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The Rainbow Skink, *Lampropholis delicata*, in Hawaii[1]

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ABSTRACT: The rainbow skink, *Lampropholis delicata*, arrived in Hawaii as an accidental import from Australia sometime about 1900, but its true identity went unknown until recently. Previously, *L. delicata* in Hawaii had been identified as *Lipinia noctua*, *Leiolopisma hawaiiensis*, and *Lygosoma metallicum* (the latter apparently does not occur in Hawaii). *Lampropholis delicata* establishes high-altitude records for reptiles in Hawaii at 1130 and 1220 m elevation on the islands of Hawaii and Kauai, respectively. Variations in body size and numbers of eggs produced in populations on Hawaii, Kauai, and Oahu suggest that competition for space and food may be lowering reproductive capacity, and inhibiting growth in the relatively dense populations on Oahu.

TAXONOMY AND DISTRIBUTION

THE RAINBOW, penny, or garden skink, *Lampropholis* (*Leiolopisma*) *delicata* De Vis 1888, arrived in Hawaii from Australia as an accidental import sometime about 1900 (Oliver and Shaw 1953, as reported for *Lygosoma metallicum*), but its true identity went unknown until recently. The earliest known collection of *Lampropholis delicata* in Hawaii is a previously unreported specimen in the collections of the Bernice P. Bishop Museum, Honolulu (BBM 899 = old BBM 219), taken on the island of Oahu in Moanalua Valley in 1909 by J. F. G. Stokes. The specimen was identified at that time as a moth skink, *Lipinia* (*Leiolopisma*) *noctua* Lesson 1830, apparently because of the general similarity of the specimen with the moth skink already known in Hawaii. But it was later reclassified as a metallic skink, *Lygosoma metallicum* (O'Shaughnessy) 1874, following the taxonomic works of Brongersma (1942) and Oliver and Shaw (1953).

The second known Hawaiian specimen was collected by W. C. van Heurn in Honolulu in 1919, and was deposited in the Rijkmuseum van Natuurlijke Histoire, Leiden, The Netherlands (CAT. NO. 4866). It was classified as *Lygosoma metallicum* and reported on as such by Brongersma (1942), who was unaware of the paper written 4 years earlier by Loveridge (1939). Loveridge had examined a small series of *Lampropholis delicata* from Oahu in the collections of the Museum of Comparative Zoology, Harvard University (CAT. NOS. 44,234–44,237), and had concluded that they represented a new species endemic to the Hawaiian Islands. He named the skink *Leiolopisma hawaiiensis*, distinguishing it from the moth skink.

When Oliver and Shaw (1953) began working up the collections they had made in 1944, they were not yet aware of Brongersma's 1942 paper calling the species in Hawaii *Lygosoma metallicum*. Independent of Brongersma, they arrived at the same conclusion that he had, after which Loveridge reexamined his type material and concurred that *Leiolopisma hawaiiensis* was, indeed, synonymous with *Lygosoma metallicum*. Other researchers since (Baker 1976, Brown 1953, Couzyn 1973, Hunsaker and Breese 1967) followed this lead and also used the name *Lygosoma metallicum*, for what is in reality *Lampropholis delicata*. As far as I am aware, *Lygosoma metallicum* does not occur in Hawaii, but three additional skink species are present: the moth skink; the snake-eyed skink, *Cryptoblepharus* (*Ablepharus*) *boutoni poecilopleurus* (Wiegmann) 1835; and the

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azure-tailed skink, *Emoia cyanura* (Lesson) 1830.

In 1972, a skink that had been captured by a pet housecat in the community of Volcano on the island of Hawaii at 1130 m (3700 ft) elevation was given to me for identification. This specimen was of interest because reptiles had not previously been known to occur in this area, or at that altitude anywhere in the Hawaiian Islands. In using the existing literature on Hawaiian reptiles, the skink keyed out to *Lygosoma metallicum*, which is common on Oahu but until this time unknown elsewhere in Hawaii. Additional specimens were collected for study from Volcano in 1972, 1976, and 1977 (BBM 5822–5840).

In 1976, while examining the collections of the Bernice P. Bishop Museum, I found an additional unreported collection of these skinks taken by K. J. Frogner in 1963 from the head of Kalalau Valley at 1220 m (4000 ft) elevation on the island of Kauai (BBM 2729–2734). Subsequently, in 1977, I collected others from Kalalau Valley, as well as from the adjacent Waimea Canyon from 1120 m (3675 ft) down to 304 m (1000 ft) elevation (uncatalogued specimens in The Australian Museum, Sydney).

A letter was sent to Harold Cogger, Curator of Amphibians and Reptiles at The Australian Museum, requesting information on *Lygosoma metallicum* in that country. Cogger's response brought up the question of the true identity of the Hawaiian forms. He wrote (in 1976):

> The identity of the introduced Hawaiian skink, whose origin has long been attributed to Australia, aroused my interest several years ago. On a visit to the U.S. I saw a copy of the (then) newly released field guide of Cochran and Goin, in which they illustrate a specimen of *Leiolopisma metallicum*. As the specimen in the photograph was clearly not *L. metallicum*, I subsequently borrowed a couple of preserved Hawaiian specimens from Dr. Sherwood Minton.
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> As expected, these were not *L. metallicum* but a beast closely allied to *Leiolopisma delicata*, a common eastern Australian species which has subsequently been shown to encompass a species-complex with several undescribed forms. As the Hawaiian specimens were not from any population with which I am familiar, I sent the specimens on to Mr. Peter Rawlinson at La Trobe University, who is an authority on this group of skinks. We subsequently confirmed that the specimens from Hawaii were a form of *L. delicata*, and that's where the matter rested.

While Cogger and Rawlinson did not pursue the matter further, each had determined the identity of this particular skink as *Leiolopisma delicata*. Since that time, however, Greer (1974) has placed *Leiolopisma delicata* in the genus *Lampropholis* (all the taxonomy used herein follows Greer), a genus common to eastern and southeastern Australia, including northern Tasmania.

The matter of the identity of the Hawaiian skink was personally taken up with Greer, who is also a Curator of Amphibians and Reptiles at The Australian Museum. He reexamined the type material of *Leiolopisma hawaiiensis* at Harvard, and studied collections of skinks I sent from the islands of Hawaii, Oahu, and Kauai (uncatalogued specimens in The Australian Museum, Sydney). Greer replied that "there is nothing in the type series of *L. hawaiiensis* that would exclude this name from the synonymy of *Lampropholis delicata*," and that "the biological identity of the Hawaiian animals is clear enough . . . in my opinion they represent the southeastern Queensland population of what is known here as *Lampropholis delicata*."

The foregoing should now clarify the confused taxonomy of the rainbow skink in Hawaii and establish *Lampropholis delicata* as the proper name for this Australian import. Of the vernacular names "rainbow skink," "penny skink," or "garden skink" used in Australia (Greer, personal communication 1977), the common name "rainbow skink" would seem appropriate in Hawaii because of the colorful irridescent hues of the scales and the rainforest distribution of many Hawaiian *L. delicata*.

Lampropholis delicata is of importance in Hawaiian zoogeography because the species establishes known high-altitude records for Hawaiian reptiles at 1130 m on Hawaii and 1220 m on Kauai. [A skink was observed but not captured at 1760 m (5800 ft) on the extinct volcano Mauna Kea on the island of Hawaii by Frederick R. Warshauer in 1977. A verbal description of the skink indicates that it was probably *L. delicata*.] All other reptiles in Hawaii are lowland forms usually ranging only to about 600 m (2000 ft) elevation (Hunsaker and Breese 1967, Oliver and Shaw

1953), with specimens of the snake-eyed skink having been taken at 975 m (3200 ft) in the Kau Desert area of the southeastern part of the island of Hawaii (Fisher 1948).

The fact that *Lampropholis delicata* occurs and thrives at significantly higher (and wetter) elevations in Hawaii than do other local lizard species is of interest in view of Greer's (personal communication 1977) comments that *L. delicata* in Australia is a "partly mountainous species generally found in wet, to dry sclerophyll forest." This would tend to explain the dry lowland through wet upland distribution of the rainbow skink in Hawaii.

It is believed that *Lampropholis delicata* first arrived in Hawaii on Oahu by accidental transport in shipments of lumber or plant materials (Oliver and Shaw 1953, as reported for *Leiolopisma metallicum*). It is not surprising, then, that these lizards could eventually reach other islands in Hawaii, and they would be expected to. In the case of the island of Hawaii population, it is suspected that residents commuting between Honolulu, Oahu, and seasonal homes in Volcano inadvertently transported the rainbow skink in potted plant materials and/or cargoes of household items. One Volcano resident reported finding a skink inside the family automobile. For similar reasons, the rainbow skink will eventually spread to other parts of the island, and to other islands and locations in Hawaii, if it has not already done so.

The Volcano population may be less than 10 years old, as none of these skinks had been reported before 1972 by any of the local residents. The Kauai skinks were first collected in 1963. Both populations, therefore, are very likely more recent than the Oahu introduction.

While population densities have not been determined for any of the populations, it was stated by Oliver and Shaw (1953) that the rainbow skink is abundant on Oahu, and that its rapid multiplication on that island had produced "remarkable" numbers of skinks. In this I can concur. Oliver and Shaw (1953) reported 44 skinks beneath a single banyan tree, and I saw an estimated 300–400 in a small area of about 100 m^2 beneath three large mango trees in Nuuanu Park, Honolulu, where they were apparently feeding on insects attracted to the many rotting mango fruits. I captured 91 skinks in a few hours, and they were so abundant that several at one time could be seen scurrying through the grass and leaves. I found several eggs under leaves and debris.

Observations in Volcano indicate that the rainbow skink is only sparsely distributed around a small area of scattered residences covering approximately 100 ha (about 240 acres). There it is commensal with humans around lawns and gardens, and along roadsides, where the skinks venture out into open sunlight in clearings, on rock and wood piles, and around buildings. More and more residents are finding them, and some report them more common now (1978) than when first observed in 1972.

In comparison to its relative scarcity in Volcano, the rainbow skink is much more abundant on Kauai, where it is common along trails, roadsides, and in relatively open areas of forests, but nowhere did I find it on Kauai quite as abundant as I observed it in some areas on Oahu. Numbers on Kauai seem to diminish in the denser, heavily shaded areas of forest, and it appears that these shinks are probably dispersing through forests by moving primarily along roadsides and trails.

It is suspected that the Hawaii Island population will disperse similarly, and it is probable that the rainbow skink will eventually become widespread and common over large areas of the island, including the Hawaii Volcanoes National Park, adjacent to Volcano, where nonnative animals are undesirable in any large numbers.

BODY SIZE AND EGG PRODUCTION

Among the three populations of *Lampropholis delicata* on Hawaii, Kauai, and Oahu, variations occur in mean body (snout–vent) length and in the numbers of eggs produced. Sexually mature females on Kauai and Hawaii are larger than females on Oahu (see Table 1). Measurements I took of adult females from Oahu averaged 38.6 mm in body length (maximum of 42 mm), while those from Hawaii and Kauai averaged 41.2 mm

TABLE 1

AVERAGE BODY (SNOUT–VENT) LENGTH AND CLUTCH SIZE (± 1 STANDARD DEVIATION) OF 64 FEMALE *Lampropholis delicata* FROM THREE ISLAND POPULATIONS IN HAWAII

POPULATION LOCATION	*N*	AVERAGE BODY LENGTH (mm)	AVERAGE CLUTCH SIZE	CLUTCH RANGE
Oahu	45	38.6 ± 1.7	3.5 ± 1.8	1–5
Kauai	9	41.8 ± 3.5	4.1 ± 1.0	3–6
Hawaii	10	41.2 ± 2.8	4.7 ± 1.3	3–7

NOTE: See text for statistical significance between means.

and 41.8 mm, respectively (maximum length of 46 mm on both islands). These averages are 2.6 mm and 3.2 mm more than that of Oahu females. Fifteen females from Oahu measured by Oliver and Shaw (1953) averaged 39.8 mm (maximum of 44 mm), 2 mm less than the average of the present Kauai female sample.

Statistical *t*-tests showed there was a significant difference between the mean body lengths of Hawaii Island and Oahu females ($t_{53} = 3.85$, $P < 0.01$); and between Kauai and Oahu females ($t_{52} = -4.31$, $P < 0.01$); but not between Hawaii Island and Kauai females ($t_{17} = -.48$, $P > 0.01$).

The apparent selection for small body size of Oahu females is due most likely to the high population densities, causing competition among individuals for available space and food. Competition with other species, as with the snake-eyed and moth skinks may also play a role. Such inter- and intraspecific competition, reducing body size, would also cause reduced egg production, and it happens that the mean number of eggs per female from Oahu is lower than the mean numbers of eggs on Kauai and Hawaii (see Table 1).

The average number of eggs reported by Oliver and Shaw (1953) for 15 Oahu females was 2.9, and none carried more than 4 eggs. Several had only 1 egg, but Oliver and Shaw qualify these figures by stating that their skinks had previously been opened for preservation purposes, and it was possible that some of the eggs could have been lost prior to counting. All eggs counted in the present study were obtained from females newly captured, or from preserved specimens that had not been previously opened.

In a series of 45 freshly opened females from Oahu that I had taken in 1977, the average number of eggs was 3.5, ranging from 1 to 5 (see Table 1). Numbers of eggs for 10 Hawaii Island females averaged 4.7, ranging from 3 to 7. Numbers of eggs for 9 Kauai females averaged 4.1, ranging from 3 to 6. None of the Hawaii Island or Kauai females had fewer than 3 eggs each, though a number of the Oahu females had only 1 or 2 eggs each. The Hawaii Island population averaged 1.2 (34 percent) more eggs per female, and the Kauai population averaged 0.6 (17 percent) more eggs per female, than Oahu females.

Statistical *t*-tests showed there was significance in the mean numbers of eggs between Hawaii and Oahu females ($t_{53} = 2.81$, $P < 0.01$), but not in the mean numbers of eggs between Kauai and Oahu females ($t_{52} = 1.41$, $P > 0.01$).

In an oviparous species, the number of eggs produced varies to some extent with individual body size. Larger individuals with more internal body capacity lay more eggs than do smaller individuals of the same species. This phenomenon is summarized by Lack (1954, pp. 45–52), whose summary also shows that egg production increases with the age of females if the older females are larger. It was observed that larger females of the rainbow skink did, indeed, tend to carry more eggs (see Figure 1). An analysis of the regression slope showed that body size versus clutch size was significant at the 0.025 percent level ($F_{1,4} = 12.2$, $P < 0.025$), and it approached significance at the 0.01 percent level.

In the case of the Hawaii Island females, I found that as numbers of eggs increased from 3 to 7, the average body length increased

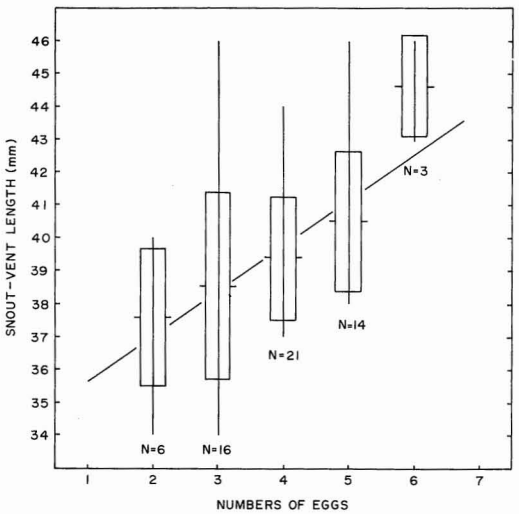

FIGURE 1. Combined snout–vent lengths versus clutch sizes of 60 female *Lampropholis delicata* from populations on Hawaii, Kauai, and Oahu. Other specimens containing as few as 1, or as many as 7 eggs, were not included in the data because of small sample size. Horizontal lines represent means; vertical lines represent ranges of snout–vent lengths; boxes on either side of the mean represent 1 standard deviation; N = sample size. The regression line equation is $Y = 34.5487 + 1.27619(X)$. The mean of the Y axis is 39.48 mm; the mean of the X axis is 3.78 eggs.

about 1.5 mm for each additional egg. By comparing egg volume with body length it was calculated that an increase in body length of at least 1.2 mm would be required to accommodate each additional egg. This measurement falls within the actual 1.5 mm increase measured.

In animals, a correlation between reproductive capacity and food availability is also generally accepted (Lack 1954, pp. 45–52). An animal that eats only enough food to maintain itself without reproducing can either reproduce and starve, or it can cease reproducing and survive. If, however, food is in excess of nonreproductive nutritional needs, and other factors are not limiting reproduction, then the reproductive capacity of individuals can be expected to reach its maximum potential. All of the rainbow skinks taken on Hawaii and Kauai in this study were collected near midday, and stomachs appeared full, indicating each was able to capture whatever food was wanted within the first half-day of foraging. It appears, therefore, that sufficient food is available to these populations for optimum growth and reproductive effort. Stomach contents observed in the Oahu skinks, which were collected in midafternoon, seemed less engorged, but no precise, comparative measurements were made of any of the lizards for volumes of food consumed.

An analysis of the kinds of food eaten was made on a collection of rainbow skinks from Volcano. The foods were principally various Coleoptera, Corrodentia, Diptera, Embioptera, Homoptera, Hymenoptera, and Lepidoptera. Besides these insects, invertebrates such as annelids, arachnids, and symphillids, were also taken.

The probable limited food and space in the dense Oahu populations, and competition with other species, may well be the limiting factors to body growth and reproduction. It seems significant to me that none of the Oahu skinks had the maximum of 6 to 7 eggs as observed in the Kauai and Hawaii populations, although 24 (53 percent) of my 45 Oahu females, as well as a number of those 15 Oahu females observed by Oliver and Shaw (1953), did have body sizes large enough to carry 6 or 7 eggs. The relatively low maximum egg number in Oahu *Lampropholis delicata* (5 eggs) seems to indicate that limiting factors are in force which are inhibiting female growth and reproductive potential on this island.

No comparative data are available on body lengths and egg production of *Lampropholis delicata* in Australia (Greer and Cogger, personal communications), but it could probably be shown that the populations on Hawaii and Kauai show significantly higher measurements in both parameters than do the Australian populations.

In summary, the present investigation regarding the arrival, establishment, interisland spread, and selected ecological aspects of *Lampropholis delicata* in Hawaii adds to existing knowledge of how certain alien species can become established in new island habitats and niches, and can flourish in the absence of coevolved ecological restraints.

ADDENDUM

Subsequent to completion of this manuscript, the following new data were obtained on the distribution of the rainbow skink in Hawaii from Sean McKeown (personal communication 1978). All observations and collections were made since September 1975. Oahu—common many localities; Kauai—common many localities; Hawaii—collected from Hilo and Volcano; Molokai—collected in the vicinity of Hotel Molokai; Maui—common around Kahului and Hana; Lanai—common in many localities including Lanai City at 457 m (1500 ft) and high fern forest locations at 838 m (2750 ft). These data add three new islands (Molokai, Maui, and Lanai) to the statewide distribution of *Lampropholis delicata*, which rounds out its range in Hawaii to all the major inhabited islands. McKeown also suggests that the widespread abundance of the rainbow skink in Hawaii is a cause for the present rarity of moth skinks, and possibly the azure-tailed skink. The belief that the rapid expansion of rainbow skinks in Hawaii was replacing moth skinks was also suggested by Hunsaker and Breese (1967, as reported for *Lygosoma metallicum*).

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LITERATURE CITED

BAKER, K. 1976. The occurrence and ecological significance of metallic skinks on the islands of Hawaii and Kauai. Proc. 1st Conf. Nat. Sci., Haw. Vol. Natl. Pk.; Coop. Natl. Pk. Res. Studies Unit, Department of Botany, University of Hawaii, Honolulu, pp. 11–17.

BRONGERSMA, L. D. 1942. Notes on scincid lizards. Zool. Med. 24(1–2):125–152.

BROWN, W. C. 1953. The distribution of terrestrial reptiles in the islands of the Pacific basin. Proc. 8th Pac. Sci. Congr.; Vol. IIIA, Oceanography and Zoology; Nat. Res. Council of the Philippines, University of the Philippines, Quezon City, pp. 1479–1491.

COUZYN, D. 1973. Key to Hawaiian skinks. Div. Vert. Zool., Bernice P. Bishop Mus., Honolulu. Typescript. 1 p.

FISHER, H. I. 1948. Locality records of Pacific island reptiles and amphibians. Copeia 1 (Apr. 15):69.

GREER, A. E., JR. 1974. The generic relationships of the scincid lizard genus *Leiolopisma* and its relatives. Aust. J. Zool., Suppl. Ser. 31:1–67.

HUNSAKER, D., and P. BREESE. 1967. Herpetofauna of the Hawaiian Islands. Pac. Sci. 21(3):423–430.

LACK, D. 1954. The natural regulation of animal numbers. Oxford University Press, London. 343 pp.

LOVERIDGE, A. 1939. A new skink (*Leiolopisma hawaiiensis*) from Honolulu. Proc. Biol. Soc. Wash. 52(Feb. 4):1–2.

OLIVER, J. A., and C. E. SHAW. 1953. The amphibians and reptiles of the Hawaiian Islands. Zoologica 38(2, no. 5):65–95.