

Northwestern Hawaiian Islands Passerines

Photo: Kate Willis, USFWS



‘Ekupu‘u or Laysan finch

Telespiza cantans

SPECIES STATUS:

Federally Listed as Endangered

State Listed as Endangered

State Recognized as Endemic

NatureServe Heritage Rank G1—Critically Imperiled

IUCN Red List Ranking—Vulnerable

Northwestern Hawaiian Islands Passerines Recovery Plan— USFWS 1984

SPECIES INFORMATION: The Laysan finch is an omnivorous, ground-nesting Hawaiian honeycreeper (Family: Fringillidae) endemic to Kamole (Laysan Island) in the Northwestern Hawaiian Islands. Laysan finches have black legs, large feet, and relatively large bills suitable for eating seeds. They are vocally inventive and have a varied song repertoire. Males and females have different plumage; males are a brighter yellow over a larger proportion of their head and body than females. Males are also about 6 percent larger by weight than females. Laysan finches are known to feed on seeds, fruits, leaves, flowers, stems, seedlings, roots, carrion, invertebrates, and eggs. Typically found in pairs during the breeding season, Laysan finches are non-territorial and forage in small groups (four to twelve individuals) during the non-breeding season. The breeding biology of the species has been well-documented, in addition to studies of geographic variation in genetics, morphology, and nest substrate choice. During breeding season, males defend their mates and nest sites, while females construct nests and incubate eggs. Females rely upon males for nuptial feedings during the incubation period. In good years, Laysan finches are quite fecund, and double and even triple clutches have been documented. Given the remoteness of their habitat, Laysan finches are among the most-studied endangered birds.

DISTRIBUTION: Restricted to the approximately 200 hectare (450 acre) vegetated area of Laysan Island. Since 1967, translocated finches have occupied the 12 hectare (25 acre) and 2 hectare (4 acre) vegetated areas of Southeast Island and Grass Island (respectively) at Manawai (Pearl and Hermes Reef). Between 1973 and 1998, populations also existed at North Island and Seal-Kittery Island at Pearl and Hermes Reef; those populations were extinct by 1998.

ABUNDANCE: The U.S. Fish and Wildlife Service (USFWS) conducted transect surveys at Laysan Island during most years in 1966–2012 and now uses point-transect distance sampling surveys (Bak et al, 2024). The most recent survey was on Laysan was in 2019 and indicated a stable population estimated at 17,657 (11,994–23,320) (Bak et al. 2024). At Pearl and Hermes (Manawai), the population was estimated at more than 700 birds (with 523 on Southeast Island) in

1983 (USFWS 1984). During the summer of 2024, the Manawai ‘ekupu‘u population was surveyed using repeated point counts and extrapolating detections across suitable habitat, yielding an estimate of 420 (range 298-542) on Southeast Island. Only a single bird was detected on Grass Island (Idle 2024). This contraction in range is likely due to overwash driven by storms and large wave events.

LOCATION AND CONDITION OF KEY HABITAT: Laysan finches reside year-round on the flat, low-elevation islands of Laysan and Pearl and Hermes Reef. Climate is similar to that of nearby Midway Atoll. Finches inhabit all vegetated areas of the islands, foraging among several vegetation associations of grasses, herbs, and prostrate vines. On Laysan, however, the finches nest primarily in tussocks of the bunchgrass *Eragrostis variabilis*, whose seeds are also a major food source. *Eragrostis* is markedly less abundant at Pearl and Hermes, particularly at Southeast Island, and finches there frequently nest in marine debris (plastic crates, etc.) that have washed up onto the island. The highly invasive annual plant *Verbesina encelioides* was accidentally introduced to Manawai in 2017 and has since replaced much of the native vegetation on Southeast Island, the only islet in the atoll that still harbors a self-sustaining finch population (Idle 2024). Several freshwater seeps drain into Laysan Island's hypersaline lake; Pearl and Hermes islands have no sources of fresh water, so finches get water from rainfall and from dew accumulations on plants. Plant communities at both Laysan and Pearl and Hermes Reef have been altered by human activity, most notably by both intentional and accidental introductions of alien plants. The entire range of this species occurs within the Hawaiian Islands National Wildlife Refuge.

THREATS: Laysan finches have not generally been as strongly impacted by the factors that threaten other native Hawaiian birds, such as habitat loss, predation by introduced mammals, and disease. Habitat loss, for example, has been prevented by the island’s status as a refuge, and disease establishment has been impeded by the lack of standing fresh water necessary for mosquito breeding. However, the finches' remoteness carries with it a different, but related, set of threats:

- Invasive alien plants: Habitat quality has been degraded by weed invasions. Finches have integrated some invasive plants into their diet, but changes to the quality of nesting habitat have been more problematic: *Setaria verticillata* appears to have displaced *Eragrostis variabilis* at Southeast Island (Pearl and Hermes Reef), leading to lower nest density and lower reproductive success among nests in *Setaria*. Conversely, the more recent invasion at Southeast by *Verbesina encelioides* appears to have caused the population to quadruple within two years, only to subsequently crash.
- Population size: Small populations are plagued by a variety of potentially irreversible problems that fall into three categories: demographic, stochastic, and genetic; the former are usually most problematic. Demographic factors include skewed sex ratios and stochastic factors include natural disasters. Habitat fragmentation exacerbates demographic and genetic problems.
- Introduced mammals: The risk of rat (*Rattus* spp.) introduction via transport (i.e., ships, planes) is of concern as rats are known to have decimated passerine populations in the Northwestern Hawaiian Islands in the past as a result of shipwrecks.
- Sea level rise: Both the Intergovernmental Panel on Climate Change and the U.S. Environmental Protection Agency project sea level to increase 34-42 centimeters (13-16

inches) by 2100. The mean elevation at Southeast Island is just over 1 meter (3 feet), so that during spring tides, most of the island would be inundated. Grass Island would lose less area, but is already too small to provide significant reduction of extinction risk for the species. Therefore, if sea level does rise as projected, both of the Pearl and Hermes Reef populations would be seriously jeopardized.

CONSERVATION ACTIONS: Laysan finch persistence requires that the integrity of the island’s small, remote ecosystems be maintained. This requires excluding and removing any introduced non-native insects, plants, passerine birds, avian disease, and mammalian and reptilian land animals. Quarantine measures in place for researchers appear to be reducing the rate of new introductions, but many species already established (e.g., *Verbesina encelioides*) are extremely difficult to eradicate. Thus, rigorous statewide reduction or elimination of non-native invertebrate and plant introduction through stricter quarantine and reduced ship groundings are needed. In addition to these efforts, future management specific to the recovery of Laysan finches may include the following:

- Conduct aggressive weed control and native plant restoration to stabilize habitat quality.
- Prevent the introduction of rats and other possible predators.
- Stabilize islands to minimize erosional and submersion-based losses of land area.
- Within the next five years, translocate each population to one additional island based on the outcome of the 2024 SWOT (“Strength, Weaknesses, Opportunities, Threats” workshop).
- Once mosquitos-free habitat is available in the MHI, select predator-free sites for reintroduction informed by the fossil record (Olson and James 1989, James and Olson 1991).

MONITORING: Continue current program of point-distance survey sampling and habitat monitoring.

RESEARCH PRIORITIES: More research is needed on best quarantine techniques, methods for early detection of alien species, and eradication methods. Research priorities specific to Laysan finches include the following:

- Conduct additional demographic studies to further refine estimates of population structure, dispersal, survivorship, nesting phenology and success, and other life history and behavioral characteristics.

References:

- Bak, T., R. Camp, C. Farmer, R. Rounds, S. Plentovich, J. Vetter, and P. Banko. 2024. Nihoa and Laysan Island and passerines population abundances, trends, and habitat utilization. Hawai’i Cooperative Studies Unit Technical Report HCSU-107. University of Hawai’i at Hilo. 35 pages. <https://hdl.handle.net/10790/5393>
- Idle, J. 2024. Manawai/Holoikauaua (Pearl and Hermes Atoll) Trip Report June 29 – August 11, 2024. Unpublished report to the U.S. Fish and Wildlife Service.
- James, H. F. and S. L. Olson. 1991. Descriptions of thirty-two new species of birds from the Hawaiian Islands: Part 2: Passeriformes. Ornithological Monographs 46.
- Morin M., Conant S. 2002. Laysan finch (*Telespiza cantans*) and Nihoa finch (*Telespiza ultima*). In *The Birds of North America*, No. 639 (Poole A, Gill F, editors.). Philadelphia, (PA): The Academy of Natural Sciences;

and Washington DC: The American Ornithologists' Union.

Olson, S. L., and H. F. James. 1982. Prodrromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contributions to Zoology, No. 365.

U.S. Fish and Wildlife Service. 1984. Recovery plan for the Northwestern Hawaiian Islands passerines. Portland, (OR): U.S. Fish and Wildlife Service. 66 pp.

U.S. Fish and Wildlife Service. 2014. Laysan Finch (*Telespiza cantans*) 5-Year Review, Short Form Summary. U.S. Fish and Wildlife Service, Honolulu, Hawai'i.

Northwestern Hawaiian Islands Passerines



Nihoa millerbird *Acrocephalus familiaris*

SPECIES STATUS:

Federally Listed as Endangered

State Listed as Endangered

State Recognized as

Endemic

NatureServe Heritage Rank G1—Critically Imperiled

IUCN Red List Ranking— Endangered

Northwestern Hawaiian Islands Passerines Recovery Plan—USFWS 1984

SPECIES INFORMATION: The Nihoa millerbird is an obligate insectivore endemic to Nihoa Island in the Northwestern Hawaiian Islands. The Nihoa millerbird and its congener, the Laysan millerbird, are the only known Old World warblers (subfamily Sylviinae) known to have colonized the Hawaiian Archipelago. The Laysan subspecies, discovered first, was named “millerbird” because of its fondness for feeding on large miller moths (Family Noctuidae). Although the Laysan subspecies was driven to extinction by 1923 after European rabbits (*Oryctolagus cuniculus*) were introduced to Laysan in 1903, the Nihoa millerbird has persisted. Nihoa millerbirds are small (about 13 centimeters, or about 5 inches, in length), drably colored, and highly active due to their insectivorous habits. Male and female Nihoa millerbirds have similar plumage, but differ in size, with males being slightly larger than females. Nihoa millerbirds feed exclusively on insects and larvae, especially moths and caterpillars (Lepidoptera), gleaned from shrubs and bunchgrass tussocks. Like most insectivores, Nihoa millerbirds are territorial, and display a high degree of year-to-year territory fidelity. During breeding season, both sexes construct nests and incubate eggs.

DISTRIBUTION: Nihoa millerbirds are now restricted to the approximately 63 hectares (156 acres) area of Nihoa Island. Of those 63 hectares, approximately 40 hectares (100 acres) are considered suitable habitat for millerbird territories. With a mean territory size estimated at 0.2–0.4 hectares (0.5–1 acres), Nihoa Island can support, on average, between 100 and 200 millerbird territories. In 2011 and 2012 a total of 50 Nihoa millerbirds were translocated from Nihoa Island to Laysan Island, which has a land area of approximately 411 hectares (1,016 acres). The initial population of 50 birds has increased to more than 400 birds.

ABUNDANCE: The most recent population estimate on Nihoa Island (2022) was 1,181 (754–1,648). This is almost double the estimated population in 2010 (Bak et al. 2024). On Laysan, the initial population of 50 translocated birds has increased to 410 (275–595) birds as of 2019 (Bak et al. 2024)

LOCATION AND CONDITION OF KEY HABITAT: Nihoa millerbirds reside year-round

on the steep-sided, rocky, and shrub-covered island of Nihoa. Maximum elevation is 277 meters (839 feet), with steep cliffs on three of the island's four sides. Nihoa's vegetation community comprises about 25 species of plants; the four most abundant are (in descending order of abundance): the shrub *Chenopodium oahuense*, the shrub *Solanum nelsonii*, the shrub *Sida fallax* and the bunchgrass *Eragrostis variabilis*. Millerbirds are found throughout the island's 32 to 40 hectares (80 to 100 acres) of optimal habitat, and in suboptimal habitat as well. Millerbirds have not been observed to congregate at, or drink from, Nihoa's five to seven small freshwater seeps. The entire range of this species occurs within the Hawaiian Islands National Wildlife Refuge.

The habitat used by the translocated birds on Laysan is primarily composed of the shrub *Scaevola taccada*, with the bunchgrass *Eragrostis variabilis*, and the vine *Ipomoea pes-caprae* also present.

THREATS: Limiting factors are primarily weather (i.e., drought and storms), variations in food supply (typically due to weather), and availability of appropriate nest sites. Nihoa finches have been observed breaking and eating millerbird eggs, but the incremental mortality attributable to this behavior has not been estimated. Additional threats include:

- Invasive alien plants: Habitat quality could be degraded by weed invasions. The millerbird diet of mature and larval insects depends on the abundance of native plant populations, which could be adversely affected by competition with invasive alien plants such as *Miconia calvescens* or *Clidemia hirta*.
- Invasive alien arthropods: Preferred food insects could be suppressed by competition with, or predation by, introduced arthropods, especially invasive ants, which might not be attractive or palatable to millerbirds.
- Arthropod irruptions: Periodic irruptions of a nonnative grasshopper on Nihoa Island reduce plant cover and degrade habitat.
- Population size: Small populations are plagued by a variety of potentially irreversible problems that fall into three categories: demographic, stochastic, and genetic; the former are usually most problematic. Demographic factors include skewed sex ratios and stochastic factors include natural disasters. Habitat fragmentation exacerbates demographic and genetic problems.
- Introduced mammals: The risk of rat (*Rattus* spp.) introduction via transport (i.e., ships, planes) is of concern as rats are known to have decimated passerine populations in the Northwestern Hawaiian Islands in the past as a result of shipwrecks.

CONSERVATION ACTIONS: Nihoa millerbird persistence requires that the integrity of the island's small, remote ecosystems be maintained. This requires excluding and removing any introduced non-native plants, insects, passerine birds, avian disease, and mammalian and reptilian land animals. Quarantine measures and visitation restrictions in place for researchers appear to be controlling the rate of new introductions, but species that do become established may be extremely difficult to eradicate. Thus, rigorous statewide reduction or elimination of non-native invertebrates and plants introductions through stricter quarantine and reduction of ship groundings are necessary. In addition to these efforts, future management specific to the recovery of Nihoa millerbirds may include the following:

- Conduct aggressive weed control and native plant restoration to stabilize habitat quality.
- Monitor and, when warranted, conduct aggressive control of unstable arthropod populations.
- Prevent the introduction of rats and other possible predators.
- Future translocations to 2 or more islands within the main Hawaiian Islands could lead to downlisting.

MONITORING: Continue point-distance survey sampling counts and habitat monitoring on both Nihoa and Laysan.

RESEARCH PRIORITIES: More research is needed on best quarantine techniques, best methods for early detection of alien species, and best eradication methods. Current knowledge suggests that Nihoa millerbird reproduction may be driven by variable external environmental factors, such as rainfall, but knowledge of breeding behavior and demographics is limited. The millerbird population is small, and the extirpation of the Laysan subspecies suggests an urgent need to establish another population. Research priorities specific to Nihoa millerbirds include the following:

- Conduct additional demographic studies to further refine estimates of population structure, dispersal, survivorship, nesting phenology and success, and other life history and behavioral characteristics.
- Further study translocation techniques and habitat restoration on target islands. Keeping insectivorous passerines alive for translocation is extremely difficult, but known techniques could be refined using non-endangered closely related species.

References:

- Bak, T., R. Camp, C. Farmer, R. Rounds, S. Plentovich, J. Vetter, and P. Banko. 2024. Nihoa and Laysan Island and passerines population abundances, trends, and habitat utilization. Hawai'i Cooperative Studies Unit Technical Report HCSU-107. University of Hawai'i at Hilo. 35 pages. <https://hdl.handle.net/10790/5393>
- Dalton M, Kohley R and Heindl B. 2014. Trip Report: Population Monitoring of Millerbirds on Laysan, June 28-September 28, 2014. Unpublished report for the American Bird Conservancy and U.S. Fish and Wildlife Service. 45pp.
- Morin M, Conant S. 2002. Laysan millerbird (*Acrocephalus familiaris familiaris*) and Nihoa millerbird (*Acrocephalus familiaris kingi*). In *The Birds of North America*, No. 302 (Poole A, Gill F, editors.). Philadelphia, (PA): The Academy of Natural Sciences; and Washington DC: the American Ornithologists' Union.
- U.S. Fish and Wildlife Service. 1984. Recovery plan for the Northwestern Hawaiian Islands passerines. Portland, (OR): U.S. Fish and Wildlife Service. 66 pp.
- U.S. Fish and Wildlife Service. 2010. Nihoa Millerbird (*Acrocephalus familiaris kingi*) 5-Year Review Summary and Evaluation. U.S. Fish and Wildlife Service, Honolulu, Hawai'i.

Photo: Craig Rowland, USFWS



Northwestern Hawaiian Islands Passerines

Nihoa finch

Telespiza ultima

SPECIES STATUS:

Federally Listed as Endangered

State Listed as Endangered

State Recognized as

Endemic

NatureServe Heritage Rank G1—Critically Imperiled

IUCN Red List Ranking—Critically

Endangered

Recovery Plan— USFWS 1984

SPECIES INFORMATION: The Nihoa finch (palihoa) is an omnivorous, ground-nesting Hawaiian honeycreeper (Family: Fringillidae) endemic to Nihoa Island in the Northwestern Hawaiian Islands (NWHI). Nihoa finches have black legs, large feet, and sturdy bills suitable for seed-eating, but in all body dimensions they are smaller than the congeneric Laysan finches. Males and females have different plumage; males are a brighter yellow over a larger proportion of their head and body than females. Nihoa finches are known to feed on seeds, fruits, leaves, flowers, stems, seedlings, roots, carrion, invertebrates, and eggs. Although their social behavior has not been thoroughly studied, Nihoa finches are thought to be similar to Laysan finches in being non-territorial outside of the breeding season. During breeding season, males defend nest sites in rock crevices, while females construct nests and incubate eggs. Females rely upon males for nuptial feedings during the incubation period.

DISTRIBUTION: Restricted to the approximately 63-hectare (156 acre) area of Nihoa Island. An introduced population at Tern Island, French Frigate Shoals, was extinct by the early 1980s.

ABUNDANCE: The most recent population estimate (2022 is 6,592 (4,594–8,655)) (Bak et al. 2024).

LOCATION AND CONDITION OF KEY HABITAT: Resides year-round on the steep-sided, rocky, and shrub-covered island of Nihoa. Finches prefer open but vegetated habitat and forage in all areas of the island. Finches frequently congregate around Nihoa's five to seven small freshwater seeps, or at ephemeral puddles of fresh water. About 25 species of plants compose Nihoa's vegetation community; the four most abundant are (in descending order of abundance): the shrub *Chenopodium oahuense*, the shrub *Solanum nelsonii*, the shrub *Sida fallax*, and the bunchgrass *Eragrostic variabilis*. Finch presence is positively correlated with *Sida fallax* height and percent cover, and also with mean and maximum *Solanum nelsoni* height. The entire range of this species occurs in the Hawaiian Islands National Wildlife Refuge.

THREATS: Limiting factors for Nihoa finches are primarily weather (i.e., drought and storms), variations in food supply (typically due to weather), and availability of appropriate nest sites. During population highs, the proclivity of Nihoa finches to break conspecific eggs might increase, but this has not been studied. Additional threats include:

- Invasive alien plants: Habitat quality could be degraded by weed invasions. While the finches, being omnivorous, would likely integrate some invasive plants into their diet, native plant populations could be adversely affected by competition with invasive alien plants such as *Miconia calvescens* or *Clidemia hirta*. To the extent that such alien plants would be lower-quality food resources, the finch population would be affected.
- Arthropod irruptions: Periodic irruptions of a native grasshopper on Nihoa Island reduce plant cover and degrade habitat.
- Population size: Small populations are plagued by a variety of potentially irreversible problems that fall into three categories: demographic, stochastic, and genetic; the former are usually most problematic. Demographic factors include skewed sex ratios and stochastic factors include natural disasters. Habitat fragmentation exacerbates demographic and genetic problems.
- Introduced mammals: The risk of rat introduction via transport (i.e., ships, planes) is of concern as rats are known to have decimated passerine populations in the NWHI in the past as a result of shipwrecks.

CONSERVATION ACTIONS: Nihoa finch persistence requires that the integrity of the island's small, remote ecosystems be maintained. This requires excluding and removing any introduced non-native insects, plants, passerine birds, avian disease, and mammalian and reptilian land animals. Quarantine measures and visitation restrictions in place for researchers appear to be controlling the rate of new introductions, but species that do become established may be extremely difficult to eradicate. Thus, rigorous statewide reduction or elimination of non-native invertebrate and plant introductions through stricter quarantine and reduction of ship groundings are necessary. In addition to these efforts, future management specific to the recovery of Nihoa finches may include the following:

- Conduct aggressive weed control and native plant restoration to stabilize habitat quality.
- Prevent the introduction of rats and other possible predators.
- Within the next five years, translocate Nihoa Finches to Lisianski, the island selected by Morin and Conant and again by Rounds et al (2024) during the 2024 “Strength, Weaknesses, Opportunities, Threats”(SWOT)
- SWOT workshop. Once mosquitos-free habitat is available in the MHI, select predator-free sites for reintroduction informed by the fossil record (Olson and James 1989, James and Olson 1991 James)

MONITORING: Continue current program of point-distance survey sampling and habitat monitoring.

RESEARCH PRIORITIES: More research is needed on best quarantine techniques, best methods for early detection of alien species, and best eradication methods. Research priorities specific to Nihoa finches include the following:

- Conduct additional demographic studies to further refine estimates of population

structure, dispersal, survivorship, nesting phenology and success, and other life history and behavioral characteristics.

- Assess which management options (e.g., translocation) would be most beneficial in terms of extinction risk reduction.

References:

Bak, T., R. Camp, C. Farmer, R. Rounds, S. Plentovich, J. Vetter, and P. Banko. 2024. Nihoa and Laysan Island and passerines population abundances, trends, and habitat utilization. Hawai'i Cooperative Studies Unit Technical Report HCSU-107. University of Hawai'i at Hilo. 35 pages. <https://hdl.handle.net/10790/5393>

Morin M., Conant S. 2002. Laysan finch (*Telespiza cantans*) and Nihoa finch (*Telespiza ultima*). In *The Birds of North America*, No. 639 (Poole A, Gill F, editors.). Philadelphia, (PA): The Academy of Natural Sciences; and Washington DC: The American Ornithologists' Union.

U.S. Fish and Wildlife Service. 1984. Recovery plan for the Northwestern Hawaiian Islands passerines. Portland, (OR): U.S. Fish and Wildlife Service. 66 pp.

U.S. Fish and Wildlife Service. 2011. Nihoa Finch (*Telespiza ultima*) 5-Year Review. U.S. Fish and Wildlife Service, Honolulu, Hawai'i.



Terrestrial Invertebrates

Land snails

Orders Stylomatophora, Archaeogastropoda

ORDERS INCLUDE:

44 Achatinelline species Federally/State Listed as Endangered

13

Native Families 750 + Native Species

GENERAL INFORMATION: The Hawaiian Islands hosted one of the most spectacular evolutionary radiations of land snails known to science with 99 percent of the 750 + valid species endemic to the islands. All but two families, Hydrocenidae and Helicinidae, are in the order Stylomatophora. The families Amastridae and Achatinellidae are the most speciose with 325 and 209 species, respectively. The family Endodontidae may contain as many as 200 undescribed species; to date only 33 are described. The phylogenetic and life history traits of some species in the family Achatinellidae, especially those in the genera *Achatinella* and *Partulina* are well understood, however the basic ecology of most other species is severely lacking.

DISTRIBUTION: Land snails are known from all Main Hawaiian Islands and Northwestern Hawaiian Islands.

ABUNDANCE: Because of declines in the availability and suitability of appropriate habitat, combined with the widespread presence of introduced predators, particularly non-native carnivorous snails (*Euglandina rosea* and *Oxychilus alliarius*), rats (*Rattus* spp.), and chameleons (*Chamaeleo jacksonii*), it is believed that 60 percent of native snail species are extinct, with remaining species in steep decline. While abundance estimates are available for most species in the genus *Achatinella*, and some species in the genera *Partulina*, *Perdicella*, *Newcombia*, *Laminella*, and *Amastra*, most other species are poorly understood because of a lack of systematic surveys.

LOCATION AND CONDITION OF KEY HABITAT: Hawaiian land snails occur in all native forests, including dry, mesic, and wet.

THREATS:

- Loss and degradation of habitat.
- Non-native invasive predators, particularly carnivorous snails, rats, and chameleons.
- Small population sizes and low reproductive rates makes them vulnerable to demographic and environmental stochastic threats such as loss of genetic diversity, inbreeding, hurricanes, fires, and disease.
- Global warming.

CONSERVATION ACTIONS:

- Survey across their range for undiscovered populations.

- Conduct phylogenetic assessments to confirm species identify and the phylogenetic relationships to other populations and species. As well as to assess the potential maintenance of genetic diversity and the reduction of inbreeding impacts.
- Conduct stop-gap predator control where possible to reduce impacts from introduced predators. Actions include rat trapping and the manual removal of *Euglandina* spp. and Jackson's chameleons.
- Establish captive populations to temporarily hold individuals for safe keeping or produce offspring for reintroduction or augmentation of wild populations.
- Increase capacity and redundancy for captive rearing by establishing populations at multiple facilities.
- Construct predator-proof fences to protect wild populations and to reintroduce populations from captivity.
- Establish populations within multiple predator-proof fences to create redundancy.
- Conduct direct translocations of populations to protected habitat when necessary.
- Conduct translocations of species outside of their historical ranges when recovery potential within their range is reduced due to, but limited to, climate change, predator load, or degradation of habitat, etc.
- Improve habitat at reintroduction sites by growing and planting host plants.
- Develop capacity for detection dogs to improve efficiency of predator-removal efforts from inside new predator-proof fences and during incursions at existing fence sites.

MONITORING:

- Implement scientifically robust monitoring of populations to assess trends and threats
- Cross reference population monitoring data with a detection probability index to more accurately measure population sizes.
- Continue predator detection surveys at regular intervals, adjusting predator exclusion and/or control accordingly.
- Continue population distribution surveys in known and potential habitats.

RESEARCH PRIORITIES:

- Develop and refine survey protocols to facilitate the collection of useful population data. Including research and development of improved capture-mark-recapture techniques, as well as improvement of relative abundance indices;
- Conduct investigations to assess the impacts of disease and parasites on wild and captive snail populations;
- Develop cryo-storage techniques for tissues lines or other genetic material for long-term storage;
- Conduct investigations on effective predator control strategies, particularly for Jackson's Chameleons, *Euglandina* spp., *platydemus manokwari*, and other predators found be to be depredating Hawaiian snails;
- Improve predator-proof fencing with research and development of more effective barriers and materials;
- Conduct investigations to improve the diet of captive snail populations by working towards development of a completely cultured or manufactured diet;
- Conduct investigations to determine life-history characteristics, such as growth rate, age at first reproduction, fecundity, longevity, etc;

- Conduct investigations on the impacts of herbicide on snail populations;
- Use a modeling approach to refine captive rearing methodology in terms of the size captive populations need to be, to be resistant to stochastic declines, the numbers and size classes that can be released into the wild, and at what intervals, as well as the best distribution of individuals between cages and between facilities to hedge against extinction.

References:

- Clarke B., Murray J., and Johnston M. 1984. The Extinction of Species by a Program of Biological Control. *Pacific Science* 38: 97-104
- Cowie, R.H. 1995. Variation in species diversity and shell shape in Hawaiian land snails: in situ speciation and ecological relationships. *Evolution* 49:1191-202.
- Cowie, R.H. 2001. Can snails ever be effective and safe biocontrol agents? *International Journal of Pest Management* 47: 23-40
- Department of Land and Natural Resources – Division of Forestry and Wildlife, Snail Extinction Prevention Program. 2014. Snail Extinction Prevention Program Strategic Plan: 2015 – 2019.
- Version 1.2 Department of Land and Natural Resources, Honolulu, HI.
- Gerlach J, Barker GM, Bick CS, Bouchet P, Brodie G, Cristensen CC, Collins T, Coote T, Cowie RH., Fiedler CG, Griffiths O L, Florens FBV, Hayes K., Kim J, Meyer J, Meyer WM, Richling I, Slapcinsky JD, Winsor L, Yeung NW (2020) Negative impacts of invasive predators used as biological control agents against the pest snail *Lissachatina fulica*: the snail *Euglandina 'rosea'* and the flatworm *Platydemus manokwari*. *Biological Invasions*. 10.1007/s10530-020-02436-w
- Hadfield, M. G. 1986. Extinction in Hawaiian Achatinelline snails. *Malacologia* 67:67–81.
- Hadfield, M. G., and S. E. Miller. 1989. Demographic studies on Hawaii's endangered tree snails: *Partulina Proxima*. *Pac. Sci.* 43:1–16.
- Hadfield, M. G., S. E. Miller, and A. H. Carwile. 1993. The decimation of endemic Hawai'ian tree snails by alien predators. *Am. Zool.* 33:610–622.
- Hadfield, M. G., B. S. Holland and K. J. Olival. 2004. Contributions of *ex situ* propagation and molecular genetics to conservation of Hawaiian tree snails. *Experimental Approaches to Conservation Biology*, M. Gordon and S. Bartol, eds. University of California Press. Pp. 16 – 34.
- Hadfield, M. G., and J. E. Saufler. 2009. The demographics of destruction: isolated populations of arboreal snails and sustained predation by rats on the island of Moloka'i 1982–2006. *Biol. Invasions* 11:1595–1609. doi:10.1007/s10530-008-9409-9
- Hawai'i Department of Land and Natural Resources. 2015. Hawai'i's State Wildlife Action Plan. Prepared by H. T. Harvey and Associates, Honolulu, Hawai'i.
- Holland, B.S., C.C. Christensen, K.A. Hayes, and R.H. Cowie. 2008. Biocontrol in Hawaii: A response to Messing (2007). *Proceeding of the Hawaiian Entomological Society*. 40:81-83.
- Holland, B. S., S. L. Montgomery, and V. Costello. 2010. A reptilian smoking gun: first record of invasive Jackson's chameleon (*Chamaeleo jacksonii*) predation on native Hawaiian species. *Biodivers. Conserv.* 19:1437–1441. doi:10.1007/s10531-009-9773-5
- Me I Introduction. Honolulu: University of Hawai'i Press.
- Meyer WM, Yeung NW, Slapcinsky J, Hayes KA (2017). Two for one: inadvertent introduction of *Euglandina*

species during failed bio-control efforts in Hawaii. *Biological Invasions* 19: 1399– 1405.

Régnier, C., Bouchet, P., Hayes, K. A., Yeung, N. W., Christensen, C. C., Chung, D. J., Fontaine, B., & Cowie, R. H. 2015. Extinction in a hyperdiverse endemic Hawaiian land snail family and implications for the underestimation of invertebrate extinction. *Conservation biology: the journal of the Society for Conservation Biology*, 29(6), 1715–1723.

Sato, A. Y., Price, M. R., & Vaughan, M. B. (2018). Kāhuli: Uncovering Indigenous ecological knowledge to conserve endangered Hawaiian land snails. *Society & Natural Resources*, 31(3), 320–334.

Solem, A. 1990. How many Hawaiian land snail species are left? and What can we do for them? *Bishop Mus. Occas. Pap.* 30:27–40.

U.S. Fish and Wildlife Service. 1992. Recovery plan for the O’ahu Tree Snails of the genus *Achatinella*. Portland, Oregon.

Yeung, N.W., Hayes K.A. 2018. Biodiversity and Extinction of Hawaiian Land Snails: How Many Are Left Now and What Must We Do To Conserve Them – A Reply to Solem (1990). *Integrative and Comparative Biology*, 58(6)1157-1169