© Journal of The Royal Society of New Zealand,
Volume 27, Number 2, June 1997, pp 235–242

Morphological variation of *Emoia murphyi* (Lacertilia: Scincidae) on islands of the southwest Pacific

George R. Zug*, B.J. Gill†

We examined variation in measurements and scalation of 114 specimens of Murphy's tree skink *Emoia murphyi* from five island groups of the southwest Pacific. In the largest sample (Niuafo'ou) males were significantly longer than females. Populations from Futuna, Samoa, Niuafo'ou, Vava'u and Ha'apai showed little morphological divergence, and there were no geographic trends in scalation. We conclude that the various populations are conspecific. The lack of morphological discontinuity suggests that the lizards dispersed between the far-flung island groups recently, and makes more likely the possibility that Polynesian seafaring rather than natural spread was the agent of dispersal. The source population—whether within or beyond the known distribution of *E. murphyi*—is at present indeterminate.

Keywords: southwest Pacific, Samoa, Tonga, Futuna, *Emoia murphyi*, Reptilia, Scincidae, measurements, scalation, dispersal

INTRODUCTION

Emoia murphyi was described from a single specimen collected on Savai'i, Western Samoa, by the Whitney South Sea Expedition (Burt 1930). This small, slender skink is strongly arboreal and rarely descends to the ground. It is a member of the *concolor*-subgroup of the *samoensis* species-group within *Emoia* (Zug & Ineich 1995), and is most similar to the Fijian *E. concolor*.

Since its description, *E. murphyi* has attracted little attention (e.g. Brown 1956, in table only), reappearing in the biological literature only in the late 1980s as biodiversity surveys began to document the faunas of Pacific islands. Brown & Gibbons (1986) gave the distribution of *E. murphyi* as Samoa and Tonga without providing any details. Gill & Rinke (1990) cited museum specimens of this species to show that it occurred on the northern Tongan islands of Niuafo'ou, Niuatoputapu, and the Vava'u group. In Western Samoa *E. murphyi* occurs on both Savai'i and 'Upolu (Brown 1991; Gill 1993); it is not known from American Samoa (Amerson et al. 1982). Gill (1995) reported *E. murphyi* from Futuna and 'Alofi in the French territory of Wallis and Futuna. Recent field work by one of us (GRZ) obtained specimens of *E. murphyi* from the Tongan Ha'apai group, but Murphy's tree skink has not been recorded further south on Tongatapu or 'Eua. The known distribution of this skink is indicated in Fig. 1.

The recent redescription of *E. murphyi* by Brown (1991) relied predominantly on specimens from Niuafo'ou ($n > 80$), and we suspected that it might not reflect the full variability of this species. Specimens from Futuna seemed slightly different in colour from those from Samoa and Tonga (Gill 1995). Our goal has been to examine the widely separated populations for evidence of morphological divergence. The level of divergence potentially offers a clue to the relative age of dispersal, and hence the probable dispersal mode.

---

* Department of Vertebrate Zoology, National Museum of Natural History, Washington, D.C., U.S.A. 20560
† Auckland Institute and Museum, Private Bag 92018, Auckland, New Zealand

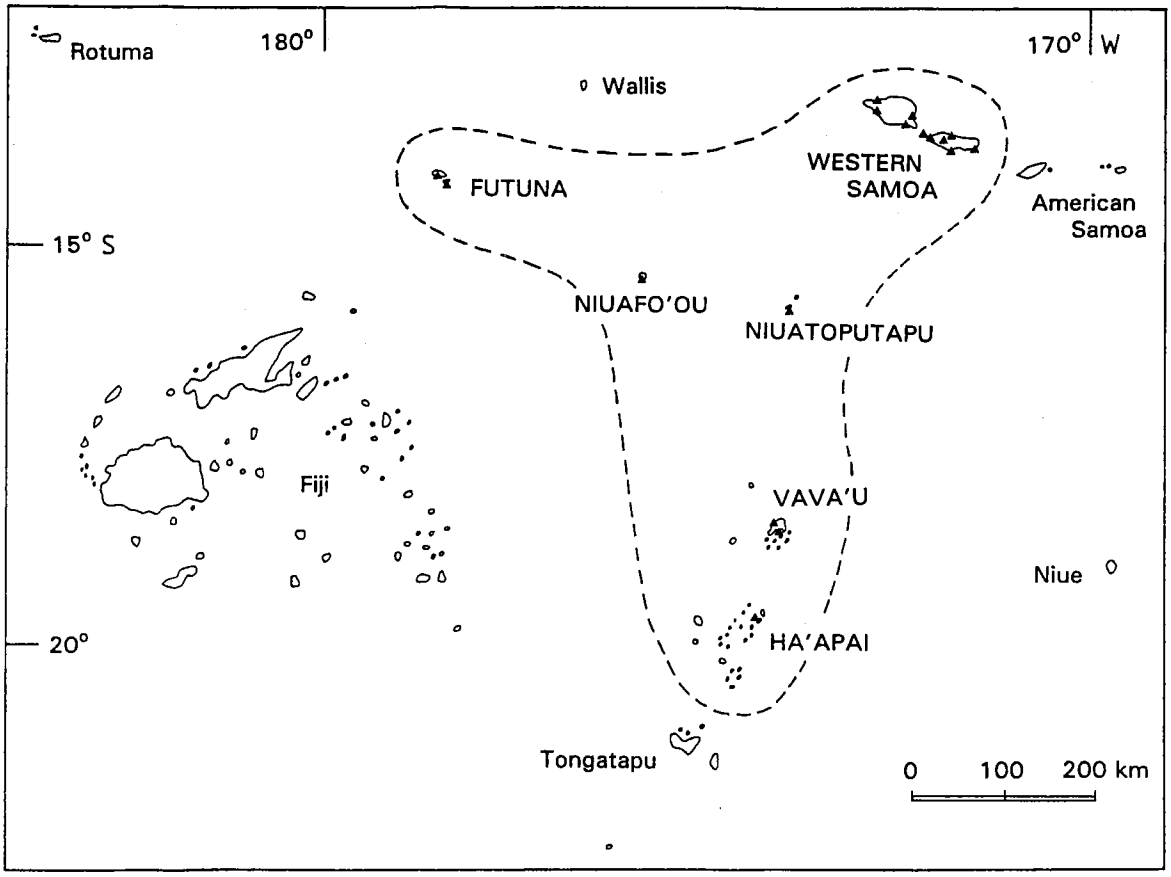

Fig. 1 Distribution of *Emoia murphyi* on islands of the southwest Pacific.

The broad distribution of *E. murphyi* and its occurrence on isolated island groups suggest the possibility of either recent human-aided (unintentional) dispersal by Polynesian seafarers during the last few millenia or natural, much more ancient dispersal. A greater degree of differentiation would have followed the latter than the former.

MATERIALS AND METHODS

Our comparison examines samples from five island groups: Futuna, Samoa, Niuafo'ou, Vava'u, and Ha'apai. The voucher and locality data are given in Appendix 1.

We recorded the following 10 morphometric and 13 scalation characters, recorded as in Zug (1991) unless noted otherwise. All measurements and counts were taken from the right side unless damaged. All measurements were to the nearest 0.1 mm as recorded by dial or vernier calipers. The abbreviations of the character names are used in the text for brevity.

Measurements

EyEar	orbit to ear distance (anterior corner of eyelids to anteromedial edge of ear opening)
HeadL	head length
HeadW	head width
Interorb	interorbital width (across top of head at suture of 2nd and 3rd supraciliaries)
HindlL	hindlimb length
NarEye	naris-orbit distance (naris to anterior corner of eyelids)
NeckL	neck length
SnEye	snout-orbit distance (tip of snout to anterior corner, or junction, of upper and lower eyelids)

SVL	snout-vent length
TrunkL	trunk or body length

Scalation

AuricLob	number of auricular lobes on anterior margin of ear opening
BlwEye	supralabial scale lying below centre of orbit
Dorsal	number of rows of dorsal scales between the parietals and base of tail, including nuchal scales
Eyelid	number of enlarged upper eyelid scales
ForefL	number of digital lamellae beneath fourth digit of forefoot
HindfL	number of digital lamellae beneath fourth digit of hindfoot (the first proximal lamella counted is the first scale wider than long in contact with a large lateral/dorsal digit scale on at least one side)
Inflab	number of infralabial scales
Interp	presence or absence of interparietal scale
Midbody	number of scales around midbody
Nuchal	number of rows of nuchal scales
Supcil	number of supraciliaries
Suplab	number of supralabial scales
Supoc	number of supraocular scales

All statistical analyses were performed on SYSTAT 5.03 (Wilkinson 1990).

RESULTS

Sexual dimorphism

Three samples (Niuafo'ou, Samoa, Vava'u) contain sufficient adult females and males (n = 23/26, 10/7, 7/9, respectively) to test for sexual differences. The expression of sexual dimorphism in size is variable in these three samples, and none of them shows significant differences of scalation between the sexes. In the Niuafo'ou sample all mensural characters display significant differences ($P < 0.05$, Student's t test), with males averaging larger than females (Table 1). In the Samoan sample significant differences occur for EyEar, HeadL, HeadW, HindlL, Interorb, NarEye and SnEye; males are somewhat larger than females. Only EyEar, HeadL, and NarEye are significantly different in the Vava'u sample. With the exception of NeckL and SnEye in the Niuafo'ou sample, TrunkL in the Samoa sample, and TrunkL and HindlL in the Vava'u sample, all characters display a homogeneity of variance ($P > 0.05$, Bartlett's χ^2 test).

The minimum SVL recorded for sexually mature females was 53.1 mm and for males was 55.0 mm, although some longer individuals may still be immature. The maximum SVL recorded was 77.6 mm (Table 2) for a male from Futuna. (When Burt (1930) first described *E. murphyi* he wrongly assumed that the single specimen available (SVL = 73 mm) was "young".)

Geographic variation

Owing to the sexual dimorphism of the mensural characters, adult male and female samples are examined separately. For scalation, the samples include both sexes and a few immature individuals, because neither sex nor maturity affects the number of scales in an individual or sample.

The pattern of variation in mensural characters is strikingly different between females and males. Only the Samoa, Niuafo'ou, and Vava'u samples have adequate numbers of adult females to allow comparison, and only TrunkL, NeckL, and NarEye display significantly different means ($P < 0.05$) among the three localities (Table 2). For males only, the Ha'apai sample is inadequate, and all characters except HeadL (samples lack homogeneity of variance) differ significantly among the samples (Table 2). For males, average size differs among the

Table 1 Selected characters of adult female and male *Emoia murphyi* from Samoa, Niuafo'ou, and Vava'u. For definition of character abbreviations, see Materials and Methods. The data are mean ± standard deviation, and range.

	Samoa		Niuafo'ou		Vava'u	
	Female	Male	Female	Male	Female	Male
n	12	8	21	26	6	10
SVL	62.4±3.16	65.8±3.22	60.8±3.50	67.1±3.31	59.5±4.49	62.2±5.36
	56.4–67.3	60.4–70.3	55.1–70.7	58.7–75.1	53.1–65.6	55.6–70.0
HeadL	13.8±0.61	15.6±0.66	13.6±0.65	16.0±0.82	13.5±0.86	15.1±1.56
	12.8–15.0	14.6–16.6	12.8–15.4	14.3–17.5	12.3–14.9	13.2–17.6
SnEye	6.1±0.38	6.8±0.31	6.1±0.26	7.2±0.92	6.0±0.41	6.3±0.63
	5.5–6.7	6.5–7.2	5.8–6.6	6.2–11.3	5.4–6.6	5.5–7.3
Dorsal	55.6±2.40	54.4±1.92	55.2±1.41	54.5±1.42	54.5±2.07	54.7±1.95
	52–60	51–56	53–58	52–58	53–58	51–57
Midbody	28.7±1.15	29.4±1.51	27.7±0.72	28.0±0.60	28.0±1.10	27.9±0.87
	27–30	28–32	26–29	27–29	27–30	27–30
HindfL	67.5±5.13	68.5±3.42	65.6±3.19	66.1±2.61	63.3±6.71	66.9±4.01
	60–78	61–72	61–70	60–70	55–73	57–71

Table 2 Selected mensural characters of adult *Emoia murphyi* displaying significant differences of means. Data as in Table 1; samples arranged north to south.

	n	SVL	TrunkL	HindlL	NeckL	NarEye
Futuna						
females	2	63.1±5.80	29.7±5.30	29.0±4.10	10.0±0.42	4.7±0.21
		59.0–67.2	26.0–33.5	26.1–31.9	9.7–10.3	4.6–4.9
males	3	74.4±5.49	35.6±3.25	32.8±1.95	11.4±0.95	5.8±0.23
		68.1–77.6	32.0–28.2	30.9–34.8	10.4–12.3	5.5–5.9
Samoa						
females	12	62.4±3.16	31.4±2.63	27.9±1.56	8.4±0.97	4.6±0.24
		56.4–67.3	27.3–35.5	25.5–30.8	7.9–9.8	4.1–5.1
males	8	65.8±3.22	31.3±0.86	32.6±2.57	9.5±1.73	5.0±0.36
		60.4–70.3	29.6–32.7	29.8–37.1	7.1–12.2	4.6–5.5
Niuafo'ou						
females	21	60.8±3.50	29.1±2.14	27.8±1.26	9.2±0.81	4.4±0.25
		55.1–70.7	26.1–34.1	25.0–31.0	7.6–11.4	4.0–5.0
males	26	67.1±3.31	31.0±1.74	32.3±1.40	10.3±1.31	5.3±0.61
		58.7–75.1	27.9–33.8	29.7–34.9	7.9–13.3	4.6–7.8
Vava'u						
females	6	59.5±4.49	28.9±4.21	27.6±1.03	8.8±0.94	4.2±0.27
		53.1–65.6	23.5–35.6	26.5–29.3	7.5–9.6	3.7–4.5
males	10	62.2±5.36	29.0±1.93	29.2±3.57	8.9±0.88	4.9±0.42
		55.6–70.0	25.6–32.0	21.1–34.0	7.5–10.4	4.2–5.5
Ha'apai						
females	1	57.1	28.7	26.6	7.5	4.1
males	1	55.0	25.4	28.4	7.6	4.4

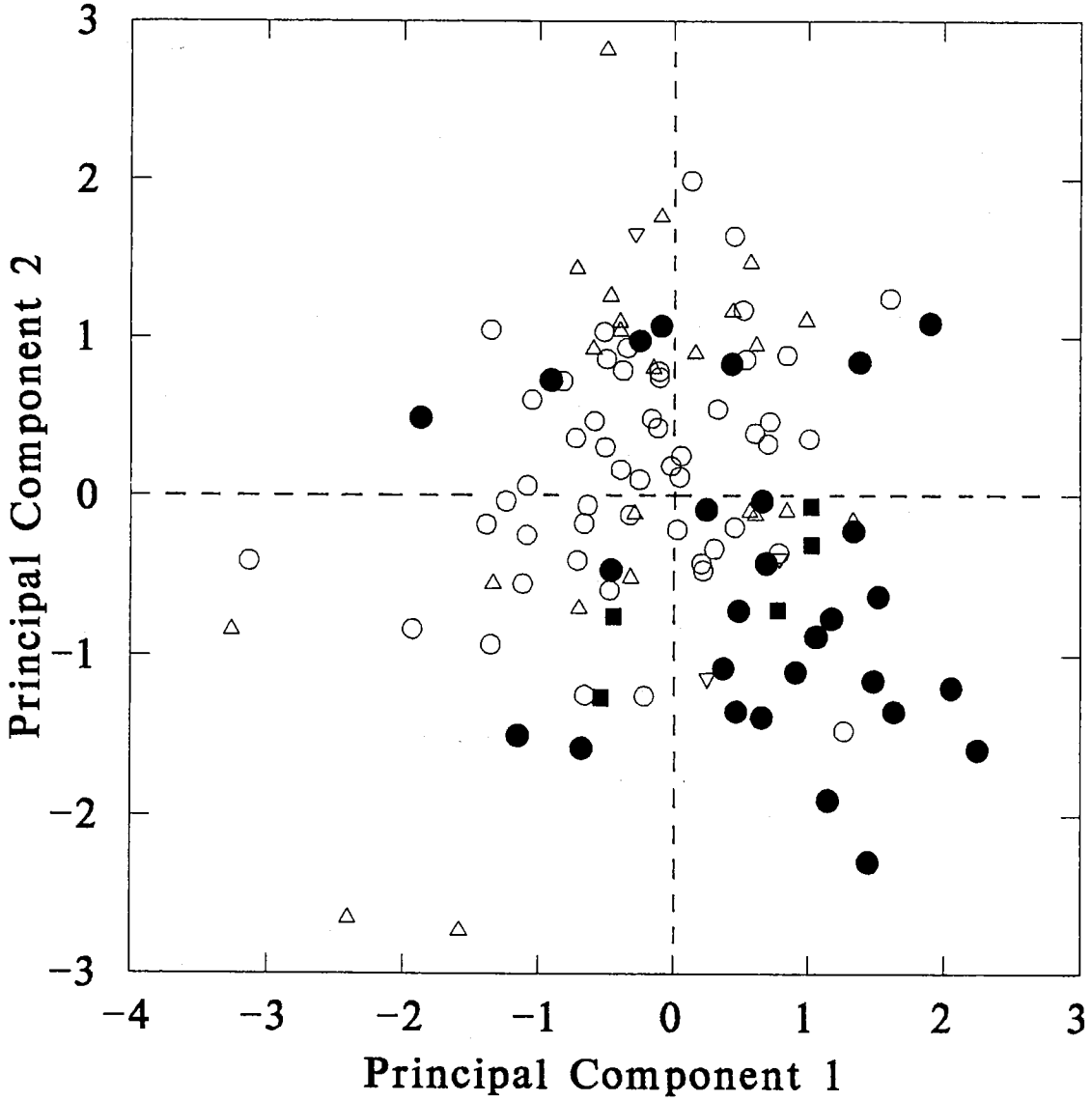

Fig. 2 Distribution of individual *Emoia murphyi* (n = 114) in multivariate space, based on seven scalation characters. Samples: solid circles, Samoa; open circles, Niuafo'ou; upright triangles, Vava'u; inverted triangles, Ha'apai; solid squares, Futuna.

Table 3 Scalation characters of *Emoia murphyi* displaying significant differences of means among the five samples. Data as in Table 1; samples arranged north to south.

	n	Eyelid	Dorsal	HindfL	Suplab
Futuna	7	9.6±0.89	56.7±0.89	65.1±3.53	7.4±0.54
		9–11	55–58	60–71	7–8
Samoa	28	10.5±0.96	55.1±2.05	68.2±4.14	8.0±0.19
		8–12	51–60	60–78	7–8
Niuafo'ou	52	11.2±1.02	54.7±1.46	65.4±3.87	7.9±0.30
		9–14	52–58	47–71	7–8
Vava'u	24	11.2±0.93	54.4±1.95	65.5±4.35	7.9±0.28
		9–13	51–58	55–73	7–8
Ha'apai	3	10.3±0.58	55.3±1.16	67.0±2.65	7.3±0.58
		10–11	54–56	64–69	7–8

populations in the order Futuna > Niuafo'ou > Samoa > Vava'u and for females Futuna > Samoa > Niuafo'ou > Vava'u.

A Principal Component Analysis (PCA) of a subset of the measurements (SVL, HindlL, HeadW, EyEar, SnEye, NarEye, Interorb) shows no evidence of geographic segregation; the individuals of all samples occupy a single area in multivariate space. In both females and males, the first component is size-related and accounts for 58% and 71% of the variance, respectively. The first three components explain 83% (females) and 92% (males) of the total variance.

Scalation similarly shows no geographic trends. Supoc is unvaryingly four scales in all samples. AuricLob (range 1–4, mainly 2), BlwEye (6th supralabial, rarely 5th), and Inflab (6, rarely 7) are nearly invariant in the samples. Supcil (7–11), Midbody (26–32), and ForefL (37–52) vary between samples but the means and variances are not significantly different. Eyel (8–14), Dorsal (51–60), HindfL (47–78), and Suplab (7–8) vary sufficiently among the samples to yield significant differences of sample means (Table 3).

Using the set of seven varying characters, PCA shows no geographic segregation in the distribution of individuals or samples (e.g. Fig. 2). The first three components of the PCA account for 62% of the variance in the total or combined sample. ForefL and HindfL are the highest-loading characters (>0.75) on the first component, Dorsal and Midbody (>–0.58) on the second component, and Supcil (>0.80) on the third component.

In life *E. murphyi* has plain dorsal coloration—speckled but not striped—that ranges from pale brown or beige through distinctly coppery tones to dull coppery olive or grey; venters are bright lime-green to strongly yellowish green. The variation in colours within each population appears to encompass the range of coloration over the entire species. The bright ventral colours are exhibited by adult males, adult females and immatures.

DISCUSSION

Sexual dimorphism

The occurrence of distinct size dimorphism in the largest of the samples (Niuafo'ou), and its irregular appearance in the other two large samples, suggest that all populations are dimorphic. The trend of males averaging longer than females is probably masked in the small samples from Samoa and Vava'u. The similarly proportioned *Emoia concolor* of Fiji is also moderately size-dimorphic (Zug 1991) without displaying any scale dimorphisms, as are various other skinks.

Geographic variation

The Futuna sample contains the largest mean SVL for males and the largest male. However, this sample contains only three adult males and has an abbreviated and skewed range in comparison to the other samples, so it seems unwise to conclude that the Futuna population averages larger than the others. Because all other mensural characters are strongly correlated with SVL, they show the same pattern.

Scalation also fails to produce any geographic trends or segregation of populations among the different localities. Where means differ significantly between samples the absolute differences are small, and in most instances the range and/or mean ± 1 standard deviation of the Niuafo'ou sample encompasses the mean of the 'deviant' sample.

The similarity of the samples suggests that none of the populations of *Emoia murphyi* has been isolated for long. The morphological uniformity suggests that some of the scattered populations may have been established accidentally by the prehistoric voyages of Polynesian seafarers, a mechanism of dispersal in the south Pacific that has been much discussed (e.g. Crombie & Steadman 1986, Beckon 1992). The source of the original population of *E. murphyi* cannot be resolved from the morphological data. The source population could be within the present known distribution of *E. murphyi*, a locality from which the species has not yet been recorded or a location from which it has been extirpated. Another possibility is that *E. murphyi* represents an introduction of an *E. concolor* morph into western Polynesia. The

Fijian populations of *E. concolor* show a higher level of regional variation than *E. murphyi* over geographically shorter distances (Zug 1991; Zug & Ineich, unpubl. data) although the variation in the Fijian population is not sufficiently documented to confirm or even suggest a source population for *E. murphyi*.

Taxonomic conclusions

At this stage we conclude from our analysis of morphological variation in *E. murphyi* that the various island populations belong to one species. Even if more data from Futuna confirm that individuals there tend to be larger than individuals from other islands, any taxonomic distinction that may be justified would probably be at an infraspecific rank.

ACKNOWLEDGEMENTS

R. Sadlier (AMS), C. McCarthy (BMNH), J. Vindum (CAS), A. Resetar (FMNH), I. Ineich (MNHN), R. Coory (NMNZ), and R. Günther (ZMB) allowed access to specimens in their care. Gill's field work in Futuna was approved by the Services de l'Economie Rurale et de la Pêche and partly funded by the Auckland Museum C.H. Worth Memorial Fund. Our independent field studies in Tonga and Western Samoa were approved by the Ministry of Natural Resources, Tonga, and the Department of Conservation, Western Samoa. Zug's research was sponsored by the Smithsonian's Scholarly Studies Program and Research Opportunity Fund. We appreciate the support and encouragement of these individuals and organisations for assisting our research into the evolution of the Pacific lizard fauna. We thank two anonymous referees for comments that improved the text.

REFERENCES

Amerson, A. B.; Whistler, W. A.; Schwaner, T. D. 1982: *Wildlife and Wildlife Habitat of American Samoa. II. Accounts of Flora and Fauna.* U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Beckon, W. N. 1992: The giant Pacific geckos of the genus *Gehyra*: morphological variation, distribution and biogeography. *Copeia 1992*: 443–460.

Brown, W. C. 1956: The distribution of terrestrial reptiles in the islands of the Pacific Basin. *Proceedings of the Eighth Pacific Science Congress*: 1479–1491.

Brown, W. C. 1991: Lizards of the genus *Emoia* (Scincidae) with observations on their evolution and biogeography. *Memoirs of the California Academy of Sciences 15*: 1–94.

Brown, W. C.; Gibbons, J. R. H. 1986: Species of the *Emoia samoensis* group of lizards (Scincidae) in the Fiji Islands, with descriptions of two new species. *Proceedings of the California Academy of Sciences 44*: 41–53.

Burt, C. E. 1930: Herpetological results of the Whitney South Sea Expedition. IV. Description of new species of lizards from the Pacific Islands (Scincidae). *American Museum novitates 427*: 1–3.

Crombie, R. I.; Steadman, D. W. 1986. The lizards of Rarotonga and Mangaia, Cook Island group, Oceania. *Pacific Science 40*: 44–57.

Gill, B. J. 1993: The land reptiles of Western Samoa. *Journal of the Royal Society of New Zealand 23*: 79–89.

Gill, B. J. 1995: Notes on the land reptiles of Wallis and Futuna, southwest Pacific. *Records of the Auckland Institute and Museum 32*: 55–61.

Gill, B. J.; Rinke, D. R. 1990: Records of reptiles from Tonga. *Records of the Auckland Institute and Museum 27*: 175–180.

Leviton, A. E.; Gibbs, R. H.; Heal, E.; Dawson, C.E. 1985: Standards in herpetology and ichthyology: Part 1. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. *Copeia 1985*: 802–832.

Wilkinson, L. 1990: *SYSTAT: the System for Statistics.* SYSTAT Inc., Evanston, Illinois.

Zug, G. R. 1991: Lizards of Fiji: natural history and systematics. *Bishop Museum bulletin in zoology 2*: i–xii, 1–136.

Zug, G. R.; Ineich, I. 1995: A new skink (*Emoia*: Lacertilia: Reptilia) from the forest of Fiji. *Proceedings of the Biological Society of Washington 108*: 395–400.

APPENDIX 1: Specimens examined (museum abbreviations follow Leviton et al. 1985).

FUTUNA, WALLIS AND FUTUNA: AIM H1582–84 (Fiua, Futuna), H1952 (Nuku, Futuna); MNHN 1986.665–66 ('Alofi); ZMB 5932 ("Futuna").

WESTERN SAMOA: AIM H1390 (Togitogiga, 'Upolu), H1407 (Asau, Savai'i); AMS R116164 (Safua, Savai'i); BMNH 1924.12.6.5 (Apia, 'Upolu), 1969.551 (Manono I.), 1969.634 (Aleisa, 'Upolu); CAS 172208 (Mulifanua, 'Upolu), 176440–41 (Salelavalu, Savai'i), 176463–65 (Safua, Savai'i), 176468–71 (Salelavalu, Savai'i), 176475–76 (Safua, Savai'i); FMNH 39204 (Aleipata, 'Upolu), 39205 (Falelima, Savai'i); USNM 268368 (Afiamalu, 'Upolu), 322743 (Salelologa, Savai'i), 322744–47 (Tafua Reserve, Savai'i), 322748–49 (Salelologa, Savai'i).

NIUAFO'OU, TONGA: AIM H1332–35; USNM 82875–77, 82879, 82881–82, 82884, 82886–87, 82890–92, 82898–900, 82902–07, 82910–12, 82914, 82917, 82920–27, 82930, 82932, 82935–38, 82940–41, 82944–47, 82949.

NIUATOPUTAPU, TONGA: NMNZ P220 (Falehau).

VAVA'U, TONGA: AIM H1303 (Okoa I.); CAS 158237–40 ("Vava'u"), 158996–97 (Ofu I.); FMNH 196830 (Neiafu, Vava'u I.); USNM 259329–30 ("Vava'u"), 333670 (Tefisi, Vava'u I.), 333671 (Utui, Vava'u I.), 333672–73 (Mangia, Vava'u I.), 333674 (Makave, Vava'u I.), 333675–83 (Leimatu'a, Vava'u I.).

HA'APAI, TONGA: USNM 333760–62 (Lifuka I.).

Received 16 September 1996; accepted 20 November 1996