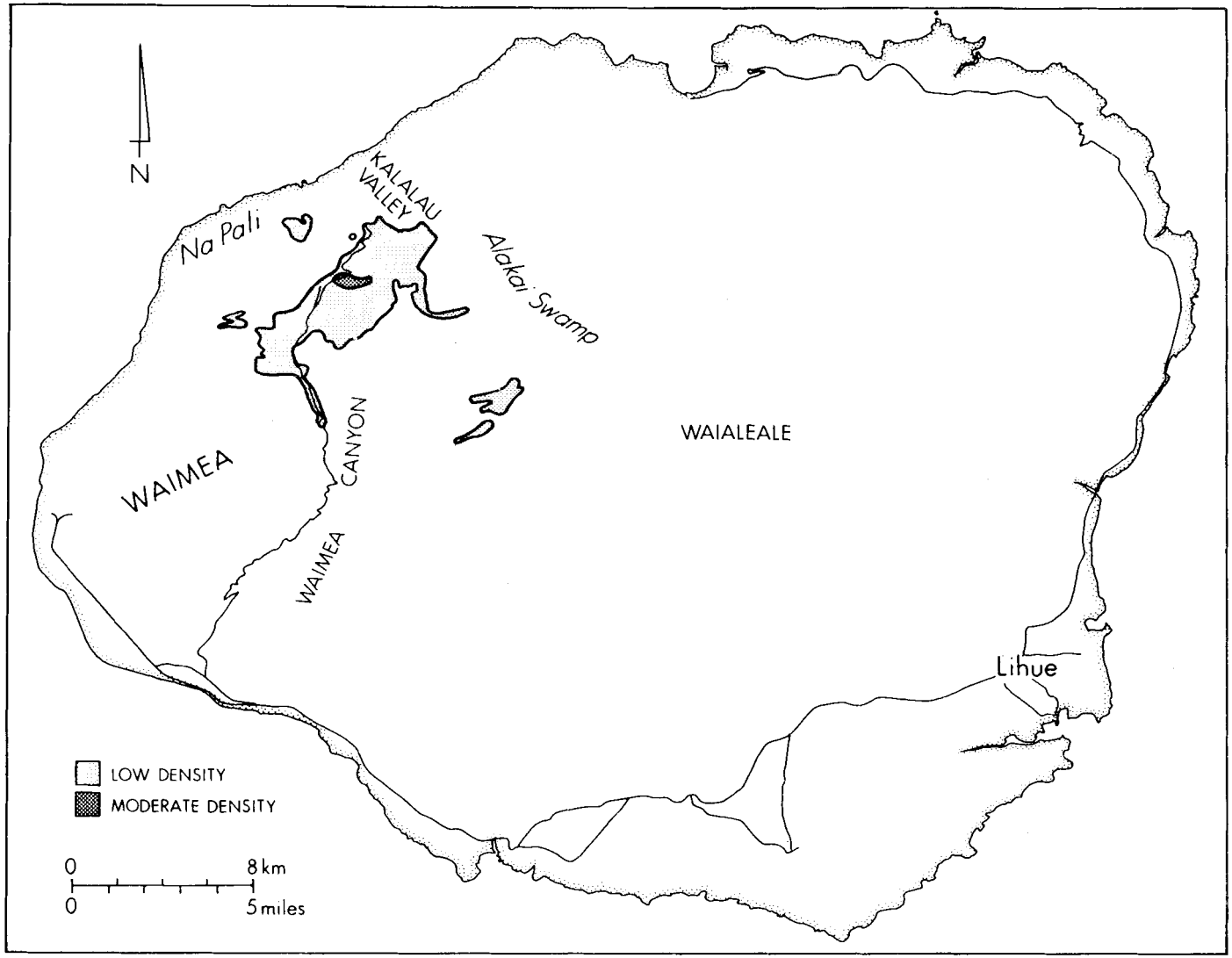

Figure 14. Distribution of Myrica faya on the island of Kaua'i.

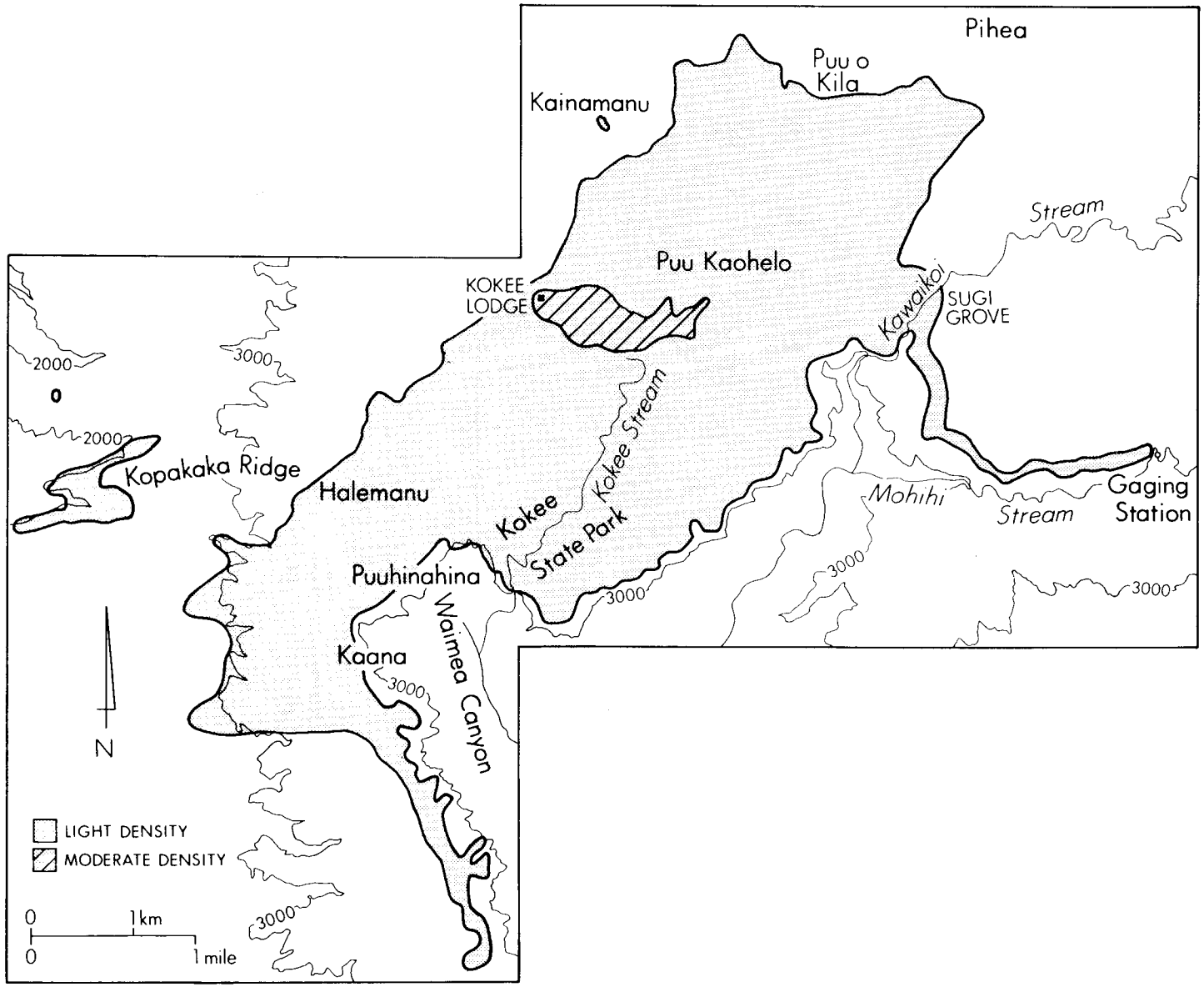

Figure 15. Distribution of Myrica faya west of Waimea Canyon and in the Kōke'e area, island of Kaua'i (quadrangle maps Makaha Point, Hawaii; Waimea Canyon, Hawaii; and Haena, Hawaii).

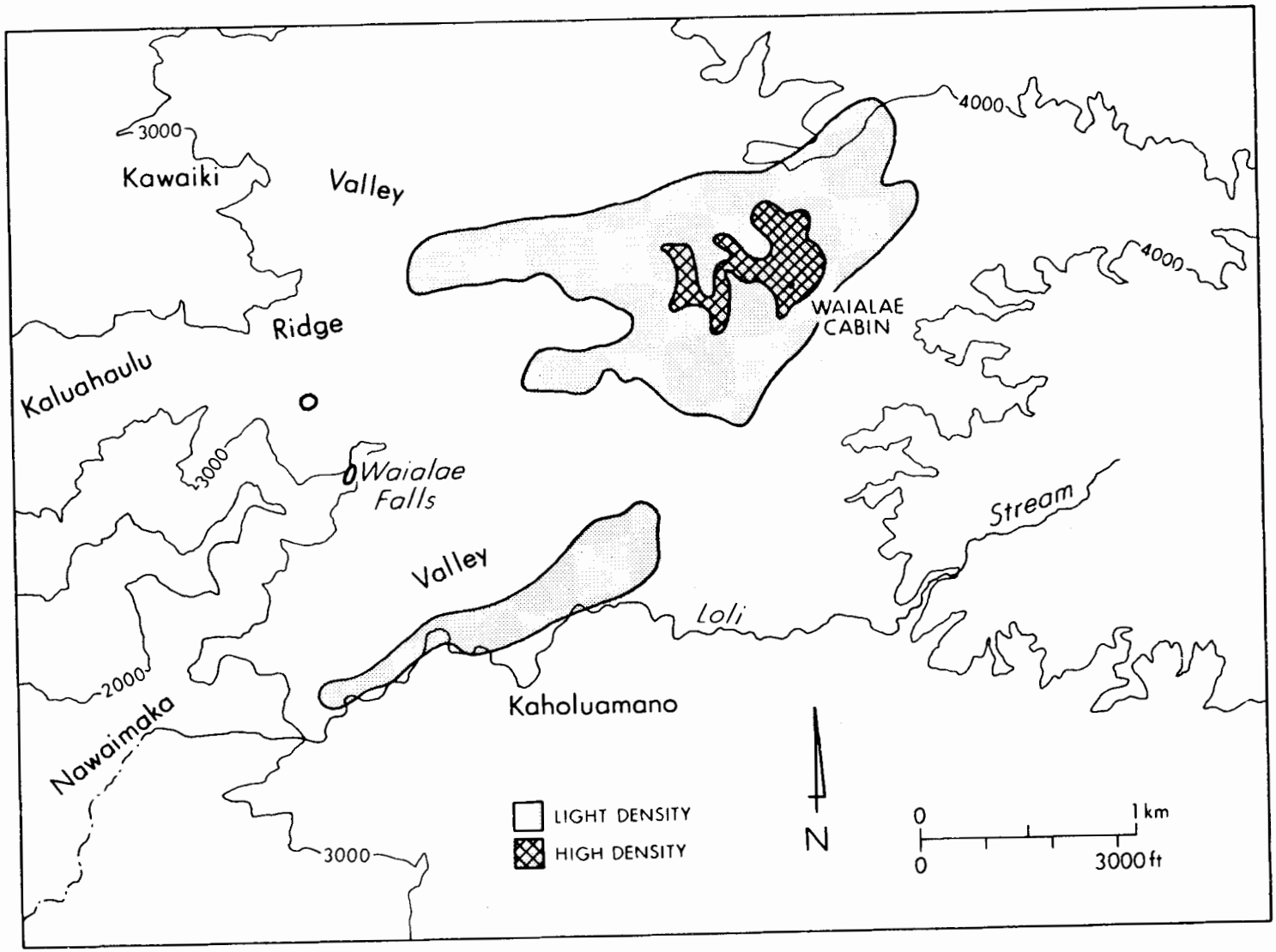

Figure 16. Distribution of Myrica faya east of Waimea Canyon in the vicinity of Waialea Cabin in the Na Pali-Kona Forest Reserve, island of Kaua'i (quadrangle map Waimea Canyon, Hawaii).

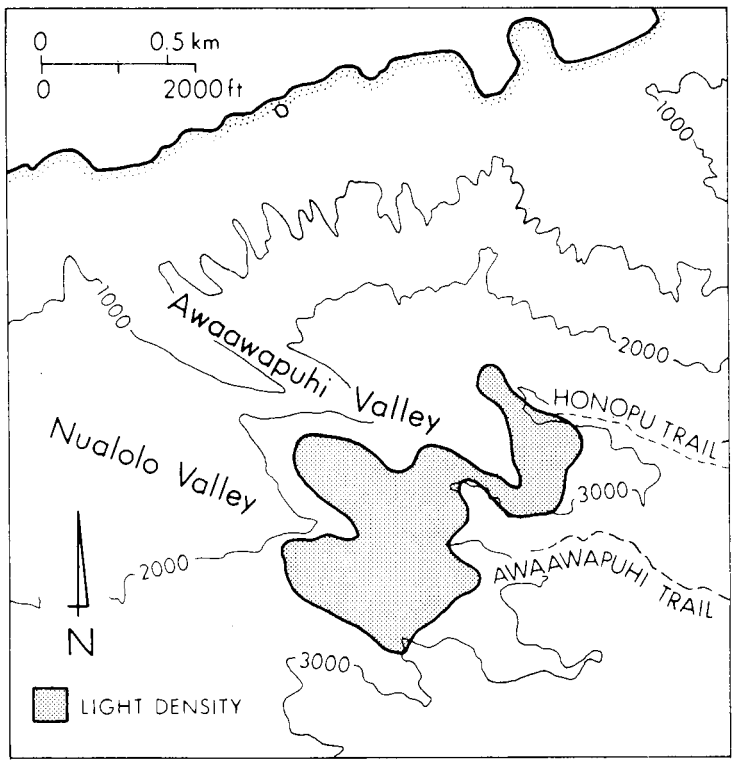

Figure 17. Distribution of Myrica faya on the northwest slopes of the island of Kaua'i within Kōke'e State Park (quadrangle map Makaha Point, Hawaii).