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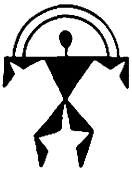

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Perkins in the English countryside with his sons. After entomology, fishing was Perkins' passion, a hobby he pursued even in the last years of his life. The camera-shy Perkins successfully evaded Hawai'i photographers, and he declined to have his portrait included in *Fauna Hawaiiensis.*

BISHOP MUSEUM OCCASIONAL PAPERS 26: 1-46 MAY 1986

The Sandwich Islands Committee, Bishop Museum, and R.C.L. Perkins: Cooperative Zoological Exploration and Publication

Anita Manning[1]

ABSTRACT

The history of a project of zoological exploration in the Hawaiian Islands is traced from the project's inception by a group of British zoologists interested in the evolution of the Hawaiian fauna to publication of its results in *Fauna Hawaiiensis*. The project is examined primarily from the viewpoint of Bishop Museum. A decision by the Museum's founder, C.R. Bishop, and its trustees to cosponsor the project with the Sandwich Islands Committee brought financial support to the project when it was critically needed. The role of *Fauna Hawaiiensis* in establishing a scientific press at Bishop Museum is explored, as is the role of the project in the development of programs at the Museum. Excerpts from letters, newspapers, and diaries convey the drama of funding the project, choosing a collector, the arduous and exciting fieldwork, and the contention associated with distributing the resultant specimens. The personality and eccentricities of the collector, R.C.L. Perkins, are seen to have influenced this history. Exploratory work on each island is summarized, while appendices provide detailed information on members of the guiding Sandwich Islands Committee, authors of *Fauna Hawaiiensis,* and publication data. Perkins' collecting itinerary has been compiled from many sources to assist curators and zoologists using his collections.

INTRODUCTION

The zoological exploration initiated in 1890 by the Sandwich Islands Committee and eventually cosponsored by Bernice Pauahi Bishop Museum resulted in outstanding collections of the land fauna of Hawai'i and in *Fauna Hawaiiensis,* a publication of continuing importance. In this paper, the project is examined predominately from the viewpoint of Bishop Museum. For Bishop Museum the undertaking inaugurated a tradition of international scientific cooperation, provided the foundation of a world-renowned entomological collection, and contributed to the initiation of scientific publishing by the Bishop Museum Press. Cosponsorship provided Bishop Museum with access to the international scientific community and recognition otherwise unavailable so early in its growth and development. The effect of the methods and personality of R.C.L. Perkins, the collector chosen by the Committee, on the project and on its results is also examined. To aid zoologists and scholars in making critical use of both the collections and *Fauna Hawaiiensis,* detailed information is provided on the actual fieldwork and on the editing of the publication.

Interest builds: a committee is appointed

In September 1890, with the year-old Bishop Museum not yet open to the public, the British Association for the Advancement of Science (BAAS) appointed a committee to

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"report on the present state of our knowledge of the Zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in [our knowledge of] the Fauna" (BAAS 1891). The Association was reacting to an interest in Hawai'i's land fauna that had built steadily since Hawai'i's discovery by the Europeans in 1778. The works of 3 men, Blackburn, Gulick, and Wilson, were the most immediate stimuli for this zoological interest. Their collections tantalized the British scientific community with unique specimens and the promise of more.

The Rev. Thomas Blackburn was a Honolulu resident for 6 years (1877–1883) while affiliated in various capacities with the city's Episcopal cathedral (Blackburn & Sharp 1885). Blackburn's avocation was entomology and his precious free time was spent collecting elusive Hawaiian insects. In 1882, Blackburn exhibited his collection in Honolulu (Hon. Libr. Assoc. 1882) and published a short summary article, "Hawaiian Entomology," in the *Hawaiian Almanac and Annual* (Blackburn 1881). Compared with the few previous attempts at collecting Hawaiian insects, Blackburn's success engendered a serious interest in Hawaiian entomology when his specimens reached English scientists. Blackburn described his collections for British journals, either alone or in cooperation with recognized authorities such as coleopterist David Sharp and hymenopterist Peter Cameron. These scientific papers usually included a plea for exploration of Hawai'i by a collector devoting full effort to scientific pursuits. Blackburn even included glowing descriptions of beautiful Hawaiian scenery, considering this a justified "digression . . . [which] may be excused for the possibility of luring fresh explorers to the islands" (Blackburn & Sharp 1885).

While Blackburn was Hawai'i's only resident amateur entomologist, many collected land snails. For collector Rev. John Thomas Gulick, land snail characteristics formed the basis of his theory on the mechanics of evolution. In 1872 Gulick brought Hawai'i's land snails, particularly *Achatinella,* to the attention of those involved in evolutionary debates by reading papers before the BAAS and the Linnean Society. He used his time in England to study at the British Museum (Natural History) (BMNH) and to visit scientists to discuss the land snails he had brought with him (Gulick 1932). Gulick continued to publish his theories and to designate new species of *Achatinella,* and in 1887 he read before the Linnean Society a lengthy paper, "Divergent evolution through cumulative segregation" (Gulick 1890). More journal articles followed in 1889 and 1890. Gulick's theories were seriously debated by evolutionists. Would these theories be reasonable when applied to equally well-documented, large, and geographically diverse series of Hawaiian birds or insects? It was impossible to test Gulick's theories using the small collections of birds and insects then available in European museums.

In 1887, four years after Blackburn's departure from Hawai'i and shortly before Gulick's paper to the Linnean Society, Scott Barchard Wilson, under the urging and tutelage of Alfred Newton of Cambridge University, arrived in the Hawaiian Islands "with the view of investigating their ornithology in a thorough way" (Newton 1892c). Wilson worked toward that objective during 18 months in Hawai'i. The specimens with which Wilson returned had much the same effect on Britain's scientific community as Blackburn's insects.

By summer 1889 Newton was pressing Wilson to conduct further fieldwork in Hawai'i (Wilson & Evans 1890–1899). When he was unsuccessful, Newton argued the need for continued exploration before the 1890 meeting of the BAAS. Newton's plea was favorably received by an audience whose appetite had been whetted by Blackburn, Gulick, and Wilson. Certainly the lure of the unknown, of new creatures to be discovered, played a part in the eagerness of the British to support exploration in Hawai'i. Equally important were the theoretical questions to be answered by examining the fauna of Hawai'i and other island areas. Peter Cameron, urging further exploration of Hawai'i, had written in 1886 that

> The investigation of the natural history of oceanic islands is now rightly regarded as a subject of great interest and importance. Not only do their fauna and flora throw much light on the manner in which species have been distributed over the globe, but many of the species themselves are, from the peculiarities of their structure, of extreme value in throwing light on the origin of species. (Blackburn & Cameron 1887)

Furthermore, time was running out. Introduced plants and animals, together with habitat reduction, were expected to result in mass extinction of species (Blackburn & Cameron 1887; Sharp 1890). Newton's suggestion was acted upon by the BAAS and the Sandwich Islands Committee was appointed with a grant of £100 (US $500)[2] (BAAS 1891).

Additional funds needed

The Committee, chaired by William Henry Flower, Director of the British Museum (Natural History), acted quickly. A meeting was held and the new Committee decided, not surprisingly,

> that the Zoology is but imperfectly known, that it is of great scientific interest and that it ought to be further investigated. That the only way to do this is to send a naturalist to the islands to explore their natural history as thoroughly as may be found possible and to transmit the objects obtained to this country to be examined and reported upon by competent authorities. (Sharp 1890)

Yet the Sandwich Islands Committee's £100 would hardly support such a plan. The Committee decided to seek additional funding even though an ornithological collector, Lionel W. Wiglesworth, volunteered to start for the Islands immediately (Wilson & Evans 1890–1899). This decision cost the Committee valuable time in the contest to reach Hawai'i's rich collecting grounds first. Wilson's ornithological discoveries had piqued the interest of Sir Lionel Walter Rothschild, who maintained a museum on his estate at Tring, England. Rothschild, not constrained by funds, dispatched Henry C. Palmer to Hawai'i, where Palmer worked, with several assistants, from December 1890 until August 1893 (Rothschild 1893–1900). Newton (1893a) and Perkins (1894) concluded that Rothschild planned to precede the Committee's collector and reap the glory of new discoveries and descriptions of new species. Certainly George C. Munro, who collected with Palmer from 1890 until 1892, believed this (Munro N.D.a). A rivalry with Rothschild marked the first 18 months of the Sandwich Islands Committee's work. Newton's feeling of lost glory is mirrored in the "Introduction" to Wilson's report on his own work:

> The loss of the season of 1891 was unfortunate for the credit of the Joint Committee; for many discoveries which its collector, had one been sent out in that year, could not have failed making fell to the lot of the persons employed by Mr. Rothschild in 1890–1892. (Wilson & Evans 1890–1899)

In its search for additional funds, the Committee turned first to the Royal Society of London, which dispensed a "Parliamentary Grant for scientific investigations," commonly called the Government Grant. Several members of the BAAS's Sandwich Islands Committee were also members of the Royal Society, and the Society appointed a committee soon after

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[2] All dollar values of British pounds are based on a 19th century exchange rate of ca. US $5 to £1. The 1985 value of one 19th century dollar is ca. US $12.95.

the 1890 BAAS meeting (Sharp 1913a). By May 1891, an additional £200 was made available to the Sandwich Islands Committee by the Royal Society (Sharp 1891a).

The Committee also hoped that the Hawaiian Kingdom's legislature and that country's wealthy citizens would support zoological exploration of their islands. David Sharp, who was to remain the Committee's secretary throughout its history, wrote on 8 November 1890 to A. Hoffnung, the Hawaiian chargé d'affaires in London, stating the Sandwich Islands Committee's plan to investigate the Islands' fauna. Sharp carefully noted that sums appropriated by the legislature or donated by Hawaiian citizens would be "expended in the islands" and would "add . . . to the wealth of the islands, rather than diminish it." Sharp also asked about the efficacy of distributing a circular to acquaint residents with the Committee's aims (Sharp 1890). The chargé d'affaires passed Sharp's letter to J.A. Cummins, minister of foreign affairs, who received it in January 1891. Cummins' speedy answer noted that the legislature's recent adjournment made government funds unavailable. Cummins did offer to distribute circulars if the Committee sent them to him (Cummins 1891). Regrettably, available copies of Cummins' letter contain a copyist's error that inadvertently deleted as much as a page from the text. The text jumps from "Unfortunately the Legislature has but recently adjourned" to "and of much larger and wealthier States but regret is expressed on all sides that so many of our historical treaties have passed into the hands of Collectors of Foreign Countries" (Cummins 1891). The surviving phrases hint at a sentiment familiar today in emerging nations whose cultural and natural history treasures rest largely in the museums of other countries. The Committee, however, considered the reply a "very favourable answer" and apparently had no objection to Cummins' suggestion, perhaps made on the missing page, that Hawai'i funding sources "would be likely to cooperate, provided that a portion of the collections obtained should be ultimately placed in the Museum at Honolulu [B.P. Bishop Museum]" (BAAS 1892). The Committee's circular, "Zoological Exploration of the Hawaiian Islands," reached Hawai'i by November 1891 (Sharp 1891c).

By coincidence, Honolulu banker Charles Reed Bishop was traveling in Europe during 1891 and in September met to discuss the Committee's plans with the new chairman, Alfred Newton, and others. Newton called Bishop's interest in the program "strong," but apparently Bishop made no definite promises (Newton 1892a). Bishop may have wished to wait and watch, being a cautious man regarding finances, particularly when scientists were involved. Bishop wrote of a scientific collection, "I do not like to 'buy a pig in a poke' " (Bishop 1894), explaining his wish to have it independently examined before buying. Later, Bishop wrote that "naturalists and scientists have their pet hobbies on which they would spend or induce others to expend almost any amount" (Bishop 1898d). It is also probable that Bishop's decision not to assist the project financially was influenced by the advice of William Tufts Brigham, the first curator of the Bernice Pauahi Bishop Museum, which Bishop had founded in 1889 in memory of his wife. When the Committee first contacted Bishop Museum seeking assistance, Brigham wrote to David Sharp that the Committee shouldn't send an entomologist to Hawai'i, since he (Brigham) "had been all over the islands and there were no insects . . . except common American ones . . ." (Perkins 1947). He had discovered this "whilst botanizing" (Holmes 1897c). Brigham's remarks were, as Museum Trustee Henry Holmes wrote, "a huge blunder" (Holmes 1897c) that gave the Sandwich Islands Committee a poor opinion of Bishop Museum. Yet Brigham was not as far from the mainstream of scientific thought as modern observers might presume. Unfamiliar with Blackburn's work (Perkins 1892–1897), Brigham was unaware of Hawai'i's potential for insect collecting. Even Blackburn had concluded that

> One of the most remarkable features in Hawaiian entomology is the extreme rarity of specimens, in comparison of the number of species, the very common insects

> being few indeed, and the rather common ones almost none at all.... My experience in this matter agrees with that of previous explorers in the islands of the Pacific Ocean, many of whom allude to the extreme paucity of insect life there. (Blackburn & Sharp 1885)

By 1895, Brigham observed that the Committee's work had "overturned the theory of the poverty of insular faunas" (Brigham 1895).

In short, the Sandwich Islands Committee received little more than kind words and encouragement from Hawai'i during 1890–1891.

Joint Committee formed

Encouraged by the Royal Society's funding and the hope of cooperation from Hawaiian sources, the Sandwich Islands Committee made its first report to the BAAS at the August 1891 meeting. The Committee received permission to cooperate with the Royal Society's committee. The combination was formally known as the Royal Society and British Association Joint Committee for the Zoology of the Sandwich Islands and, for obvious reasons, was informally termed the Joint Committee. Alfred Newton, Magdalene College, University of Cambridge, was named chairman of the Joint Committee. David Sharp, Museum of Zoology, Cambridge University, continued to serve as secretary. S.J. Hickson, University of Manchester, would remain treasurer throughout the Joint Committee's life. Newton, Sharp, and Hickson formed an executive subcommittee, authorized to act for the whole. Other members were W.T. Blanford, geologist, Osbert Salvin, ornithologist, and P.L. Sclater, editor of *Ibis* and a founder of the British Ornithologists' Union. E.A. Smith, British Museum (Natural History) malacologist, and C.V. Riley, U.S. Bureau of Entomology and Plant Quarantine, were appointed to the Committee at the 1891 meeting (BAAS 1892).

Over the next 23 years this Joint Committee, with a few additions and resignations (Appendix 1), guided a collector and generated the funds to sustain and publish the results of his work. The Committee was composed of British men, Riley having emigrated to America in 1859 (McLachlan 1895). The average age of Committee members on appointment was 58. All were university educated but not in natural history. Flower and Sharp, for instance, were trained in medicine, then a recognized "sphere for such tendencies [as natural history] in those devoid of private fortunes" (Royal Soc. Lond. 1905). Typically, Sclater began by "practicing at the Bar, but always working steadily at natural history" (Evans 1913). By 20 years after the publication of Darwin's "The Origin of Species," the mechanisms of evolution and zoogeography were common interests among the Committee's members. Sclater's position as editor of *Ibis,* a well-read ornithological journal, was used to keep the Joint Committee's efforts and needs before the scientific community. By fortune or design, several Joint Committee members served on the Royal Society and British Association committees controlling financial assistance for zoological exploration. Newton had a particular gift for piloting the Joint Committee's requests through those committees. He may have been chairman, but it was David Sharp who ably and aptly represented the mind of the Joint Committee to others in correspondence, orchestrated and edited *Fauna Hawaiiensis,* and wrote major portions of the Coleoptera sections of the *Fauna.* Newton described him as the "life & soul" of the project (Newton 1906).

A collector chosen

Following its formation, the Joint Committee faced the important and difficult task of selecting a collector upon whom the success or failure of the Committee would rest. In addition to L.W. Wiglesworth, an international field of candidates was considered for the position. Sharp and Riley discussed the possibility of the United States sending entomologist Albert Koebele to Hawai'i and the Joint Committee sending a collector specializing in the birds, mollusks, and other land fauna (Sharp 1891b; Riley 1892). In late November of 1891, Robert Cyril Layton Perkins, Jesus College, Oxford University, was invited to apply for the position through Joint Committee member E.A. Smith, with the support of Perkins' professor, Oxford entomologist E.B. Poulton. Walter Garstang, Owens College, Manchester University, wrote encouragingly to Perkins:

> Dear Perkins, Nov. 6, 1891
>
> I am glad you like the prospect & I am sure it is a capital opportunity. Of course we mustn't count our chickens, but we will hope for them.
>
> I believe that the Committee would prefer to have a man recommended to them & in whom they could trust rather than throw the post open to competition. So I have great hopes of your selection. The secretary of the committee is Dr. David Sharp, F.R.S., Museum of Comparative Zoology, Cambridge, & it is a good omen that, like you, he is an entomologist. Write to him as soon as you like now, and say that, having been invited to apply for the post by me, through Mr. Edgar Smith, you would be glad if you could be supplied with further particulars and details concerning the duties of the post and the work you would be expected to perform &c &c. You should state your qualifications fully e.g. your training at Oxford in the school of Animal Morphology, your long experience &c in the collecting line mentioning the extent of your own collections of British Hymenoptera &c &c the fact that you have published several papers on them also, and a word or two to the effect that you would throw yourself heart & soul into the work would perhaps fetch!
>
> I will write to Sharp myself also on your behalf and will write to Poulton & ask him also to help. Smith is on the committee also & I will write to him & feel sure he will support you.
>
> It will be as well if you also give Dr. Sharp the names of one or two naturalists as referees on your behalf—Poulton of course being one. I am not important enough myself for a referee I am afraid, but will write however informally for you. If you can add the name of some big Johnnie who is great upon any other land bugs except insects, in addition to Poulton, it will help (provided you can count upon his support).
>
> There! that is all I can do, I think, except to say 'Go in & win.'
>
> Yours ever,
> W. Garstang

Perkins applied immediately to Sharp who replied with details of the proposed work and a warning that the position carried no salary—only expenses would be paid (Sharp 1891c). Perkins was not deterred and wrote on 12 November affirming his application (Sharp 1891d). In the next 1½ months Perkins pressed his case in interviews with several Committee members (Sharp 1891e). Persistence, recommendation, and qualification blended, and in the first week of January 1892 the Joint Committee chose Perkins from a field of candidates. Chairman Newton quickly wrote to Charles R. Bishop, subtly suggesting that it was still possible for Bishop to sponsor the project.

> My dear sir, 9 Jany 1892
>
> I have delayed troubling you with a letter until I should be able to furnish you with some positive information as to the action of the Committee . . . I have now to tell you that the Committees . . . have, within the last week selected from the various candidates who offered their services, Mr. Robert C.L. Perkins, B.A. of Jesus College, Oxford, and this gentleman will proceed to Honolulu, via San Francisco, with as little delay as possible. I accordingly have to bespeak on his

> behalf the valuable assistance of yourself and of any of your friends whether private persons or members of the Hawaiian Government, which I hope will regard favorably the important enquiry with which he is entrusted. Although I had not previously known Mr. Perkins, I feel sure from the testimony of others well qualified by personal acquaintance with him that I may safely recommend him to your notice and consideration—and I may add that he will perhaps stand in greater need of such attentions as you may be so good as to bestow upon him for I understand that he has never visited any foreign country.
>
> Mr. Perkins' instructions are to lose no opportunity of collecting examples of all Classes of Fauna—though he will be directed to a few special points. It is impossible for me at present to say how long he will stay in the islands. The belief of the Committee is that the proper investigation of their Zoology would require his residence for a couple of years, but the funds as yet at our disposal (£300) are manifestly insufficient for so long a period. We intend however to apply for a renewal of the grants. I should state that Mr. Perkins renders his services gratuitously—his actual expenses alone being defrayed by the Committee—and this fact will, I trust, dispose all who are in a position to assist him the more readily to further his object. . . . (Newton 1892b)

While his superiors continued to worry about money, the 26-year-old Perkins, with a bit more than a month before departure, prepared for his great personal and scientific adventure. Meetings were arranged with Sharp, Newton, Scott Wilson, and other specialists, during which Perkins absorbed hints on collecting techniques and localities, animals especially wanted, and preservation methods. He read the few articles written on the Hawaiian fauna and arranged for customs clearances and passage. Hurried notes about equipment passed between Sharp and Perkins. Silver pins were ordered for insect mounting, and Sharp offered to lend Perkins his sieve for sifting insects from leaf litter (Sharp 1892a).

By mid-February Perkins had departed England, arriving in New York on 24 February and in Honolulu on 10 March 1892. The *Daily Bulletin* noted:

> Mr. Perkins has lost no time in pursuing his journey, as he arrived here by the steamer Mariposa yesterday. Honolulu is becoming a meeting place for scientists. There are here now Professor Marcuse of Germany and Preston of the United States investigating vagaries of the earth's axis, and Mr. Perkins to make a thorough examination and report of the zoology of the group. (Daily Bulletin 1892)

Perkins proved a poor correspondent, notwithstanding the instructions he received from Newton before leaving England that keeping the Committee fully informed was necessary to ensure the renewal of grants (Newton 1892b). Perkins did not write enroute and waited more than 2 weeks before notifying Newton of his arrival in Hawai'i. Nor did Perkins' letters give Sharp and Newton sufficient information to satisfy the inquiries of other Committee members or the granting committees. In 1896, during the second trip Perkins made for the Joint Committee, Newton was still chiding him:

> When I meet members of the Committee they always ask where you are and what you are going to do next. To question No. 1 I generally answer "In the Sandwich Islands" & to No. 2 "To stay there for the present" but this does not always content them. Which shews [*sic*] how difficult it is to please them. (Newton 1896e)

Fieldwork initiated

Perkins went enthusiastically and immediately to work in the field, if not at the writing table. He found Hawaiian forests receding at a frightening rate: while sugar cultivation was not expanded in 1892, coffee plantations were extended in 'Ola'a, an important bird habitat on the island of Hawai'i, and while construction of the road from Hilo to Kīlauea Crater was slow, Honolulu streets were expanding and attracted "a rapid extension of the use of bicycles" (Thrum 1892). Obtaining a guide, Perkins made several trips into O'ahu forests, educating himself on the Hawaiian fauna (Perkins 1892–1897). March, April, and May were devoted to learning and adjustment (see Appendix 4 for details). This period was discouraging for Perkins, but Newton consoled him:

> Everyone who goes to collect natural history things in a foreign country must make up his mind to the fact that weeks or even months will be wasted at the beginning—& if the country is partially civilized more time is likely to be wasted, through misleading information (given with the best of intentions) than if it were wholly unknown. . . . I have always been on my guard against the local informant—though it may happen that he is not always wrong. (Newton 1892e)

Perkins found O'ahu a poor collecting ground for the novice and felt he could learn more quickly in a district "where the birds were known to be numerous in species and individuals. . . . On this account I left Oahu for Kona, Hawaii, in June 1892" (Perkins 1892–1897). Indeed the choice had been well made:

> When I first arrived in Kona the great Ohia trees . . . were a mass of blooms and each one of them was literally alive with hordes of the crimson Apapane and scarlet Iiwi, while . . . the Oo could be seen on the wing, sometimes six or eight at a time. The Amakihi was numerous in the same trees, but less conspicuous, and occasionally one saw the long-billed Hemignathus. Feeding on the fruit of the Ieie could be seen the Hawaiian crow commonly and the Ou in great abundance. The picture of this noisy, active and often quarrelsome assembly of birds, many of them of brilliant colours was one never to be forgotten. (Perkins 1892–1897)

In Kona, the Greenwell family gave Perkins permission to hunt on their ranch. Greenwell hospitality left Perkins with warm memories of the brothers Arthur and Henry and sisters Lily and Christina, whom he called "most charming girls" (Perkins 1937). After collecting on Hawai'i until mid-October 1892, he returned to O'ahu.

Having learned to identify many Hawaiian birds and insects and to recognize their habits, Perkins now devoted a profitable 6½ months to O'ahu fieldwork. The experience gained in Kona did not eliminate the problems of working on O'ahu. Perkins complained that

> the whole of the mountains here is made up of countless ridges. One is practically confined to the ridge one is on, while the bird might be quite near, yet . . . inaccessible. . . . How different from Kona! One might hunt a bird, of which few individuals survive, for years without success. The chance of such a bird being on the very same ridge as is the collector and on the same part of that ridge at the same time is very small unless the bird really exists in some numbers. (Perkins 1892–1897)

In early May 1893, Perkins moved from O'ahu to Moloka'i, where he worked until November. There he contended with extremely wet forest conditions, as he hiked high in the mountains. Despite 2- or 3-ft deep trenches around his tent, the ground inside became a pool of mud. His discomfort was rewarded with the discovery of *Drepanis funerea,* a new species of *mamo* (Perkins 1892–1897).

In July 1893, he hiked alone into Moloka'i's Pelekunu Valley from the ridge above. After a descent punctuated by a fall of some feet, Perkins waded down the valley's stream until he encountered some Hawaiians:

> For a long time I could not convince them that I was alone and when I told them that I was from Kaunakakai, they said no malahini [*sic*] [newcomer] could find his

> way from there and kept looking back to see if others were coming behind me! One of the natives, a boy of about 18, took me off to his house in the village about a mile or two from where I met them. There are only about twenty houses on the beach.... They got me a change of clothes as I was wet through and plastered with mud, and fed me on fish & taro.... I saw the winding-up exercises at the school. The children's performances were creditable but their number was small. I had expected to find grass houses in this valley and even possibly see tapa making, but there was nothing of the kind. The natives are a sturdy and energetic lot, as they had no horses.... (Perkins 1892–1897)

In August, Perkins spent the first 2 weeks based at the Kala'e home of Rudolph W. Meyer, where he thoroughly enjoyed "the varied and well cooked food" (Perkins 1892–1897), conversations on "Darwin's theories" (Perkins 1948), and the companionship of Meyer's sons on tramps to the high mountains (Perkins 1936a).

From mid-December 1893 until late February 1894, Perkins collected on Lāna'i, where the Hayselden family provided access to collecting sites, home-cooked dinners, and good conversation. There he experienced the problems of a dry camp, i.e., where water had to be packed in. Feral cats were numerous and Perkins shot many. One day while he was away from camp, cats tore up bird skins that he had left there (Perkins 1892–1897).

After a quick return to O'ahu, Perkins made his first attempt at collecting on Maui in early March 1894. There he met Matthias Newell, a Marianist brother and enthusiastic amateur naturalist; Newell provided advice on collecting sites and gave Perkins a few entomological specimens (Perkins 1892–1897).

Perkins began 1½ months of Kaua'i work in mid-May 1894, based at the home of George C. Munro, Palmer's 1891–1892 assistant. Munro allowed Perkins to read his field notes, providing him with knowledge of Palmer's collecting sites (Munro N.D.b). Munro's action was particularly ironic, as Palmer, who had left the Islands in August 1893, had refused Perkins this information to protect Rothschild's dominant position in the "race" with Newton. Sundays on Kaua'i were occasionally spent with the Gay family going to church and, later, talking with Mr. Francis Gay from whom Perkins heard "about plants and birds and all other Hawaiian matters and ... learnt much ..." (Perkins 1892–1897).

Having made an in-depth search on each of the major islands, Perkins made a short return trip to Lāna'i and then spent his last month in Kīlauea and Kona on Hawai'i. Lāna'i results were disappointing. Feral goats had destroyed important bird habitats. Near Kona's Holokalele, Perkins found that *Moho nobilis,* which he had found plentiful in 1892, was now scarce, and wild cattle, mongooses, and myna birds were everywhere (Perkins 1892–1897). This destruction was repeated on every island, while sugar and coffee acreage increased annually. The Bureau of Agriculture and Forestry had been established within the government to assist growers, and parasitic insect introductions were under consideration (Thrum 1893, 1894). Clearing of forests together with introduced animals reduced forest habitat for endemic wildlife. Not surprisingly, Perkins' letters to C.R. Bishop about the work of the Joint Committee carry an overtone of urgency. In reply to one letter Bishop wrote, "It makes one sad and regretful to be told that anything of the fauna or flora is extinct, and there is no doubt that many things indiginous [*sic*] in and peculiar to Hawaii have become extinct, and that others are fast following toward a like fate" (Bishop 1898c).

The Joint Committee decided that the rainy season so hampered Perkins' collecting that he should return to England on 1 September 1894 (Sharp 1894a). Perkins spent the next 4 months at the Cambridge University Museum of Zoology overseeing the pinning and labeling of his insect specimens. The possibility of a return to the Islands remained contingent on the uncertain renewal of grants.

Advice from home

In his first 6 months of exploration, Perkins cast about for a plan to organize his search. Should he investigate each island in depth, then move on, or move about among the islands frequently? While stressing that the final decision was Perkins', Newton and Sharp offered conflicting advice. Newton favored a long O'ahu stay, hoping that Perkins would find the rare and, Newton hoped, not-yet-extinct birds that he so desired (Newton 1892e). Sharp felt that short, quick interisland trips had benefited Blackburn and would give Perkins and the Committee an idea of the fauna of the different islands (Sharp 1894b). Newton countered that while he didn't "deny the possibility of the existence of Tom Tiddler's grounds,[3] . . . they are not common enough to make it worth anybody's while to look for them, & that on the whole a better living is to be earned by steady work than by lottery tickets" (Newton 1893c). In this first of his 3 expeditions, Perkins developed a hybrid collecting strategy, staying for long periods on an island, but traveling about frequently on that island.

The Joint Committee, through Newton and Sharp, gave Perkins the freedom to decide where and when he would collect. They soon recognized that Perkins possessed such knowledge of the conditions in the Islands that "it would [be] the height of folly for us to direct you to go in this that or the other place" (Newton 1894a). Newton did caution Perkins to shun the areas where Lord Rothschild's collector, Palmer, was working:

> . . . it is inexpedient for you in your character as the representative of scientific effort to come in competition with the unscientific collector with practically unlimited means, when your own are unfortunately restricted. (Newton 1892e)

Equally important was the question of how to fulfill the demanding task of collecting comprehensive, well-documented samples of the entire land fauna. Should he favor one biological group over another? Were insects, or birds, or mollusks more important? Sharp urged Perkins to be even-handed, repeatedly advising that Perkins "do something in other groups besides the insects; otherwise naturalists will think I am selfish in getting an entomologist sent to the islands" (Sharp 1892g). Sharp felt his responsibility very strongly in this matter. After a month's silence, he wrote Perkins:

> I wished to leave you for some time without sympathy entomological, in hopes you would denounce me as a useless being and give all your attention to shells and other things. Now I think it is time for the insects to have an innings again so I mean to persecute you with letters, till I feel sure you have got another 200 new species . . . I expect . . . you are tired of a biological diet of snails and are off to Maui to get some fine birds and several hundred new species of insects . . . . (Sharp 1893a)

It was a rare Newton or Sharp letter that did not contain a reminder to collect some particular specimen: Newton continually asked for rare and possibly extinct birds; not to be forgotten were nestlings and eggs (Newton 1892e,f); Hickson hoped pond mud contained protozoa; Sharp wanted bird lice from the indigenous birds (Sharp 1892e), and galls (Sharp 1892f); malacologist Cooke wanted land snails "with the animals in them collected into spirit" (Sharp 1894d). Sharp conceded that Perkins should "get plenty of butterflies as . . . people take much more interest in them than they do in sensible things like beetles & Hymenoptera" (Sharp 1892i). In the end, the rarest birds and the insects got most of Perkins' attention, in part because local residents would collect common birds and land snails (BAAS 1892). Perkins, though, attributed his "comparatively great failure as a shell

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[3] Refers to a place where things are easily obtained without interference.

collector to the fact that there was no malacologist . . . urging me to look out for this or that" (Perkins 1936d).

Sharp's and Newton's letters also reminded Perkins of the reason for collecting the Hawaiian land fauna. Not only was he to collect the birds, insects, land snails, lizards, and bats, but he was also to note his "observations on the habits or distribution of the creatures . . . . Great interest is felt in the details of the Sandwich island fauna . . ." (Sharp 1892b). Sharp reminded Perkins: "We want a great deal of information as to the modifications of species in the different islands . . ." (Sharp 1892d), and cautioned him: "Be sure in the different islands not to miss taking a thing because you have got it previously in another island, for we want very much exact information as to what occurs in each island" (Sharp 1892e). Even recently introduced insects were to be captured:

> If these . . . forms shew [*sic*] no variation, why have those that have been so much longer there (on the Wallace hypotheses) varied so enormously? Gulick tried to make a reason for the shells, & I think failed; if the insects that are winged shew [*sic*] the same general phenomena as the Mollusks, it kills his theory. (Sharp 1892j)

Newton and Perkins engaged in a long-distance debate about the organization and classification of the Hawaiian honeycreepers. While Newton disagreed with some of Perkins' ideas, he encouraged Perkins to continue observing and theorizing:

> If "collectors" in other parts of the world had been employing their brains in your way we should be in a far better position to tackle these problems, and I can't sufficiently commend you for bearing them in mind. (Newton 1896b)

Personality in the field

The advice of Newton and Sharp was tempered and flavored by Perkins' own personality and his experiences in the field. Experience showed that, at least for Perkins, it wasn't practical to collect birds on the same day as insects and shells (Newton 1892d). Perkins complained that when he tried this, he usually saw a good bird while holding his insect-collecting net and a desired insect while holding his gun! Additionally, Perkins contended that the birds most coveted by Alfred Newton, such as *Chloridops kona* and *Rhodacanthis palmeri,* were found in the highest forest, while the endemic trees that hosted most of the native insects occurred at the 612–914-m (2,000–3,000-ft) level (Perkins 1892–1897).

Both for financial reasons and from personal preference, Perkins worked alone most of the time. After a few days with a guide in a new area, Perkins would work alone. Although Sharp occasionally renewed his suggestion that Perkins employ a young boy to "run after the dragon-flies" (Sharp 1894c), Perkins felt that such an untrained person was in the way (Munro N.D.b). Guides and attendants required wages and food, and this definitely restricted Perkins' use of them. Perkins complained that Hawaiians, not blessed with his minute appetite, ate "a great deal and this is rather a disadvantage of taking natives with one" (Perkins 1892–1897). When forced to employ a gang of trail cutters, Perkins recalled that "at a $1 a day a man and food supplied, such trips were necessarily as expensive as some of my solitary ones were cheap!" (Perkins 1936b). Doubtlessly Perkins' thrifty ways lengthened the time the Sandwich Islands Committee was able to employ him.

Perkins' solitary fieldwork caused those at home some not unreasonable worry. Sharp suggested that in case Perkins have an accident in the mountains, an assistant would be able to summon help (Sharp 1894d). The idea had merit. By the time Sharp made his diffident proposal, Perkins had been briefly lost in the mountains at least 4 times and threatened by haughty wild boars on O'ahu (Perkins 1892–1897), had escaped a charging wild bull on Moloka'i (Newton 1893a), had twice fallen into deep, fern-covered cracks on

Maui, and had been rescued by a Hawaiian on horseback when stranded by the ʻĪao Stream in flood. Perkins escaped most adventures with only minor injuries, such as a toe crushed by a rock when fording ʻĪao Stream and self-doctored with a poultice of "hard-tack soaked in boiling water" (Perkins 1892–1897)! But the dangers were real, as attested by the death of a guide's horse (Newton 1892e) and the near death of a guide (Perkins 1896a).

Actually, Perkins was not a confirmed loner; he enjoyed the company of fellow collectors Brother Matthias Newell, George C. Munro, and, on his second and third trips, Albert Koebele. Similarly, a Hawaiian bird catcher, described by Perkins as a "passenger rather than a worker" (Perkins 1936b), made a desirable companion. One unnamed bird catcher took Perkins

> to the very tree in which it [*Drepanis pacifica*] had been shot at the time when the 1830 flow was approaching Hilo. He was in the forest then, and a dozen were killed at that time. Whenever he has been with me, all the time as we go along he gives what is no doubt an exact imitation of the Mamo's call. . . . Though he tried hard, he never succeeded in getting any response to his call. (Perkins 1892–1897)

Still, Perkins' methods were solitary when compared with Henry Palmer's parties of up to 5 mounted hunters and Hawaiian guides. They could cover twice the area by dispatching one party headed by Palmer and a second headed by his assistant (originally Munro and later Wolstenholm) (Deverill 1891–1892).

The mechanics of fieldwork

As Perkins learned the haunts and habits of the birds and insects, he learned which "dodges" (techniques) he needed to capture them. The sifting dodge, for which Sharp had lent Perkins his sieve, separated insects from leaf litter (Sharp 1892d). The light dodge attracted insects at night, using a lantern near the tent fly on which insects landed and could be captured (Sharp 1892e). Some familiar European techniques, such as turning over stones, did not work well in Hawaiʻi (Sharp 1892c). Perkins improvised techniques as his experience in Hawaiʻi grew. A dodge for beetles involved clearing "small areas of a few feet, especially where the soil was sandy or of fine grit and then from time to time one would see the smaller Carabids begin to move on the cleared space" (Perkins 1931). Perkins learned that by whistling imitations of their songs, he was able to attract birds close enough to shoot them (Perkins 1892–1897).

Equipment, or the lack of it, was also important in Perkins' work. David Sharp tried to keep Perkins well supplied with the special equipment needed by a general zoology collector. The distance from suppliers forced Perkins to anticipate his need for specific items 5–6 months in advance (Sharp 1892f). The fine, silver pins needed for microlepidoptera would not stick well in cork, and Sharp sent sheets of vegetable pith as a cork substitute (Sharp 1892d). Improvisations were suggested by Sharp to sustain Perkins between supply shipments: if ethyl alcohol or formaldehyde was not available as a preservative, substitute whiskey (Sharp 1892h); if thin cork was needed for pinned insects, substitute sliced bottle corks (Sharp 1892d).

Keeping specimens safe in the field was a constant problem. Mountain dampness caused insect boxes to fall apart, and birds shot in the morning rotted by afternoon (Perkins 1892–1897). Mold, a constant threat, was prevented by liberal applications of carbolic acid in boxes (Sharp 1892e). Even in Honolulu specimens were not safe:

> When I had turned out my captures of the day in the evening, I was called away to the telephone, leaving the insects on my table against the open window. On my return after a considerable delay, I found most of these had disappeared, and

> a great stream of the ant Pheidole was coming and going through the window carrying off their booty. (Perkins 1892–1897)

Packing and shipping resembled trial by combat; sawdust was the only padding available and the chance of damage was great on the long voyage to England. A case sent in September 1895 reached England in January 1896, and Sharp had to report that "the spirit all came out of the two bottles of shells you put on top of the butterflies in paper & produced a sort of solution of Vanessa" (Sharp 1896a).

In October 1892, Perkins shot on O'ahu what he believed was the rare *Hemignathus obscurus ellisianus,* which Alfred Newton desired so fiercely. The bird fell over a cliff. Perkins spent 2 days looking for it, clearing a large area of undergrowth using a cane knife (Perkins 1892–1897). The plants were sacrificed without reward, as the bird was never found. Perkins stated:

> There is no doubt that a bird collector should bring out a couple of good dogs at any cost. At least 25 p.c. of the birds I see I cannot shoot at (for fear of not being able to gather them) and the same percentage I lose, although I shoot at no bird, rare or common, unless I think I have a good chance of picking it up. (Perkins 1892–1897)

A trained retriever would have ensured that every bird shot went into Perkins' collecting bag. Offers of such a dog came from Charles R. Bishop (Perkins 1893b) and, later, from Rev. Charles M. Hyde, a Bishop Museum trustee (Perkins 1895). Although in May and June 1894, Perkins used "Nixie," one of a pair of hunting dogs left in the Islands by Henry Palmer (Perkins 1892–1897), he never acquired a dog of his own.

In England, Scott Wilson had advised him that a tent was unnecessary, but Wilson had worked mainly from the mountain houses of Island families. Perkins quickly decided that serious collecting of both birds and insects would require him to spend long weeks in the highest mountains above these cabins (Perkins 1892–1897) and soon after his arrival in Hawai'i ordered a tent. The weight of the tent added considerably to his pack. Consequently, Perkins frequently carried only the fly, which added 9 pounds to his load (Perkins 1896c).

Perkins' preference for going barefoot in the wet forests was as idiosyncratic as his solitary collecting. In June 1892, on the Kona lava fields, he wore out a pair of "porpoise-leather shooting boots" and began collecting barefoot (Perkins 1892–1897). Although Sharp warned Perkins of the risk of a "serious wound to the foot" (Sharp 1892f), Newton treated the affair lightly:

> Glad we both are to find you writing so cheerfully—even when you are going barefoot. It is well that you mentioned that fact, for if we ask for any more money we shall be able to make our appeal the more touching! But I really suppose that boots of some kind are to be had, if you cared to have them. . . . (Newton 1892g)

Perkins' preference for going barefoot was even more eccentric in light of his usual method of transportation on an island: he walked. And he was fast. In early November 1892, after his return from Kona, Hawai'i, Perkins felt that before doing general collecting on O'ahu, he should survey the island. He did this by walking around the island with a New Zealand journalist (Perkins 1892–1897):

> The walkists are named De Bomford and Perkins. They walked from Honolulu via Koko Head to Waimanalo on Monday Nov. 7th; on Wednesday to Kahuku, and on Thursday back to the city, a good forty miles which was done in 10.5 hours actual walking. This is good work in these degenerate days. (Friend 1892)

Similar accomplishments were recorded on every island. On Kaua'i, in May 1894, Munro, then working on the Gay and Robinson ranch, wrote in his diary:

> Took Perkins up to Kaholumanu [*sic*] [and] he walked the whole way up[,] to the small astonishment of the natives, [as] he had been in the habit of doing so all over the Islands. (Munro 1892–1895)

Horses were acceptable for carrying food and equipment but not for carrying Perkins. On his arrival in Hawai'i, Perkins tried riding horses both on O'ahu and Hawai'i. The experience was not pleasant and Perkins "was so active on his feet and a horse is an impediment in forest work [that] he decided he was better without it" (Munro N.D.b).

To cover what were long distances even for Perkins, interisland steamers and stage coaches were needed. The interisland steamship companies, Wilder Steamship Company and Inter-Island Steam Navigation Company, offered Perkins a reduced fare (Newton 1892d). Neither Sharp nor Newton seems to have appreciated this financial assistance to the Committee. A cabin-class round trip from O'ahu to the island of Hawai'i was $50, ca. £10 ($647.50 at 1985 prices). With a total budget of £300 in the first year, Perkins could not have afforded many such trips at the full fare. Munro gives a vivid picture of the departure of a steamer from Honolulu harbor:

> The Interisland Company's Steamship W.G. Hall advertized time of leaving is 10 a.m. so we are aboard in time. A large crowd of natives are collected to see her off and as usual, there are men haranguing the multitude in the native tongue on religious or other topics. The morning has been very close and hot on account of a few showers of much needed rain, during the night, the perspiration has been just streaming off us wetting all our underclothing. We get away a little after the time and get a little refreshing breeze as we get out of the harbour, and bid Adieu to Oahu for a time. (Munro 1891)

Certainly the interisland trips were not pleasure excursions. Perkins relates a rough night crossing of the *W.G. Hall* from O'ahu to Hawai'i in July 1894:

> The steamer was crowded and I could not get a mattress to lie on, nor even a pillow. The school-children were all returning to the various islands for their summer holidays and practically all of them were very sea sick, lying on mattresses on the deck, so that one could not walk about. (Perkins 1892–1897)

Land transportation was little better than a pitching sea vessel. Of the stage from Pāhala to Kīlauea, Hawai'i, Perkins did not complain, but wryly noted:

> The drive was too much for my fellow passengers, the rough road over rocky places causing them to bounce up and down like india-rubber balls. They stayed in bed the next day. (Perkins 1892–1897)

Perkins, of course, went out for a full day of collecting.

Bishop Museum lends support

Even as Perkins prepared to leave England in 1892, Alfred Newton, as chairman of the Joint Committee, began his campaign to ensure renewal of the grants from the British Association and Royal Society. His review of Hawaiian ornithology in the March 1892 issue of *Nature* was a straightforward advertisement for the work of the Joint Committee. The article poses questions about the Hawaiian fauna and assures readers that Perkins' work will answer these questions if he "is enabled to prolong his stay for sufficient time; but that depends upon the financial support he may receive" (Newton 1892c). Newton relied on 2 factors in his fund raising strategy: publicity and results. Newton was to produce the publicity and Perkins the results. Newton and Sharp constantly badgered Perkins for information on his plans, observations of the fauna, tidbits that highlighted the increasing degradation of the forests, and, most importantly, specimens. Newton was not above drama to advance the Committee's work. He reported to Perkins that at the 1896 British Association meeting he had "fetched the audience" with Perkins' account of finding a promising collecting site only to discover that "the imported ants had cleared off everything almost. It even stirred Poulton . . . & for a few minutes he became animated on the subject" (Newton 1896e). *Nature, Ibis,* and other suitable journals reported Perkins' progress and movements for more mundane but positive publicity.

Competition for grant funds was keen and all of Newton's skill was used to accomplish renewal. Irregularity of shipping and postal delays made it nearly impossible to arrange the arrival of specimens in England to coincide with the meeting of a Royal Society or British Association grant committee. Of the August 1892 British Association meeting, Newton wrote that he had "squeezed another £100 out of the British Association (we asked for £200 but I did not expect more than half)" (Newton 1892f).

But even with Newton's efforts at fund raising and Perkins' economies in the field, the Committee needed additional and more stable sources of funding. Sharp suggested to Perkins that "the Committee may perhaps be driven to eke out its slender resources by disposing of a few specimens to museums" (Sharp 1893b). Lord Rothschild had indicated his willingness to purchase duplicate specimens (Sharp 1894c). Newton was loath to accept this offer, as his rivalry with Rothschild, whom he often denounced in harshly anti-Semitic terms, had progressed considerably during Perkins' first trip to the Islands. The Committee was also experiencing increasing problems in transmitting funds to Perkins through the convoluted banking systems of the late 19th century. During one delay, Newton apologized to Perkins, saying "I only trust you will not be hard up and have to eat your boots or do something desperate in the meanwhile" (Newton 1895c).

The Committee began to look upon a partnership with the Bernice P. Bishop Museum as its best hope of stable supplemental funding. The Bishop Museum had been growing during Perkins' first period of fieldwork, 1892–1894. Under Charles R. Bishop, the Trustees, and Curator Brigham, Polynesian Hall was added to the buildings, the library holdings increased, regular public hours were initiated, and many specimens were added to the collections. Bishop had begun to endow the Museum, having previously paid all expenses personally (Hyde 1893).

Bishop had traveled extensively in 1892–1893, but he nonetheless had time for conversations as well as correspondence with Perkins. Bishop expressed respect for Perkins' abilities both as a scientist and a collector, calling him "a wonderfully keen and energetic naturalist" (Bishop 1895b), who was "thorough and enthusiastic in his work" (Bishop 1893b). In June 1893 Bishop decided that it would indeed be to Bishop Museum's advantage to, as Newton colorfully phrased it, "get a share of the spoil" (Newton 1893b). Bishop addressed his initial inquiry asking for entomological specimens for Bishop Museum in a letter to Perkins, who sent the letter on to Newton. Newton wrote Perkins that, while Bishop Museum might receive some expedition specimens, the Joint Committee would be more generous if monetary assistance were given. Also, Bishop's equitable treatment of Palmer and Perkins had irked Newton (Newton 1893c). For instance, Bishop had urged R.W. Meyer, his ranch manager on Moloka'i, to help both collectors to the fullest extent possible (Bishop 1893a). Newton obviously undervalued the assistance Perkins had received as a result of such recommendations to landowners in Hawai'i. Pack animals, guides, use of mountain cabins and tents, permission to shoot and—not to be overlooked—homecooked meals were all provided to Perkins without charge. These privileges and kindnesses were not accorded every applicant. In 1894, for example, professional collector Milton Flood was refused permission to shoot birds on Bernice Pauahi Bishop Estate lands when he failed to produce documentation showing he acted for "some reputable scientific society" (Damon 1894).

Perkins conveyed Newton's message to Bishop, adding a liberal advertisement for the work of the Joint Committee, a warning about how quickly "introduced beasts" were "cleaning out the native ones," and a lament on "how exceedingly difficult it is to raise money for this sort of work" (Perkins 1893a). When Bishop wrote to Perkins asking him to collect solely for the Bishop Museum, Perkins replied that he was obligated to the Joint Committee and that the Museum should cooperate with them (Perkins 1894). Bishop was frustrated by an unbusinesslike approach to the matter, stating that "if the societies in whose employ he [Perkins] is working would allow him to supply our museum, and would state the terms, I would know what to do" (Bishop 1893c).

Bishop and the Trustees soon abandoned hope of getting Perkins' exclusive services or of obtaining his specimens without joining with the Committee. A formal request suggesting cooperation was sent by Bishop to Newton in July 1894 (Newton 1894b) and reiterated by the Trustees in August (Sharp 1894f).

Negotiations continued after Perkins' return to England in 1894. Briefly, the Joint Committee's position was that they were "most seriously hampered for want of funds" to continue the work and if Bishop Museum contributed, then the Joint Committee would "more readily entertain any proposition . . . to share in the disposal of the collections" (Sharp 1895a). Discussions were necessarily protracted when a letter routinely took a month to travel one way between Hawai'i and Britain. So Perkins actually returned to the Islands and began his second expedition before the Bishop Museum became an official partner. On 27 March 1895, the Trustees, acting on Bishop's suggestions and with his assurances of bearing the cost personally, approved a resolution offering to pay ⅓ of Perkins' expenses of both the first and second tours in return for ⅓ of the specimens collected (BPBM T 1895a).

Bishop, who was then residing in San Francisco, California, countersigned and forwarded the resolution, which reached the Joint Committee in May 1895. Newton and Sharp were pleased, calling the Trustees' offer "both practical and liberal—but at the same time it is clearly an advantage to the Honolulu Museum to acquire such a valuable set of the native fauna as it covers—and this without risk or trouble" (Newton 1895b).

Newton and Sharp noted a problem with Bishop Museum's proposal. The Committee had already promised the first and second sets of specimens to British institutions in recompense for the funding given by the British Association and Royal Society. Since Perkins in his early collecting was not taking specimens to supply 3 institutions, there would not always be 3 specimens of all species of birds, insects, or land snails. These facts were not clearly stated to the Bishop Museum Trustees. Certainly, they understood the third set of specimens was less than ⅓, as Trustee Charles M. Cooke, Sr., proposed that the Museum ask for the fourth as well as the third pick (BPBM T 1895b). Perkins assured the Trustees that the agreement was "both simple and reasonable" and that under the proposal "there is not a single species of bird so far collected, of which at least one and generally several specimens would not come to you" (Perkins 1895). In early August 1895, after discussing the matter with Curator Brigham, the Trustees and C.R. Bishop signed the new agreement calling for them to receive the third set of specimens (BPBM T 1895c). By not joining with the Sandwich Islands Committee in 1891, Bishop had gained a chance to judge the Committee's collector by results but had reduced his bargaining position for a more advantageous division of those results. Sharp stated: "the [Bishop] Museum only comes into the arrangement after the success of the investigation is well assured whereas the committee has had to run the risk of its being a failure" (Sharp 1895c).

The British Association at its September 1895 meeting authorized the partnership and another £100 (BAAS 1895). British grant funds now supported processing and labeling of specimens, procurement and shipping of supplies to Perkins, and other expenses originating in Britain. Bishop Museum's contribution was paid directly to Perkins for his support in the Islands. This arrangement eliminated the small expense and large problem of transferring British funds to Perkins. Funding was no longer a constant source of worry in Newton's and Sharp's letters. They were, Newton said, "on Velvet" (Newton 1895b). Newton assured Perkins that if Perkins would continue the work and the Bishop Museum Trustees would "stump up," the Joint Committee would keep him in the field (Newton 1896c).

Return to fieldwork

With the next round of grants from the British Association and the Royal Society still in question, and Bishop Museum's continued support uncertain, Perkins returned to Honolulu on 24 March 1895 (PCA 1895). Newton and Sharp now offered little advice about places for, and methods of, collecting. Shortly after the resumption of fieldwork, Sharp admitted to Perkins, "I recognize that you now know so much more about what is wanted than I do, that I had better not express an opinion—for fear you might attend to it" (Sharp 1895b).

Throughout April and May 1895 Perkins was once again collecting on the lands of the Gay, Robinson, and Knudsen families on Kaua'i, sometimes in the company of George Munro (Perkins 1892–1897).

June brought an extended stay on the island of Hawai'i, where Perkins worked largely in the Ka'ū and Puna districts, with special emphasis on the 'Ōla'a and Kīlauea areas (Perkins 1895–1901). On his return to O'ahu in September, he was held in a quarantine imposed to curb a cholera epidemic. In October Perkins returned to the lands of Gay and Robinson once more. Such return trips were, in part, necessitated by the Joint Committee's acquiescence to the request by the BMNH for the first set of specimens taken by Perkins. As the government's chief scientific depository, the BMNH, with heavy representation on the Joint Committee, was not to be denied, considering the strong financial support received from the "Government Grant" (Sharp 1895a). Of course, the addition of Bishop Museum to the sponsors increased the pressure on Perkins to collect multiples of the various birds and insects taken on his 1892–1894 trip.

During December 1895 to January 1896, above 'Amauulu in Hilo on the island of Hawai'i (Perkins 1892–1897), Perkins hoped to obtain specimens of *Hemignathus sagittirostris,* a bird discovered by Palmer (Perkins 1896a). In this dense forest he hired men to cut trails, and Perkins describes their life:

> [We] built a rough house about 20 ft by 10 ft roofing it first with banana leaves and above this with the fly of my tent. The latter was erected separately and the other house was used as a shelter when eating, and sometimes for the purpose of trying to dry our clothes. . . . Owing to the excessively heavy rainstorms, a fire was kept up continually in the open during my stay, great logs, practically dead treetrunks, being supplied to this, so that by removing the upper ones one could always cook rice or boil water for coffee in spite of the rain. (Perkins 1892–1897)

Perkins, successful in obtaining a series of the birds, bragged to both Bishop Museum Trustee C.M. Hyde and Bishop of his triumph over Rothschild's collectors:

> They got 4 specimens & I beat them again with this. I made out its habits & anatomy & found Mr. R. had classified it utterly wrongly. . . . It now goes by the name I gave it of "nuku pololei" [straight-billed]. (Perkins 1896b)

The bird had apparently never attracted the attention of Hawaiian bird catchers and feather gatherers and was unknown to those accompanying Perkins in 1895 (Perkins 1896b).

In the forests near Kaūmana, Hilo, Perkins again encountered mongooses in great numbers. Alfred Newton vented his rage on these creatures, who never missed a chance to dine on birds or their eggs:

> I have gnashed my teeth at what you write of Mongeese, and am ready to consign them to the place of torment that no doubt awaits the German Emperor and President Cleveland to say nothing of other officials—Yet I am sure you will give me credit for being a kind-hearted Christian. (Newton 1896a)

Perkins spent March, April, and May 1896 on Hawai'i and Maui. Scott B. Wilson was again visiting Hawai'i, and Newton hoped that Wilson would help Perkins with the bird collecting. Wilson, however, seemed uninterested in the rigors of collecting and did little while in the Islands. Newton despaired of any ornithological work being done by him:

> Nothing more have I heard of or from Wilson. . . . If he took up a photographic craze & left his dog behind, not much could be expected from him. . . . (Newton 1896d)

Collecting in the West Maui Mountains with Brother Matthias was a more rewarding collaboration. During this second trip Perkins often worked with Albert Koebele, then employed by the Republic of Hawai'i to control agricultural pests. Perkins and Koebele had made insects newsworthy. Perkins' success was reported by Honolulu's daily press: "R.C.L. Perkins, the naturalist, has been spending a few days on Kauai finding 'bugs' of interest where other people supposed there was nothing" (PCA 1896a). Even a canceled trip made copy: "It was the intention of naturalist R.C.L. Perkins to leave on the W.G. Hall yesterday morning, but on account of indisposition he was forced to put off his tramp after his ever present friends the birds and beasts" (PCA 1896b). Koebele's battle with the coffee pests was front page news, and when the 2 men worked together it was reported: "Prof. Koebele & R.C.L. Perkins, the 'buggists,' are doing Maui" (PCA 1896d).

Perkins succeeded in fulfilling his secret desire to experience an earthquake during a September 1896 trip. Headlined "This Was No 'Night Mare' [*sic*]; How They Took It," the *Pacific Commercial Advertiser* interviewed Perkins and other passengers returning to O'ahu about their experiences:

> R.C.L. Perkins, the naturalist, was visiting T.J. Higgins in Olaa when the quake came, and was particularly delighted at being present. Mr. Perkins has been gathering birds and bugs and incidentally waiting for an earthquake on the island for the past four years, and having secured every species of bird, has devoted his time and energies lately to locating earthquakes. In a conversation with a reporter for this paper after the arrival of the Kinau yesterday Mr. Perkins said: "I was awakened the moment the shock began; my lamp was in danger of falling from the dresser, so I got up and placed it on the floor and then sat down alongside of it, merely to experience the thing in its fullest force, and I was quite successful. I was very sorry when it was over, but I hope when I am on Maui next week to have another try at it as it comes back. I would not have missed it for anything, I can assure you." (PCA 1896c)

January 1897 brought a generally unprofitable, abbreviated trip to the Lāhainā area. A trip to Kaua'i in February proved more rewarding, but perhaps a bit too exciting:

> I took no tent with me on this occasion but Mr. Francis Gay had one fixed up at about 2000 ft. in the mountains in the Makaweli district. . . . There were very

> high winds at this time, and one night in a gale of wind and torrents of rain accompanied by thunder and lightning my tent crashed down on me and in the dark I managed to make my way down to a small shack which I had noticed at a lower elevation. This was in the region of ants and I had great trouble in keeping myself free from the swarms of Pheidole when lying on the floor at night and my food at all times. (Perkins 1892–1897)

Work on O'ahu during this second expedition consisted of short work periods between trips to the other islands. One such field trip in early March 1897 concluded what Perkins anticipated were his last 2 years in Hawai'i (Perkins 1892–1897). He departed Honolulu 9 March on board the steamer *Peru* bound for San Francisco (PCA 1897). In San Francisco Perkins had several talks with Bishop before returning to England, where he arrived in May (Perkins 1897a).

Between May 1897 and mid-1899 Perkins supervised the preparation of the insect collections, helped Sharp distribute specimens to specialists for study, and studied material in his own specialty, Hymenoptera. During this time he reflected on what future he might shape for himself. He considered joining an expedition to New Guinea (Perkins 1897b), or the massive project Biologia Centrali-Americana, run by Joint Committee members Godman and Salvin (Perkins 1898d). He most seriously considered collecting Hawaiian insects solely for sale in the collectors' market. He would not think of shooting birds for profit; they were already too rare (Perkins 1898a). Perkins, however, obviously disliked the thought of becoming a professional collector out of financial need. E.B. Poulton, his old Oxford professor, encouraged him not to be repulsed by the thought, suggesting Wallace, Bates, and Belt as models (Poulton 1897).

During this period of indecision, Perkins was considered as a candidate for director of Bishop Museum. In October 1897, in a disagreement with the Trustees over what Bishop called Brigham's "unruly tongue" (Bishop 1897e), Brigham resigned, not for the first time. Regardless of hopes for an accommodation, Bishop and the Trustees conducted an extensive search for a replacement, consulting such respected scientists as David Starr Jordan of Stanford and Alexander Agassiz of Harvard. Jordan's suggestion of zoologist Leonhard Stejneger was thoughtfully discussed. Both Munro and Sharp suggested Perkins, who refused to consider the position, saying that Brigham "would go back as soon as he had sufficiently annoyed the Trustees and made them properly humble!" (Perkins 1898b). In the end, Perkins was right. Agassiz "spoke favorably of Brigham's work and advised the trustees to hold on to him" (Bishop 1898b). In February 1898, Brigham and the Trustees were indeed reconciled and Brigham rehired, now with the title "Director" (BPBM T 1898b).

Concurrent with a discussion of how to staff the Museum, Bishop and Holmes corresponded about continuing the collection and study of Hawaiian natural history materials. When Perkins left the Islands in 1897, Trustee Holmes wrote Bishop that it was imperative to continue collecting the diminishing insect fauna "which through Perkins' labors is likely to be as interesting and important as Darwin believed it would be" (Holmes 1897a). Bishop agreed, and his 1897–1898 letters often include a reminder to the Trustees: "Is it not quite important to get a man soon who can carry out the work so well begun by Perkins?" (Bishop 1898a).

In early 1899, while the Bishop Museum still searched for a collector, the Sandwich Islands Committee began to consider sending Perkins to Hawai'i to investigate questions of insect distribution and local variation, particularly on O'ahu. In soliciting Bishop Museum's participation, Sharp noted that as the Museum was to receive the third set of specimens collected, it was to its advantage to support this trip. The specimens collected would be combined with those collected on the first and second trips (Sharp 1899). Therefore, if Perkins collected 6 specimens of a species, 1 each on the first and second trips and 4 on the third trip, Bishop Museum would receive 2 of the 4 collected on the third trip, or 50%. A comparison of the collecting dates on specimens in the Bishop Museum and BMNH collections, based on data extracted by Bishop Museum staff Dr. Wayne Gagné and Hans Megens (see Appendix 4), indicates that this method of distributing the specimens was in fact used, and Bishop Museum has more third-expedition specimens than the BMNH, the depository for the first set of specimens.

In March 1899 the Bishop Museum Trustees again voted to bear ⅓ of Perkins' expenses (BPBM T 1899b), and the Joint Committee asked the British societies for matching support. Both the BAAS (1900) and the Royal Society of London agreed (Royal Soc. 1901), offering a total of £300. On May 30, 1900, after an outbreak of bubonic plague in Honolulu necessitated a delay of some months, Perkins was again in the Hawaiian press:

> Eminent Naturalist Again in Town
>
> Prof. R.C.L. Perkins, the naturalist, returned to Honolulu today after an absence of several years in England . . . . "As before, I am sent out by the societies at home to gather specimens and mount them. It is my intention to be in Honolulu quite a long time and in the Islands about one year. My stay may be even longer than that, for the work before me is quite extensive". . . . He went on to say that he would not on this visit have anything to do with birds. His intention is to gather as complete a line of butterflies and insects as may be found in the Islands. One of the first calls made by the naturalist this morning was upon Professor Koebele, the local entomologist. The latter opened up his collection of butterflies, and the two men busied with them for a long time. Some of the specimens were new, and were only located by means of what may be called a "bugicon" or dictionary of flies and bugs. Professor Perkins is stopping at the Arlington. . . . It may be added that he is one of the most famous men in his line in the world. (Hawn. Star 1900)

Perkins' third field trip ran until early December 1901 (see Appendix 4 for details). With the exception of a few short trips to Maui and Hawai'i, he was almost constantly at work on O'ahu. As Perkins worked exclusively on entomology, no bird collecting was done until mid-November 1901, despite proddings from Newton (Perkins 1901c).

During Perkins' absence the Islands had been annexed by the United States and accorded territory status. Perkins' reports of the expansion of both plantation and city under stimulus of American capital depressed Newton:

> It is sad to hear a repetition of the old story—the extinction of the original fauna by the introduced exotic species, but there is a crumb of comfort in the fact of an Himatione having learnt to eat scale-bugs, for that may be the saving of it for a time at least. . . . I am glad the new railway saves you some troublesome travelling, but I imagine it can't fail to work still greater mischief in desolating the country. (Newton 1900)

In 1901 the Joint Committee's failure to receive renewal of the British grants coincided with Perkins' October marriage to Zoe Atkinson, daughter of Honolulu educator and editor-writer, A.T. Atkinson. The 2 events ended 6 years of active fieldwork under the direction of the Joint Committee. Perkins was weary of the hard, wet work in the high forests, declaring that "my collecting days are done, & I am not sorry for this" (Perkins 1901a). Of course, Perkins' collecting days were not "done," as he went on to organize and administer the Entomology Division at the Hawaiian Sugar Planters' Association's (HSPA) Experiment Station, searching out predators of sugarcane pests in many Pacific areas. He retired in ill health to England in 1909, where he was for many years retained by HSPA as a consultant (Fullaway 1956).

A share of the spoil and more

Perkins' 6 years in the field were supported by £1,400 from the Royal Society, £1,034 from Bishop Museum, and £500 from the BAAS, a total of £2,934, or $14,670 ($189,976.50 in 1985). Additionally, Bishop Museum paid approximately $200 in shipping, customs fees, and crates to have its specimens shipped back to Hawai'i (BPBM 1896–1908; 1899–1902; 1908–1916).

The Museum's agreement with the Joint Committee was to pay ⅓ of Perkins' expenses and, in fact, it paid just over ⅓. In return, the Bishop Museum received the third set of specimens. Throughout negotiations with the Joint Committee and later during the period of active cooperation, C.R. Bishop was concerned about getting equitable treatment:

> Considering what the Museum is likely to receive and has received, it seems to me that we have a rather one-sided agreement with the English Societies—I hope that it may turn out that I am mistaken in this opinion. (Bishop 1897f)

Trustee Henry Holmes answered Bishop's worries over the division of Perkins' collections:

> I do not think that the Museum will have much to complain of what it will get of the collections made by that gentleman. Are you giving the societies in England sufficient credit for the large amount of work that they are expending upon these collections? They[,] too, have put up two-thirds of the actual expenditure for collecting, and are doing all the work in connection with the care and distribution of the specimens and in providing, and interesting, scientists to work them out. (Holmes 1897d)

Alfred Newton was also concerned about the division of Perkins' specimens, especially the birds. The BMNH was strongly represented on the Joint Committee, and Newton and Sharp of the Museum of Zoology, the Committee's hardest workers, watched as the cream of Perkins' effort was carried off to London. The first division of Perkins' birds brought the BMNH 175 specimens, including 26 species new to the collection (Sharpe 1906). Newton complained that R.B. Sharpe, BMNH bird curator, "went back rejoicing. . . . All this without their having taken any trouble in the matter" (Newton 1895d). Newton's Museum of Zoology netted 147 bird specimens (Cambridge 1896). In the same division, Bishop Museum received only 88 specimens (BPBM 1896), and Perkins was intensely dissatisfied. In sympathy with Perkins' complaints about Bishop Museum's allotment, Sharp confided:

> Entre nous: I was very vexed to find the set selected for the H[onolulu] Museum was so small; and I at once stated to some of the Committee that in any future division of specimens there must be a person appointed to specially represent the H. Museum. If you think this will do please let me know. The H. Mus. has not made any statement to me, but should it do so, I shall of course lay it before the Committee. (Sharp 1895d)

Perkins suggested that he be empowered to give the Bishop Museum its specimens directly, but both Newton and Sharp advised him that the Joint Committee would never sanction the idea. Newton suggested that Perkins mark specimens he recommended for return to Bishop Museum, and Newton would try to arrange such a division. "I quite see the necessity of keeping these good people satisfied and so I hope they will be in the end," Newton remarked (Newton 1895f). By mutual agreement Perkins represented Bishop Museum at future divisions of the "spoil" (BPBM T 1897a). With Perkins attending the 1897 division of birds, the BMNH received 81 bird specimens (Sharpe 1906), the Museum of Zoology 87 (Cambridge 1898), and Bishop Museum 97 specimens (BPBM 1897). The division of the largely unknown insect fauna was protracted (1898–1913), being contingent upon Sharp and Perkins finding specialists willing to identify and describe them.

Bishop Museum gained more than "spoil" from its association with the Joint Committee and Perkins. Charles R. Bishop and the Trustees gained access to the opinions and advice of Newton, Sharp, and Perkins during a period of learning, expansion, and direction-setting for the Bishop Museum. Bishop's original plan envisioned a small museum housing the collections of Mrs. Bishop and other royalty, with the addition of birds, shells, and ferns he had acquired especially for the purpose. Bishop wanted his memorial to bring honor to his wife and he was not too proud to ask for—and accept—advice. Curator Brigham was a frequent and important source of advice. Three Bishop Museum Trustees took a particularly active interest in the Museum's future: Rev. Charles M. Hyde, secretary of the trustees, who had scholarly experience and whose letters glow with enthusiasm for the Museum's work; Sanford B. Dole, many years trustee president and a noted amateur ornithologist; and Henry Holmes, a financial supporter whose "anonymous friend" often purchased needed collections and who freely expressed his opinion of proper work for the Museum. Into this babel of advice came the voices of Newton, Sharp, and Perkins.

Newton's opinion was solicited before investing in costly ornithology books (Hyde 1899). Sharp and Hyde, the secretaries, developed in their correspondence a mutual respect that helped seal the 2 organizations in their agreement.

Perkins offered subdued advice and taught without appearing to demand or insist, though his letters might discourse on the care of entomology collections (Perkins 1898c) or the need for field study of the habits and life cycle of land snails. Perkins managed to say that the Bishop Museum's decision not to lend its land snails to E.R. Sykes for study and revision with the material collected by Perkins had been a mistake—without making Bishop or other trustees feel defensive (Bishop 1897c).

Bishop's museum plan evolved as he learned from those whose opinions he respected. He demonstrated this ability to expand his vision of Bishop Museum's work in his changing attitude toward the study of entomology. Although in 1893 Bishop made inquiries about acquiring a share of Perkins' insect collections for the Museum (Perkins 1892–1897), he admitted that he was "more anxious to fill out our collection of birds than I am of insects" (Bishop 1895a). Perkins frequently indicated the scientific importance of the insect fauna, its rapid extermination, and the potential for entomology at Bishop Museum:

> I expect it will be the insect department of your museum which will eventually give it most renown with outside countries because of the much greater field afforded by them. Birds like antiquities &c can hardly be much increased after a short time while an insect fauna is always yielding new things. For this reason I should never advise the purchase of foreign birds or insects, because sooner or later some one will have to look after this department & it will always be easy to get specimens of birds and insects from any country in return for Hawaiian insects, or indeed for the native birds, except the commonest kinds. In any case a large collection from any one country is not what you want as it seems to me but rather typical specimens from outside countries and as perfect a collection as possible of Hawaiian species. . . . (Perkins 1896b)

Bishop's ideas had so changed that in 1898 he wrote Jordan at Stanford University that the "first work" of Bishop Museum was to continue Perkins' entomological collecting (Bishop 1898b). Bishop's attitude toward publishing scientific studies was to undergo a similar metamorphosis.

Publication: *Fauna Hawaiiensis*

With the close of fieldwork in 1901, the Joint Committee in 12 years had fulfilled the first part of its charge—"to send a naturalist to the islands to explore their natural history as thoroughly as may be found possible" (Sharp 1890). The second half of its responsibility—to arrange for the collections obtained in the islands "to be examined and reported on by competent authorities"—took 16 years (Sharp 1890).

To complete the work of the Joint Committee it was necessary to disseminate the information obtained. As Newton said, "the primary object of the Committee is the investigation of the Zoology of the Islands in general & not the aggrandizement of this that or the other Museum in particular" (Newton 1895e). By prior agreement the ornithology specimens were used in the completion of Wilson's *Aves Hawaiienses* before being distributed to depositories. The problem of locating specialists to work on the remaining, largely entomological fauna fell to Sharp, and he began to think about the solutions in 1892, soon after Perkins reached Hawai'i. The Hymenoptera he reserved for Perkins, but other groups were almost immediately sent to specialists (Sharp 1892e). Sharp discouraged publications based solely on the early collections, because decision-making based on small collections "leads one into all sorts of muddles about genera" (Sharp 1892i). Sharp hoped funding would allow publication of the specialists' reports in a separate book (Sharp 1894c). Initially, neither Sharp nor Perkins worried about other investigators "anticipating" them (Sharp 1894e). Still, some preliminary reports were made: Brunner van Wattenwyl described Orthoptera in 1895, Beddard some earthworms in 1896, and Collinge and Sykes slugs and snails in 1897. Eventually, the Committee's comfortable edge over other workers having eroded, Sharp capitulated and wrote a paper on beetles. "If only to secure the recognition to you," he told Perkins (Sharp 1896b).

Perkins had successfully excited Bishop about the collecting of the Hawaiian fauna to the point of Bishop's urging the Museum's Trustees to cooperate with the Joint Committee. Now, in late 1896, Sharp hoped to enthuse Bishop about publishing the results of that work in the descriptive volumes be envisioned:

> I am afraid we shall have great difficulty in getting the large amounts of descriptive and observational matter published owing to their extent. The Birds and Shells have, it is true, been in large part done, but I am afraid that the remaining groups to be properly published and illustrated will cost something like £2000. . . . You have been so very good to Zoology that it has occurred to me you might possibly be inclined to help us in the matter of publication. (I am writing privately, not on behalf of the Committee, the subject not having yet come before them in any way.) I should think the Committee ought to take the view that if so, and you wished it, the Volumes might avowedly appear under the auspices of the B.P. Bishop Museum. . . . I fear there will be no course open to us except to have the results scattered in a score or more of papers in the Transactions of various Societies in different parts of the World. I am sure you will forgive me for my suggestion which I am well aware is a rude one; and I know also that the more liberal people are, the more claims are made on them. Please therefore, if you so prefer, take no notice whatever of this second part of my letter. (Sharp 1896d)

Bishop, constantly beleaguered by requests for financial assistance, complained that "it is quite easy to suggest these large contributions, but not so convenient to meet them" (Bishop 1897d). Nevertheless, Bishop forwarded Sharp's request to the Museum Trustees, where it joined a debate begun in 1893 when Brigham had first advised publishing the results of his research (Brigham 1893). The Trustees took no action then, as other projects claimed limited funds; however, Brigham renewed his request periodically. Bishop did not begin the debate over publishing entirely opposed to the idea. He had considered limited publishing as early as 1895 and included publishing as a proper activity for Bishop Museum in the 1896 Deed of Trust. Yet Bishop remained concerned about cost, and throughout most of 1897 counseled the Trustees against any "considerable printing" (Bishop 1897b).

The campaigns of Brigham and Sharp to have Bishop Museum sponsor scholarly publications gained strong allies in 1897, namely C.M. Hyde and Henry Holmes. In a letter to Curator Brigham, Bishop urged caution while acknowledging Hyde's advocacy of publishing:

> You say "Dr. Hyde assured me that you (I) desired the Museum to have scientific serial publications, both as a means of spreading a knowledge of our treasures and as serving as a basis of exchange with the various Museums and scientific societies whose publications we greatly need." I think that the Doctor must have, in his enthusiasm, given a more liberal interpretation to what I may have said than I had in mind. No doubt it should be our aim, within the limits which have been marked out for the Museum, to make it interesting to scientists and a value to science, and not merely a show-place, and the Trustees will from time to time consider what should be and what can be done in that direction. (Bishop 1897a)

Holmes campaigned vigorously to persuade Bishop that descriptive, scientific publishing was the proper work of Bishop Museum.

> . . . is it not the business of the Museum to publish within its means whatever contributions to knowledge may be made by its staff? To disseminate knowledge is equally as important as to discover it, and if the Museum is going to be recognized by the Scientific Institutions of the World it will be through its publications as much as through the contents of its buildings. . . . Surely you will allow, that the publication of works descriptive of the fauna of the Hawaiian Islands is very properly the work of the Hawaiian Museum. I hope I am not guilty of heresy in thinking it will be better to postpone building the Annex [Hawaiian Hall] even for a year so that more funds might be available for doing this truly Hawaiian work [*Fauna Hawaiiensis*]. Will it be wise to have spent $5,000. in collecting Hawaiian fauna and not spend a dollar to publish descriptions of and the results of the investigation of such fauna? . . . Is the credit of this work to go to others? If there is any work that properly belongs to the Museum it is this, which is so valuable and important that I would consent to all other work standing still until this is done. (Holmes 1897b)

Holmes reassured Bishop that the Trustees would bear the costs within the existing endowment and fully understand the costs before committing themselves (Holmes 1897b). Holmes stressed that, "if we fail to take any part in this work [*Fauna Hawaiiensis*], I fear the Museum will share very little in the credit attached to this very important matter" (Holmes 1897d). Bishop was slowly won over and by December 1897 allowed that, providing the British societies gave Bishop Museum credit for their contribution, he would favor publishing the results of Perkins' and Brigham's work over building new exhibition space (Bishop 1897g).

In May 1897, with Bishop still undecided, the Trustees opened negotiations with the Joint Committee on sponsoring the volumes Sharp had first contemplated in 1892. They suggested that the work be placed in either of the Museum's planned series, the *Memoirs* or *Occasional Papers* (BPBM T 1897b). As with the negotiations over sponsorship of Perkins' fieldwork, the distance between Hawai'i and England meant a protracted exchange of letters.

Midway in the discussion, Brigham's resignation complicated matters, as Hyde explained to Sharp:

> Brigham severed his connection with the Museum Oct. 2, 1897. No one has been appointed to succeed him. I was absent in Japan at the time and since my return I have had all that I could do in pushing forward the business of the various trusts, that had been deferred awaiting my return. You will see that without a Curator, Director or Editor, it would be very difficult for the Trustees to assume any direct responsibility for the publication of the results of Mr. Perkins' investigations. Is it not possible for the Trustees of the B.P. Bishop Museum to assist pecuniarily in the expense of publication receiving due credit for the same without bearing the whole burden? We are planning to build an Annex, and our available funds must go largely for that. We might spare some definite amount from our annual income, if not out of proportion to other usual expenditures. (Hyde 1898)

When Brigham rejoined the Museum in February 1898, there was no suggestion or discussion by either Bishop Museum or the Joint Committee of returning publication to Bishop Museum. Instead, they continued to discuss a mechanism by which Bishop Museum could contribute financially to the publishing and match the resulting publication to its planned *Memoirs*.

Based on discarded proof pages (which Hyde had "hunted up in the wastepaper basket") showing the format of the Museum's publications, the Joint Committee settled on the quarto size and print style of the *Memoirs* (BPBM T 1898a). In May 1898, the Bishop Museum Trustees agreed to pay up to £500 as ½ the cost of "publishing the history and results of the exploration of the Fauna of the Hawaiian Islands" (BPBM T 1898c). Bishop deemed the Trustees' decision "wise" (Bishop 1898d). The Royal Society's publication fund stood ready to add the matching £500, "provided the Government Grant Review Committee are satisfied with the allocation of the specimens collected by the Committee" (Foster 1898). Having obtained the necessary funds, Sharp now added the considerable duties of editor of *Fauna Hawaiiensis* to his other labors for the Joint Committee.

Authors and other headaches

As editor, David Sharp had a number of responsibilities: to find competent specialists who would agree to work out collections, urge them to follow through and complete the work, try to satisfy author demands for descriptive plates while ensuring that available funding covered the entire project, deal with printers and proof copy, arrange distribution of the completed parts, and explain to still another inquiring subscriber that, no, *Fauna Hawaiiensis* was not completed yet. Like a master juggler, Sharp satisfied his audience and in the end it was said that "the 'Fauna' ... throughout has the high standard usually associated with the name of Sharp" (Gardiner 1913).

Sharp's editorial problems began immediately. The Bishop Museum Trustees objected to the use of "Sandwich Isles" in the proposed title "Fauna Hawaiiensis or the Zoology of the Sandwich Isles," returning the Committee's proof sheet with "Hawaiian Islands" substituted (BPBM T 1898d). Sharp explained that since the group was known as the Sandwich Islands Committee "we shall have to leave the words 'Sandwich Islands' on it in some form" (Sharp 1899). The addition of "Hawaiian" in parentheses after "Sandwich" in the final title appears to be Sharp's compromise. The Bishop Museum Trustees did not carry out Hyde's suggestion of printing an alternate title page for substitution in Honolulu (BPBM T 1899a).

With funding assured, publication of available manuscripts commenced quickly, and parts of both Volumes 1 and 2 were published in 1899. After 1900 publication slowed down. Parts were issued sporadically between 1901 and 1910, when Volumes 2 and 3 were finally finished. Volume 1, however, lingered unfinished until 1913, when Perkins finally completed the "Introduction" as Part 6. (See Appendix 3 for details.)

In seeking authors, editor Sharp, himself a respected coleopterist, drew on his many contacts in British and European scientific circles. Even so, Sharp experienced difficulty in getting zoologists to undertake the "working out" of Perkins' specimens. The very uniqueness and diversity that had driven the Joint Committee to pursue the collection of the Hawaiian fauna caused some scientists to shy away from describing the specimens. After the International Congress of Zoologists met at Cambridge in 1898, Perkins wrote Hyde to say, "Many of the big Continental entomologists came & looked through my collection but we could not persuade any of them to help in working it out. It was 'magnifique mais tres difficile' & they would have none of it!" (Perkins 1898d). Lepidopterist Meyrick remarked that working with Hawaiian insects was "as if we were doing those of another planet" (Sharp 1896c). Finding authors for the Coleoptera sections was so difficult that Sharp eventually filled the gap himself, doing more of this descriptive work than he would have preferred (Sharp 1904). Authors who completed a description of first-expedition specimens often declined to do a supplement based on material from the second and third trips. Others failed to finish jobs they had begun. Paramount among these might-have-been authors was Robert McLachlan, an Odonata specialist who kept the dragonflies for 4 years before returning them unworked (Perkins 1898d). Many of those who agreed to work out collections and actually stuck with the job needed a good bit of editor Sharp's prodding. "As soon as possible" was a constant request in Sharp's letters to authors.

The authors of *Fauna Hawaiiensis* (see Appendix 2) reflect a changing time in science. Most of the older authors were amateurs—clergy, doctors, the wealthy. Amateurs predominated in botany and zoology at a time when such studies were acceptable as hobbies but not as careers. The younger authors, in contrast, held university degrees in zoology rather than the classics. They represented a new era of trained professionals attached to museums, universities, or economic entomology centers. Amateur and professional alike, the authors had a strong interest in evolution. They were predominately British and all, with one exception, were male.

Although Sharp chose and encouraged authors and edited and organized the volumes, the scientific quality and the usefulness of *Fauna Hawaiiensis* are due to the work of the authors, some of whom brought special talents or perspectives to the job.

Vernon Kellogg and Bertha Chapman coauthored an article on Hawaiian Mallophaga, which appears in *Fauna Hawaiiensis.* Kellogg, known for his work in popularizing biology, had a strong interest in evolution, particularly the evolutionary importance of biting lice (McClung 1939). Chapman studied under Kellogg at Stanford University, where they collaborated on other works; she is the only female contributor to the *Fauna.* Their article in *Fauna Hawaiiensis* presents a puzzle. Originally published in the *Journal of the New York Entomological Society* (Kellogg & Chapman 1902), then reprinted in the *Fauna* (1904), the article does not treat material collected by Perkins or any of his known associates. A possible solution to the puzzle is presented by E.C. Zimmerman's statement in *Insects of Hawaii* that the Mallophaga specimens collected by Perkins disappeared before they could be studied (Zimmerman 1948: 72). Sharp apparently used the Kellogg-Chapman article to fill the gap caused by the lost specimens.

George Kirkaldy was one of the first entomologists hired by Perkins in 1903 for the professional staff of the Entomology Division of the Hawaiian Sugar Planters' Association's (HSPA) Experiment Station. Kirkaldy, asked to describe the Hemiptera for the *Fauna,* became one of Sharp's biggest frustrations and received many "as soon as possible" letters. Sharp spent 5 years seeking return of the described specimens before abandoning all hope (Sharp 1909). Biographers frankly described Kirkaldy as "fond of controversy" (Perkins 1910), noting that he was led into many errors "by his love of revolution" (Sharp 1910). His inflexible adherence to the rule of priority in nomenclature was the source of "polemics with coworkers" (Terry 1910).

Edward Meyrick was a well-known specialist in Pacific microlepidoptera, yet he was chosen to describe the macrolepidoptera of the *Fauna*. He was criticized for ignoring moth genitalia and immature stages when naming species. To reconcile his theories on the origin and distribution of Pacific insects with the species he described, Meyrick created a South Pacific archipelago, Palaeonesia, which he contended had sunk 3,658 m (12,000 ft) below the ocean (Busck 1938).

Perkins wrote or coauthored 9 parts of *Fauna Hawaiiensis*, ca. ½ of the total work. Two of those parts, "Introduction" and "Vertebrata," are of exceptional usefulness to zoologists now interested in the Hawaiian fauna. The "Introduction" condenses Perkins' observations during his many years of Hawai'i fieldwork. His poor health delayed publication of both sections. The years of wet, cold work in Hawaiian forests and later exploratory work for the sugar planters combined with dengue fever, malaria, appendicitis, an ossified cysticercus on his liver, and other maladies to make Perkins' later years ones of constant illness. Sharp sent many encouraging letters urging Perkins to finish these 2 parts. Although Perkins discusses the birds in both the "Introduction" and "Vertebrata," there are no systematic descriptions of avian species in *Fauna Hawaiiensis*. Perkins gives 2 explanations for this decision. To William Alanson Bryan, Bishop Museum curator of ornithology and author of a 1915 book on the natural history of Hawai'i, Perkins stated that the "Vertebrata" would complement Bryan's work, as descriptions and synonymy had been "done to death already" (Perkins 1902). To George Munro, longtime friend and correspondent, Perkins stated that his lack of access to study skins prevented him from dealing with the "specific characters of the Drepanids" and that "my work on the birds [was] incomplete and unsatisfactory to myself" (Perkins 1945). Actually, the birds Perkins collected were systematically described by Scott Wilson, with considerable assistance from Newton, in *Aves Hawaiienses*. In addition to quoting Perkins' 1893 and 1895 *Ibis* articles, Wilson constantly cites Perkins' field observations. "Mr. Perkins says," "Mr. Perkins observed," or "Mr. Perkins states" appear in many *Aves Hawaiienses* descriptions. Wilson also figured and described *Drepanis funerea*, the only new bird species found by Perkins.

Lord Walsingham was an amateur lepidopterist, educated at Eton and Trinity Colleges, and a trustee of the British Museum. Like Meyrick, he was a controversial figure. His quick descriptions of new species were often based on questionable characteristics (Durrant 1920). Sharp found him an irregular correspondent, and Walsingham took 12 years to produce his microlepidoptera contribution. Meyrick, who would have liked to step in, chafed at Walsingham's slowness. When the manuscript arrived it included a request for illustrative plates costing £412. "Imagine my dismay," Sharp moaned (Sharp 1901). Eventually Walsingham donated £100 to defray the cost of the plates (Sharp 1902b). Sharp, a coleopterist through and through, in a rare verbalizing of his frustrations as editor, described the microlepidoptera section as "big, costly, pretentious, and uninteresting except to 3 or 4 people" (Sharp 1906).

In addition to the authors of record, others were involved in the preparation of *Fauna Hawaiiensis*. For instance, plates for the book were done by various artists and lithographers, including M. Anne Sharp. David Sharp said of his daughter: "[She] is getting really skillful & works for almost nothing while living with me" (Sharp 1905).

"The Fauna" continued

Despite Sharp's economies of employing his daughter "for almost nothing," in 1902 the Fauna faced a financial crisis. The £1,000 contributed by the Royal Society and Bishop Museum had been spent, and Sharp admitted that "if the Honolulu people will not contribute more, I shall have to close the *Fauna* and publish the rest as separate papers in Scientific Societies Transactions" (Sharp 1901). Quite diplomatically Sharp wrote the Bishop Museum Trustees that the Joint Committee had now published "about the amount we anticipated we should be able to give you for your subscription of £500" and asked for another £500 plus £200 to pay for "working out the collection" (Sharp 1902a). This the Trustees authorized in April 1902 (BPBM T 1902b). The Joint Committee was only able to match the Bishop Museum's £700 with a Royal Society grant of £200 for preparation and study of specimens (Royal Soc. 1904). Excluding specimen preparation, *Fauna Hawaiiensis* cost £1,600, or $8,000 ($103,600 in 1985). Bishop Museum carried the major portion, £1,000, the Royal Society gave £500, and Lord Walsingham £100. In addition to specimen handling, Bishop Museum had additional costs of $760, principally for crates, shipping, and reshipping the books to subscribers and library exchange partners (BPBM 1896–1908; 1899–1902; 1908–1916). In October 1901 the relatively new Territorial bureaucracy created a new financial problem for Bishop Museum. Under U.S. federal laws, books printed abroad could not be imported for sale without payment of a duty. When part 3 of Volume 1 of *Fauna Hawaiiensis* arrived, Customs demanded a sizeable duty. After a futile attempt to have the rule waived, the Trustees were forced to declare *Fauna Hawaiiensis* "not for sale" to avoid duty on the remaining 10 parts (BPBM T 1902a). Of course this ended any hope of recovering even part of the printing costs by sales of the book.

The "Introduction" and "Preface" with an "Index" were the last parts of the *Fauna* to be printed. Sharp again harnessed his daughter, who compiled the "Index" (Sharp 1912). At Sharp's suggestion, plates of key Joint Committee members and Charles Reed Bishop were included. Perkins, who successfully avoided being photographed until late in his life, declined to be included. One can imagine Sharp as he perused the finished Volume 1, Part 6, ready to heave a sigh of relief at finally being rid of the "FH." With horror he read the caption of Plate 1: "Likeness of the Honorable Charles *Robert* Bishop aet. 88, Founder of the Bernice P. Bishop Museum at Honolulu, and to whom the Fauna Hawaiiensis is dedicated." Bishop Museum's copies had already been shipped and Sharp was forced to write the Museum Trustees and beg them to reprint the caption, correcting Bishop's name, and tip in the new page before distributing their exchanges (Sharp 1913b).

Because the Joint Committee was a temporary body, it was necessary to dispose of the remaining volumes of *Fauna Hawaiiensis.* The surplus books were wholesaled to a London book dealer and the proceeds added to the Committee's treasury (Brigham 1912). Now the Joint Committee had an odd problem—what to do with surplus funds! The Committee eventually turned over the entire sum, £176.16.3, to the Bishop Museum, recommending that £50 be given to Perkins in recognition of his service to the project (Hickson 1914). The Museum Trustees, led by Henry Holmes, expanded on the idea:

> Mr. Holmes said that while in San Francisco recently [1914] he had spoken about this to the Honorable Charles R. Bishop and that the latter had expressed the opinion that Mr. Perkins had been but poorly paid for his services and that the whole of the refund should be turned over to him; and Mr. Holmes believed that if this were done it would be very gratifying to Mr. Bishop. . . . (BPBM T 1914)

On a unanimous vote the Trustees agreed to send Perkins the entire sum. Upon receipt of the Trustees' check, Perkins immediately wrote in return:

> I have duly received draft no. 2881, (Bishop & Co.) for £176.16.3 & herewith express my sincere thanks for the great liberality with which I have been treated by the Trustees in this matter. It is, further, very pleasing to me to think that my work on the Fauna has been appreciated by those who were so largely responsible for the assistance which rendered it possible. (Perkins 1914)

In retrospect: nothing better

At the close of the Joint Committee-*Fauna Hawaiiensis* project, Bishop Museum had expended $12,130 ($157,083.50 in 1985). From the establishment of the British Association's committee in 1890 to the issuing of the last part of *Fauna Hawaiiensis* in 1913, Newton, Sharp, and Perkins had devoted 23 years of often frustrating effort. Perkins called the project "the big work of my life" (Perkins 1901b). Trustee Holmes, more than satisfied with *Fauna Hawaiiensis,* felt "that nothing better had ever been done by this Museum than that of contributing towards its costs" (BPBM T 1914). Bishop, who worried that the Museum might not get a fair return for its money and that scientific publishing was too expensive, was gratified by the results of the investment:

> Mr. Holmes mentioned that when in San Francisco recently [1912] he had talked with the Honorable Charles R. Bishop on Museum matters and found him greatly pleased now that the Museum had assisted in the making of the Perkins Entomological Collection and in the publication of the results in the form of the Fauna Hawaiiensis, observing that the Museum had never attempted any work that would be of more value, and commented upon the great demand which was apparent for the Fauna. (BPBM T 1912)

In his final report to the BAAS, Sharp provides perhaps the best comment on the worth of the nearly quarter century of work by the Joint Committee, Perkins, and Bishop Museum. "Fauna Hawaiiensis" is, Sharp stated, "the true report of [the work of] this Committee" (BAAS 1913).

ACKNOWLEDGMENTS

The list of individuals and institutions who aided me in this 5-year research effort would be a long one. Deserving of special gratitude for his encouragement, understanding, and forgiving nature is Dr. Steven L. Montgomery, who also provided entomological advice. Without the devoted and persistent effort of volunteer Leilani Pyle in transcribing the archaically phrased, scrawled letters of Alfred Newton, this paper would simply not have been possible. Volunteer Kathleen Hamlin made a significant contribution in rechecking and verifying citations in Appendix 4. Special thanks go to volunteer Jane Medler for reading manuscript material at the Entomological Library, British Museum (Natural History) (BMNH), and to the Trustees of the BMNH for providing Bishop Museum copies of many documents. David Forbes gave valuable assistance in preparing Appendix 3.

Among the many Bishop Museum staff members who provided necessary advice and explanations of terms and techniques were the staff of the Bishop Museum Library and Drs. Wayne C. Gagné, Francis G. Howarth, Frank J. Radovsky, and Alan C. Ziegler.

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APPENDIX 1

MEMBERS OF THE JOINT COMMITTEE

	Years of Membership
Blanford, William Thomas (1832–1905)	1890–1905
Flower, William Henry (1831–1899)	1890–1899(?), Chairman 1890–1891
Godman, Frederick Du Cane (1834–1919)	1899–1912, Chairman 1907–1912
Godwin-Austen, Henry Haversham (1834–1923)	1890–1912(?)
Hickson, Sydney John (1859–1940)	1890–1912, Treasurer 1892–1912
Newton, Alfred (1829–1907)	1890–1907, Chairman 1892–1907
Riley, Charles Valentine (1843–1895)	1891–1895
Salvin, Osbert (1835–1898)	1890–1898
Sclater, Philip Lutley (1829–1913)	1890–1912
Sharp, David (1840–1922)	1890–1912, Secretary 1890–1912
Smith, Edgar Albert (1847–1916)	1891–1912

This list is based on annual reports of the Committee in the *Report of the British Association for the Advancement of Science* (BAAS) (1891–1913) and a circular, "Zoological exploration of the Hawaiian Islands" (Joint Committee 1891). Flower and Godwin-Austen apparently served on the Committee until 1899 and 1912, respectively, although neither appears in the BAAS reports after 1891. Both were fellows of the Royal Society and probably were the Society's representatives on the Joint Committee. The Royal Society's *Proceedings* (1892–1896) and *Year Book* (1897–1904) include no listing of Committee membership. David Sharp (1913a) lists both men, without comment, as Committee members in his "Preface" to *Fauna Hawaiiensis.*

APPENDIX 2

FAUNA HAWAIIENSIS AUTHORS AND THEIR SECTIONS

	Section. Volume (part): pages
Ashmead, William Harris (1855–1908)	Hymenoptera Parasitica. 1(3): 277–364
Bagnall, Richard Siddoway (1889–1962)	Thysanoptera. 3(6): 669–701
Beddard, Frank Evers (1858–1925)	Annelida. 2(4): 413–26
Carpenter, George Herbert (1865–1939)	Collembola. 3(4): 299–303
Chapman (Cady), Bertha Louise (1873–1956)	Mallophaga. 3(4): 305–21
Dollfus, Frederic Jules Adrien (1858–1921)	Crustacea, Isopoda. 2(5): 521–26
Forel, Auguste Henri (1848–1931)	Formicidae. 1(1): 116–22
Godwin-Austen, Henry Haversham (1834–1923)	Anatomy of Mollusca. 2(4): 271–412
Grimshaw, Percy Hall (1869–1939)	Diptera. 3(1): 1–78
	Diptera Supplement. 3(2): 79–86
Kellogg, Vernon Lyman (1867–1937)	Mallophaga. 3(4): 305–21
Kirkaldy, George Willis (1873–1910)	Hemiptera. 2(6): 531–99; 3(2): 95–174
Meyrick, Edward (1854–1938)	Macrolepidoptera. 1(2): 123–275
	Microlepidoptera Supplement. 3(4): 345–66
Pearce, Nigel Douglas Frith (1862–1939)	Acarina. 3(6): 702–04
Perkins, Robert Cyril Layton (1866–1955)	Introduction. 1(6): xv–ccxxviii
	Hymenoptera Aculeata. 1(1): 1–115
	Vertebrata. 1(4): 365–466
	Orthoptera. 2(1): 1–30
	Neuroptera. 2(2): 31–90
	Coleoptera (part). 2(3): 117–270; 3(6): 581–644, 650–66
	Hymenoptera Supplement. 2(6): 600–12
	Orthoptera Supplement. 2(6): 687–90
	Diptera (Pipunculidae and *Idiomyia*). 2(6): 697–700
	Strepsiptera. 3(6): 667
Scott, Hugh (1885–1960)	Coleoptera (part). 3(5): 415–22, 431–34, 455–74, 502–05, 508–38; (6): 644

Appendix 2, Continued.

	Section. Volume (part): pages
Sharp, David (1840–1922)	Preface. 1(6): xi–xiii Coleoptera (part). 2(3): 91–116; 3(3): 175–292; (5): 367–579; (6): 645–50
Shipley, Arthur Everett (1861–1927)	Entozoa. 2(4): 427–41
Silvestri, Filippo (1873–1949)	Thysanura. 3(4): 293–97 Myriopoda. 3(4): 323–38
Simon, Eugene (1848–1924)	Arachnida. 2(5): 443–519 Arachnida Supplement. 3(4): 339–44
Speiser, Paul Gustav Eduard (1877–1945)	Diptera Pupipara. 3(2): 86–92
Stebbing, Thomas Roscoe Rede (1835–1926)	Crustacea Amphipoda. 2(5): 527–30
Sykes, Ernest Ruthven (1867–1954)	Mollusca. 2(4): 271–412
Walsingham, Thomas de Grey (1843–1919)	Microlepidoptera. 1(5): 469–759

APPENDIX 3

PUBLICATION DATES FOR *FAUNA HAWAIIENSIS*

This compilation of *Fauna Hawaiiensis* is based on a reserve copy in the Bishop Museum Library. The volumes are bound in the wrappers.

Part	Pages	Plates	Date
Volume 1			
1*	1–122	I–II	Mar. 20, 1899
2	123–276	III–VII	June 8, 1899
3	277–364	VIII–IX	Aug. 1, 1901
4	365–468		Nov. 19, 1903
5	469–760	X–XXV	Dec. 1, 1907
6	ix–ccxxviii**	I–XVI***	Jan. 15, 1913
	1–46†		Jan. 15, 1913
Volume 2			
1	1–30	I–II	Aug. 19, 1899
2	31–90	III–V	Sept. 25, 1899
3	91–270	VI–X	Feb. 8, 1900
4	271–442	XI–XIV	May 19, 1900
5	443–530	XV–XXI	Oct. 17, 1900
6	531–700		Dec. 17, 1910
Volume 3			
1	1–78	I–III	Dec. 30, 1901
2	79–174	IV–V	Dec. 23, 1902
3	175–292	VI–VII	Apr. 9, 1903
4	293–366	VIII–XII	Apr. 9, 1904
5	367–580	XIII–XVI	Dec. 18, 1908
6	581–704	XVII–XIX	Dec. 17, 1910

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* An unnumbered 2-page "Map of the Hawaiian Islands" appears between p. 122 and pl. I. A "Notice to Binder" with vol. 1, pt. 6 (1913) states, "This map may be placed between plate iv and plate v of the Introduction (1: 6), where there is an explanation of it."

** The title page states that vol. 1, pt. 6, contains p. i–ccxxviii. The numbered pages in all copies examined in this study (bound and in wrappers) start with p. ix. Unnumbered pages do not account for p. i–viii, and the initial signature appears to be missing.

*** The plates for vol. 1, pt. 6, are numbered separately from pt. 1–5.

† The index is numbered separately from the text pages. Three copies are bound in the wrapper with vol. 1, pt. 6. A "Notice to Binder" states that a copy of the Index should be bound with each volume.

APPENDIX 4

CHRONOLOGY OF R.C.L. PERKINS' FIELDWORK AND TRAVEL IN THE HAWAIIAN ISLANDS, 1892–1901

This chronology is based on correspondence, diaries, recollections, specimen label data, and interisland passenger lists. It may be used to place individual specimens in the context of overall collecting efforts, supplement sketchy label data, detect errors introduced in label copying, and compensate for the absence of most of Perkins' diaries. The diaries were destroyed by Perkins after he used them in writing the "Introduction" to *Fauna Hawaiiensis* (Perkins 1936c). In 1936, prompted by correspondence with Bishop Museum Trustee Albert Judd, Jr., and Research Associate George Munro, Perkins made copies of the surviving diaries for the Bishop Museum Library. Perkins termed the originals "all but illegible" (Perkins 1936c) and the copies "exact" (Perkins 1936e). These copies, beginning with his first diary, cover the following collecting trips:

June 20–Sept. 10, 1892	Hawai'i
Oct. 24–Nov. 5, 1892	O'ahu
May 11–June 29, 1893	Moloka'i
July 9–Sept. 25, 1893	Moloka'i
Jan. 5–Feb. 23, 1894	Lana'i
Mar. 6—May 1, 1894	Maui
May 15–June 16, 1894	Kaua'i
July 4–July 14, 1894	Lana'i
July 20–Aug. 15, 1894	Hawai'i
Dec. 19, 1894–Jan. 1895	Hawai'i
Apr. 9–May 22, 1895	Kauai'i

To compensate for the diaries destroyed, Perkins wrote brief recollections of most of his other trips. These 1936 typescripts chronicle the following collecting trips:

Apr.–May 1892	O'ahu
Sept.–Oct. 1892	Hawai'i
Nov.–Dec. 1892	O'ahu
Nov. 1892–early 1893	O'ahu
May–June 1893	Moloka'i
Mar.–June 1894	Maui; Lana'i
June–Oct. 1895	Hawai'i; Kaua'i
Dec. 1895–Jan. 1896	Hawai'i
Feb. 1896	O'ahu
Mar. 1896	Hawai'i
May 1896	Maui
June 1896	Moloka'i
July 1896	Kaua'i
Aug.–Sept. 1896	Hawai'i
Oct. 1896	Maui
Jan.–Feb. 1897	O'ahu; Maui; Kaua'i
1900–1901	O'ahu

Label data from insect specimens in the British Museum (Natural History) and Bishop Museum, and from bird and arthropod specimens available at Bishop Museum were also consulted in preparing this chronology. Mollusca label data were too general to be of value. Labels with obviously erroneous data were disregarded. For example: specimens of *Nesoprosopis* could not have been collected by Perkins on O'ahu in February 1892, as he was then enroute to Hawai'i from England. Such impossible collecting dates probably represent material given to Perkins by Munro and other resident collectors.

Another major information source is the interisland passenger lists published in the O'ahu daily newspapers. This resource is limited in 3 ways: travelers' names were published only for sailings of passenger steamers to or from O'ahu; Perkins seems to have ridden freight steamers when passenger steamers didn't fit his schedule; and passenger lists were not published at the time of Perkins' 1900–1901 expedition.

Collecting localities, written as in the source (e.g., on the specimen label), are listed in alphabetical order when the day of activity is not known. As was the practice in the 1890s, Perkins did not use the diacritical marks now used in writing Hawaiian. Thus, to avoid creating incorrect or misleading localities, diacritics have not been added to Perkins' place names. Kau and Ka'u, for example, refer to several different places in the District of Ka'u on the island of Hawai'i. Similarly, references such as "near Honolulu" or "behind Waialua" are expressed as Perkins wrote them. Where the locality, as written in the original source, appears to be an obvious copying error or misspelling, the most likely name has been suggested in brackets. One place name is a special case. Kaholuamanu and Kaholuamano refer to the same place high in Waimea Valley, Kaua'i, where early European bird collectors took many specimens. Perkins tends to spell the name with an "o" ending, but both he and others occasionally use the "u" ending. There are appropriate Hawaiian legends to fit both spellings, and each spelling has been listed in the chronology without comment.

Chronology users must make their own decisions regarding the specific locations indicated by Perkins. Some are obscure and not locatable with certainty. For help in determining the locations indicated by place names, the reader is referred to *Place Names of Hawaii,* M.K. Pukui, S.H. Elbert & E.T. Mookini, The University Press of Hawaii, 1976; *Reference Maps of the Islands of Hawai'i,* J. Bier, The University Press of Hawaii, 1976–1977; and the series of topographic quadrangles (1:24,000) for the Hawaiian Islands published by the U.S. Geological Survey. Perkins left almost no explanations of his locality names. His shunning of Hawaiian guides may have left him without information regarding more specific designations for collecting sites and led to diary references such as "high forest," and labels such as "forest near Honolulu."

Chronology

In the following chronology each information resource, such as Perkins' diaries, is keyed to a number (see Resources Cited below). Numbers in parentheses following each line in the chronology indicate the resource on which the entry is based.

1892

Mar. 10	Arrives O'ahu from England (7)
Mar.	O'ahu: fieldwork
	Kaala Mts (1, 3, 5, 11, 15)
	Koolau Range, Waialua plains (5)
	Waialua (1, 3, 5, 11, 15)
	Waianae Mts (3, 5)
Apr.	Honolulu (5)
	behind Honolulu (1)
	Kaala Mountains (1, 5, 15)
	Waimea (3)
	Waianae Mts (1, 3, 5, 15)
May	forest near Honolulu (1)
	Nuuanu Valley (1)
June	Waianae Mts (3)
June 3	Travels from O'ahu to Hawai'i (12, 15)
June	Hawai'i: fieldwork
	Kaawaloe (*sic*) (3) [Ka'awaloa]
	Kona (1, 3, 5, 15)
	Kona, Greenwell's property (15)
June 6	Kealakekua (1)
June 20	Kona (15)
June 25	down to Kaawaloa (15)
June 26–27	travels to Kealakekua (15)
June 28	Pulehua (15)
June 29	lower dairy (15)
June 30	Kona (3, 5)
July	Kaawaloa (10)
	Kau (3)
	Kona (1, 3, 5)
July 6	Kaawaloa; below Holokalele pond (15)
July 8	up to Pulehua (15)
July 9	Kona (3)
July 12	Kona (3); Nahuina (15)
July 16	Nahuina (15)
July 17	Pulehua(23)
July 18	Kaawaloa to Pulehua (15)
July 21	Kaawaloa (15)
July 22	Kona (5)
July 24	Kona (3, 5)
July 26	Kaawaloa (15)
July 27	Kona (3, 5)
July 29	Kaawaloa (15)
July 31	Holokalele (15)
Aug.	Hualalai (5, 15)
	Kaawaloa (23)
	Kau (5)
	Kona (1, 3, 4, 5)
Aug. 1	Pulehua to Kanahaha (15)
Aug. 4	Kona (3, 5)
Aug. 5	Pulehua to Hualalai (1, 15); Kona (5)
Aug. 6	Kaawaloa (15)
Aug. 7	Pulehua (15)
Aug. 9	Kona (5)
Aug. 10	Kanahaha (15)
Aug. 12	Kanahaha (15)
Aug. 14–15	Hualalai (15)
Sept.	Kaawaloa (1, 3)
	Kona (1, 3, 4, 5)
	Mauna Loa (4)
Sept. 2	Kona (3)
Oct.	Kona (1, 3, 5)
Oct. 14	Travels from Hawai'i to O'ahu (12, 15)
Oct.	O'ahu: fieldwork
	Honolulu (1, 5)
	mts near Honolulu (1, 4)
	Lanihule (*sic*) Ridge (1) (Lanihuli)
	Nuuanu Valley (1)
Oct. 24–27	Nuuanu Valley (1, 15); Honolulu Mts (5)
Oct. 27	mts near Honolulu (1)
Oct. 31	Nuuanu Valley, Konahuanui side (15)
Nov.	O'ahu: fieldwork (4)
	Honolulu (3, 4, 5)
	Mts Honolulu (4)
	mts near Honolulu (1)
	Konahuanui (1)
	Nuuanu Valley (1)
	ridges around Nuuanu Valley (1)
Nov. 1–5	Pauoa Valley to Konahuanui (15)
Nov. 7–10	walks around O'ahu in 3 days (15)
Dec.	Halemano (1, 15)
	Mt Kaala (1)

1893

Jan.	O'ahu: fieldwork
	Halemano (1)
	Kaala Mts (15)
	Mt Kaala (1)
	Koolau Range, Halemano to Waimea Valley (15)
	Waialua (5)
	mts behind Waialua (1)
Feb.	Halemano (1)
	Kawailoa Gulch (1)
	Koolau Range (3, 5)
Mar.	Kaala Mts (3, 15)
	Kawailoa Gulch (1, 3)
	above Waialua (15, 22)
	mts behind Waialua (15, 22)
	Waianae Mts (3)
	Waianae Range, Leilehua (3)
Apr.	Kawailoa (3, 4, 15)
	Kawailoa Gulch (5)
	Kawailoa Riv (4)
	behind Waialua (1)
	Waianae Mts (3)
May	Wailua (5)
May 8	Travels from O'ahu to Moloka'i (9)
May	Moloka'i: fieldwork (1, 3)
	Kaunakakai (5)
	Molokai Coast (5)
	Molokai Mts (5)
	Molokai Plains (3, 5)
May 11	Kaunakakai (15)
May 12	Molokai Mts (3, 5)
May 12–13	Makakupaia (15)
May 14	travels to Kaunakakai (15)
May 15–16	Moloka'i: no fieldwork (illness) (15)
May 17–31	Makakupaia and surrounding area (15)
June	Molokai Mts (3, 4, 5)
	Molokai Mts, lower slopes (3)
June 1	Makakupaia to Kaunakakai (15)
June 2–3	Kaunakakai (15)
June 4	Kaunakakai to Makakupaia (15)
June 5	Makakupaia (15)
June 6–7	Makakupaia–Kaunakakai–Makakupaia (15)
June 8–12	Makakupaia area (3, 15); Molokai Mts (5)
June 13	above Pelekunu (15); Molokai Mts (5)
June 14–15	Makakupaia area (15); Molokai Mts (5)
June 16–17	Makakupaia–Kaunakakai–Makakupaia (15)
June 18–22	Makakupaia area (3, 15); Molokai Mts (5)
June 22–24	Makakupaia–Kaunakakai–Makakupaia (15)
June 24	Molokai Mts (3)
June 25–28	Makakupaia area (15)
June 29	travels to Kaunakakai (15)
June 30	Travels from Moloka'i to O'ahu (7, 15)
July 1–4	O'ahu: no apparent fieldwork (9)
July 5	Travels from O'ahu to Moloka'i (7)
July	Moloka'i: fieldwork
	Kaunakakai (15)
	Molokai Mts (1, 3)
	above Kalawas (*sic*) (1) [Kalawao]
July 9–12	highest forest area (15)
July 13–16	into Pelekunu Valley and back (15)
July 17	travels to Kaunakakai (15)
July 18–19	Kawela (15)
July 20	Kaluaaha (15)
July 21	Kaunakakai (15)
July 21–23	Moloka'i: no fieldwork (illness) (15)
July 24–26	Makakupaia (1, 15)
July 27	travels to Kaunakakai (15)
July 28–29	Kaunakakai area (15)
July 30	to Mauna Loa (15)
July 31	travels to Kala'e (15)
Aug.	Molokai Mts (1, 3, 5)
	Kalae (5)
	forests above Pelekunu (5)
	head of Pelekunu (1)
Aug. 1	Kalamaula, near Kalae (15); above Kalawao (1)
Aug. 2	head Kalawao; Waikolu to Makakupaia (15)
Aug. 3	Kalae (15)
Aug. 4	Kalamaula (15)
Aug. 5	Waikolu (15)
Aug. 6	Puukolekole (15)
Aug. 7	Kalae (1, 3, 15)
Aug. 8	above Kalawao (1, 15)
Aug. 9–10	Waikolu (15)
Aug. 11	Kahanui (1); Waikolu (15)
Aug. 12	Waikolu (15)
Aug. 13	above Makakupaia (3, 15)
Aug. 15	travels to Kaunakakai (15)
Aug. 16	Makakupaia (15)
Aug. 17	mts above Kamalo (15)
Aug. 18–26	Makakupaia area (3, 15)
Aug. 27	beyond Pelekunu pali (15)
Aug. 28	Waikolu (15)
Aug. 29–31	Makakupaia area (15); forest above Pelekunu (5)
Sept.	Molokai: fieldwork (3)
	Kahanui (1)
	Molokai Mts (1, 3, 5)
	above head of Pelekunu (1)
Sept. 1	travels to Kaunakakai (15)
Sept. 3	Kaunakakai (16)
Sept. 5	coast (15)
Sept. 6	up to Makakupaia (15)
Sept. 7	Molokai Mts (3, 5)
Sept. 8–14	Makakupaia and high forest (3, 15); Molokai Mts (5)
Sept. 15	travels to Kaunakakai (15)
Sept. 16	travels to Makakupaia (15)
Sept. 17–23	Moloka'i: fieldwork (1, 3, 5)
	Makakupaia area (15)
	Molokai Mts (3, 5)

1893, cont.	
Sept. 24	Makakupaia (15); Waikolu (1)
Sept. 25	Waikolu (15); Molokai Mts (5)
Sept. 26 (ca.)	Travels from Moloka'i to O'ahu (15)
Oct. 9	O'ahu: no apparent fieldwork (16)
Oct.	Travels from O'ahu to Moloka'i (15)
Oct.	Moloka'i: fieldwork (1)
	Kahanui (1)
	Kaunakakai (15)
	Pelekunu (15)
Nov. 18	Travels from Moloka'i to O'ahu (12)
Nov. 18–Dec. 10	O'ahu: no apparent fieldwork (9)
Dec. 11	Travels from O'ahu to Lana'i (9)
Dec.	Lana'i: fieldwork (1, 3, 5)
	Halepaakai (3)
	Lanai Gulch (1)
1894	
Jan.	Lana'i: fieldwork (5)
	Halepaakai (3, 20)
	gulch near Hayselden's (20)
	behind Koele (3)
	near Koele (3)
	Koele (5)
	Mts Koele (1, 3, 4, 5)
	Lanai Mts (3)
Jan. 5–6	gulch behind Koele (15)
Jan. 7–8	Palawai (15)
Jan. 11–12	highest peak (15)
Jan. 13	above Palawai (15)
Jan. 14	to Koele, night at Hayselden's (15)
Jan. 18	night at Hayselden's (15)
Jan. 28	to Koele (15)
Jan. 30–31	Waipaa (15)
Feb.	Awalua (5)
	Halepaakai (3)
	Mts Koele (3, 5)
	behind Koele (1)
	windward side of Lanai (1)
	main ridge (15)
	coast at Manele (15)
	above Waipaa (1, 15)
	near Waipaa (1, 15)
	above Waipaa looking toward Maui (1)
Feb. 1–20	Waipaa (15)
Feb. 21–22	Awalua (15)
Feb. 23	Travels from Lana'i to O'ahu (15)
Feb. 23–Mar. 6	O'ahu: no apparent fieldwork (23)
Mar. 6	Travels from O'ahu to Maui (7, 15)
Mar.	Maui: fieldwork
	Haleakala (1, 5)
	Iao Valley (5)
	Kahului sandhills (1)
	Olinda (1)
	Wailuku (3, 5)
Mar. 7 ff.	Haleakala (4)
	Iao Valley (3)
Mar. 8	Wailuku (23)
Mar. 9	Iao Valley (3)
Mar. 12	Makawao to Haleakala (1, 3, 15)
Mar. 13–23	Haleakala (3, 5, 15, 23)
Mar. 24	travels to Wailuku via Makawao and Pa'ia (15)
Mar. 25–26	in Wailuku and travels to Haleakala via Pa'ia and Makawao (15)
Mar. 27–30	Haleakala (1, 3, 4, 5, 15)
Mar. 31	Olinda (1, 15)
Apr.	Haleakala (3, 5)
	Iao Valley (1, 3, 5)
	Olinda Woods (1)
	West Maui (1)
	West Maui Mts (5)
Apr. 2	Olinda (15)
Apr. 5–11	Haleakala (1, 3, 5); Olinda (15)
Apr. 12–13	travels to Wailuku and returns via Makawao and Pa'ia (15)
Apr. 14–15	Maui: no apparent fieldwork (15)
Apr. 16–18	Iao Valley (15)
Apr. 19	sandhills (15)
Apr. 20–21	Iao Valley (15)
Apr. 22	to Wailuku, sees Brother Matthias Newell (15)
Apr. 23	Iao Valley (15)
Apr. 24	sandhills (15)
Apr. 25–28	Iao Valley; Iao ridges (15)
Apr. 29	to Wailuku, sees Brother Newell (15)
Apr. 30	Waihee (15)
May	Haleakala (3)
	Iao Valley (1, 3, 5)
	Wailuku (3, 5)
	West Maui Mts (3, 5)
May 1–4	Iao Valley (15)
May 5	sandhills (15)
May 12	Travels from Maui to O'ahu (12, 15)
May 13–14	O'ahu: no apparent fieldwork (9)
May 15	Travels from O'ahu to Kaua'i (15)
May 16	walks from port of 'Ele'ele, Kaua'i to Makaweli (15)
May	Kaua'i: fieldwork (1, 3)
	mts above Makaweli (1)
	Waimea (3, 5)
	mts Waimea (1, 3, 4, 5)
May 19–20	Kaholuamanu with G. Munro (10)
May 21–25	Kaholuamano area (15)
May 26–30	Kaholuamanu with G. Munro (10)
June	Kaua'i: fieldwork (3)
	Waimea (5)
	mts above Waimea (3, 5)
June 1–6	Kaholuamano area (15)
June 7	Rests at Munro home (10)
June 8	Kaholuamano area (15)
June 9	Waimea (15)
June 11–15	Hanapepe (15)
June 15	Rests at Munro home (10)
June 16	Travels from Kaua'i to O'ahu (12, 15)
June	O'ahu: no apparent fieldwork (9)

1894, cont.	
June 25?	Travels from O‘ahu to Lana‘i (9, 15)
June	Lana‘i: fieldwork (5)
	Hale Paakai (5)
July	Lana‘i: fieldwork (3)
	Hale Paakai (1, 3, 5)
	above Koele (?Mahana) (*sic*) (1)
	Mts Koele (3, 5)
	Lanai Hale (1, 3)
	Manele (3, 5, 15)
July 5	Hale Paakai (1, 15)
July 13	Hale Paakai (15)
July 13	Travels from Lana‘i to O‘ahu (15)
July 14–19	O‘ahu: no apparent fieldwork (15, 16)
July 20	Travels from O‘ahu to Hawai‘i (12, 15)*
July 22	lands on Hawai‘i at Punalu‘u, travels by stage to Kilauea (15)
July 22–25	Hawai‘i: fieldwork
	Kilauea (1, 25)
July 25	travels by stage to Punalu‘u (15)
July 26	travels from Kealakekua "up to Greenwell's" (15)
July 28	Holokalele (15)
Aug.	Kilauea (1)
	Kona (1, 3, 5)
Aug. 2	Pulehua (15)
Aug. 15	leaves Kona (15)
Aug. 22	Travels from Hawai‘i to O‘ahu (12)
Aug. 22–Sept. 1	O‘ahu: no apparent fieldwork
Sept. 1	Leaves O‘ahu for England (12)
1895	
Mar. 24	Arrives O‘ahu from England (12)
Apr.	O‘ahu: fieldwork
	Honolulu (5)
Apr.	Travels from O‘ahu to Kaua‘i (9, 10)
Apr.	Kaua‘i: fieldwork
	Koholemanu (*sic*) (3) [Kaholuamanu]
	Kaholuamano (1, 3, 4, 5)
	Kaholuamanu (5)
	Makaweli (1, 3)
	Waimea (3, 5)
Apr. 9 ff.	Kaua‘i: fieldwork (15)
Apr. 11	travels to Waimea for supplies (15)
Apr. 12	Kaholuamano (15)
Apr. 13–30	Kaholuamano area (15); Kaholuamanu (5)
May	Halemanu (1, 3, 4, 5)
	Kaholuamanu (3)
	Makaweli (1)
	Waimea (3, 5)
May 1	Kaholuamano area (15)
May 2–3	Makaweli (15)
May 4	return from Koholuwau; Mana (10, 15)
May 7	Waiawa to Halemanu mt house (15)
May 8–21	Halemanu area (15)
May 22	travels to Knudsen's (15)
May 25	Travels from Kaua‘i to O‘ahu (10, 23)
late May/early June	O‘ahu: no apparent fieldwork (23)
June	O‘ahu: fieldwork
	Honolulu (3, 5)
	Konahuanui (3)
June 12	Travels from O‘ahu to Hawai‘i (12)
June	Hawai‘i: fieldwork
	Kau (3, 5, 15)
	Olaa (5)
	Puna (3, 15)
June 14–19	Kilauea (3, 25)
	Olaa (1, 3, 25)
July	Kau (3, 5)
	Kilauea (1, 3)
	Olaa (1, 3, 5)
	Puna (3)
July 18	Hilo (17)
July 22	Puna (23)
Aug.	Hilo (3)
	Kau (3, 5)
	Kilauea (1, 3, 5)
Aug. 4	Kau (23)
Aug. 6	Kilauea (17)
Sept.	Kau (3, 5, 15)
	Kilauea (1, 3)
	Puna (15)
Sept. 17	Volcano House with Z. Atkinson and party (25)
Sept. 19	Travels from Hawai‘i to O‘ahu with Z. Atkinson (12)
Sept. 19–Oct. 6	O‘ahu: no apparent fieldwork (17, 23)
Oct. 7	Travels from O‘ahu to Kaua‘i (7)
Oct.	Kaua‘i: fieldwork (1, 15)
	Makaweli (3)
Nov.	Kaholuamano (3)
	Kaholuamanu (3, 10)
Nov. 10	Travels from Kaua‘i to O‘ahu (12)
Nov.	O‘ahu: fieldwork
	Waianae Coast (3)
Nov. 29	Travels from O‘ahu to Hawai‘i (12)
Dec.	Hawai‘i: fieldwork
	Amaulu, Hilo (*sic*) (3) [‘Amauulu]
	above Amuala (*sic*) (1) [‘Amauulu]
	Hilo (3, 5)
	above Hilo (1, 3)
	Kau (5)
	Kaumana, Hilo (3)
	Puna (3)
Dec. 19–27	Amaula area (*sic*) (15) [‘Amauulu]
Dec. 26	above Amaulu, Hilo (*sic*) (3) [‘Amauulu]

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* In 2 letters to C.R. Bishop (23 June and 18 July 1894: Resource 15), Perkins indicates he plans to go to Maui as well as Hawai‘i before returning to England. No evidence (label data, interisland travel, etc.) can be found, however, to suggest that Perkins' plan to visit Maui was carried out.

	1896
Jan.	Hawai'i: fieldwork
	Hilo (1, 3, 4, 5, 17)
	Kaumana (1)
	Olaa (3, 7)
Jan. 24	Hilo (11)
Jan. 28	Travels from Hawai'i to O'ahu (12)
Jan. 29–Feb. 6	O'ahu: no apparent fieldwork (11, 16)
Feb. 7 ff.	O'ahu: fieldwork
	Waianae (1, 3, 5)
	Waianae Coast (1)
	Waianae Mts (1, 3, 5, 15)
	leeward side of Waianae Mts (15)
Feb. 28	Travels from O'ahu to Maui (12)
Feb. 29–Mar. 7	Maui: fieldwork (11)
Mar. ?	Travels from Maui to Hawai'i (9)
Mar.	Hawai'i: fieldwork
	Kona (3, 15)
Mar. 24	Kona (6)
Mar. 26	Kona (11)
Apr. 6	Travels from Hawai'i to Maui (6)
Apr.	Maui: fieldwork (11)
	Haleakala (3, 5)
Apr. 12	Travels from Maui to O'ahu (12)
Apr. 12–?	O'ahu: no apparent fieldwork
after Apr. 18	Travels from O'ahu to Maui (8, 11, 15)
Apr.	Maui: fieldwork
May	Haleakala (1, 3, 4, 5, 15)
	Iao Valley (1, 3, 5)
	Olinda (1)
May	West Maui Mts (3, 5, 15)
June 2	Travels from Maui to O'ahu (7, 12)
June	O'ahu: no apparent fieldwork
June	Travels from O'ahu to Moloka'i (9)
June	Moloka'i: fieldwork (15)
	Molokai Mts (1, 3)
June 20	Travels from Moloka'i to O'ahu (12)
July	O'ahu: fieldwork
	Honolulu (1, 3, 4)
	mts near Honolulu (3)
	end of Koolau Range (3)
	back of Tantalus (3)
July 14	Travels from O'ahu to Kaua'i (12)
July	Kaua'i: fieldwork (1, 5, 15)
	Lihue (1, 4)
July 21	Lihue (23)
July 26	Travels from Kaua'i to O'ahu (12)
July 27	O'ahu: no apparent fieldwork
July 28	Travels from O'ahu to Kaua'i (12)
Aug.	Kaua'i: fieldwork (4, 15)
	high plateau (1, 3)
	Kaholuamano (20)
Aug. 9	Travels from Kaua'i to O'ahu (12)
Aug.	O'ahu: fieldwork
	Honolulu Mts (1, 3)
Aug. 18	Travels from O'ahu to Hawai'i with A. Koebele (12)
Aug.	Hawai'i: fieldwork (1)
	Hilo (3, 5)
	Kau (3, 5)
	Kilauea (1, 3, 5, 15)
	Kona (5)
	Olaa (1, 3, 15)
Sept.	Kau (3, 5)
	Kilauea (1, 3, 15)
	Kona (3, 5)
	Olaa (1, 15)
Sept. 13	Olaa (13)
Sept. 15	Travels from Hawai'i to O'ahu (12)
Sept.	O'ahu: fieldwork
	Honolulu Mts (1)
Sept.	Travels from O'ahu to Maui (14)
Sept.	Maui: fieldwork
	Iao Valley (1, 3, 5)
Oct.	Haleakala (1, 3, 5, 15)
	Puunianiau base camp (14)
	West Maui Mts (5)
Oct. 18	Travels from Maui to O'ahu (12)
Oct. 19–Nov. ?	O'ahu: no apparent fieldwork
Nov.	O'ahu: fieldwork
	Honolulu (1)
Nov. 20	Travels from O'ahu to Hawai'i (12, 14)
Nov.	Hawai'i: fieldwork
	Kau (3)
	Olaa (1, 3, 5)
	Puna (5)
Nov. 23	Puna (11)
Dec.	Kau (3)
	Kilauea (1, 5, 20)
	Puna (3, 5)
	Olaa (5, 20)
Dec.	Travels from Hawai'i to Maui (9, 14)
Dec.	Maui: fieldwork
	Lahaina (14)
	Haleakala (5)
Dec. 18	Travels from Maui to O'ahu (12)
Dec.	O'ahu: no apparent fieldwork (9)
Dec. 30 (ca.)	Travels from O'ahu to Maui (14)
	1897
Jan.	Maui: fieldwork (3, 5, 11, 15)
	coast of Lahaina (1, 15)
	Mt Lahaina (1, 15)
	Wailuku (3)
	West Maui Mts (3, 5)
Jan. 5	Travels from Maui to O'ahu (12)
Jan.	O'ahu: fieldwork (3)
	Waianae (5)
	Waianae Coast (1, 3, 5, 15, 20)
	Waianae Mts (5)
Jan. 12	O'ahu, in Honolulu (18)

1897, cont.

Jan.	Travels from O‘ahu to Kaua‘i (14)
Jan.	Kaua‘i: fieldwork (1, 3, 15, 20)**
	Makaweli (1)
Feb.	between Hanapepe and Makaweli gulches (20)
	Makaweli (3, 5, 15)
	Waika (10)
	Waimea (3, 5)
Feb. 3	Makaweli (23)
Feb. 13	Travels from Kaua‘i to O‘ahu (12)
Feb.	O‘ahu: fieldwork
	Honolulu (5)
	Waianae (5)
Feb.	Travels from O‘ahu to Hawai‘i (9)
Feb.	Hawai‘i: fieldwork
	Hilo (1, 3, 15)
Feb./Mar.	Travels from Hawai‘i to O‘ahu (9)
Mar.	O‘ahu: fieldwork (20)
	Honolulu (3, 5)
	Honolulu Mts (1)
	Koolau Range (3, 5)
Mar. 9	Leaves O‘ahu for England (7, 12)

1900

May 30	Arrives O‘ahu from England (7)
May (31?)	O‘ahu: fieldwork
	Honolulu Mts (2)
June	Honolulu (2, 3)
	Honolulu Mts (2, 3)
	SE Koolau (3)
	Tantalus (3)
	Wahiawa (3)
July 1–10 (ca.)	O‘ahu: no apparent fieldwork (illness) (19)
July 18–20 (ca.)	O‘ahu: no apparent fieldwork (mounting specimens) (19)
July	O‘ahu: fieldwork
	Honolulu (2, 3)
	Honolulu Mts (2, 3, 24)
	Koolau Range (2)
	NW Koolau Range (3)
	back of Tantalus (3)
July 21 ff.	Konahuanui (19)
Aug.	Honolulu (2)
	Honolulu Mts (2)
	Koolau Mts (2, 24)
	back of Tantalus
Sept.	Honolulu (2, 3)
	Honolulu Mts (2, 3)
	NW Koolau (3)
	Tantalus (3)
	Waialua (2, 21, 24)
	Waialua Coast (21, 24)
	Waialua end of Koolau Range (2)
Sept.	Travels from O‘ahu to Hawai‘i (9)
Sept.	Hawai‘i: fieldwork
	Hualalai (2)
Oct.	Kona (2)
	Mauna Loa (15, 24)
Oct.	Travels from Hawai‘i to O‘ahu (9)
Oct.	O‘ahu: fieldwork
	Honolulu (2)
Oct./Nov.	Travels from O‘ahu to Hawai‘i (9)
Nov.	Hawai‘i: fieldwork
	Mauna Loa (15, 24)
Nov.	Travels from Hawai‘i to O‘ahu (9)
Nov.	O‘ahu: fieldwork
	Honolulu (2, 24)
	Honolulu coast (2)
	Honolulu end of Koolau Range (2)
	Honolulu Mts (2, 3)
	Konahuanui Ridge (2, 24)
	NW Koolau Mts (24)
	head of Pauoa (2)
	back of Tantalus (2, 24)
Dec.	Honolulu (2, 24)
	Honolulu end of Koolau Range (2, 24)
	Honolulu Mts (2, 24)
	Konahuanui ridge (2, 24)
	NW Koolau Mts (24)
	pali back of Maluhia (24)
	Nuuanu Pali (2, 24)
	head of Pauoa (2)
	head of Pauoa R (24)
	head of Pauoa Valley (2)
	Tantalus (2)
	back of Tantalus (2, 21, 24)
	Waialua (3)
Month unknown	Maui: fieldwork
	Haleakala (21, 24)

1901

Jan.	O‘ahu: fieldwork
	Honolulu (2, 3, 24)
	Honolulu Mts (3)
	SE coast Oahu (2)
	Waianae (3)
	Waianae Coast (2, 3, 24)
	Waikiki (3)
Feb.	Honolulu (21)
	Honolulu Mts (2, 24)
	Konahuanui Ridge (2)
	NW Koolau Mts (24)
	Koolau Range (2)

** Perkins' 1936 typescripts and label data of a very few insect specimens seem to place Perkins in Hilo in January as well as February. There appears to be ample evidence, however, that Perkins was on Kaua‘i in January and early February, and the January Hilo insects may simply be mislabeled, or the gift of another collector, such as Koebele.

1901, cont.	
	SE Koolau Range (5)
	Waimea (3)
	SE Koolau Range (5)
Mar.	Honolulu (21)
	Konahuanui Ridge (2)
	NW Koolau (2)
	Waialua (21, 24)
Apr.	Honolulu (2)
	Kawailoa (21)
	NW Koolau Range (3)
	SE Koolau Range (3)
	Mokuleia (21, 24)
	Waimea (24)
	Waimea watershed (2)
	Wahiawa (2, 21, 24)
May	NW Koolau Mts (24)
	Mokuleia (24)
	Waialua Coast (21)
	Waianae Mts (5, 21)
June	Honolulu Mts (2, 21)
	Koolau Mts (4)
	SE Koolau Range (3)
	Pauoa Valley (head of) (3)
	back of Tantalus (2)
	Waialua (2, 21, 24)
July	Honolulu (21)
	NW Koolau Mts (2, 3)
	SE Koolau Range (3)
Aug.	N Koolau Range (2)
	NW Koolau Range (2, 3)
	SE Koolau Range (3)
	Waialua coast (2)
Sept.	Waialua coast (3)
Sept.	Travels from O'ahu to Maui (9)
Sept.	Maui: fieldwork
	Iao Valley (2, 3, 24)
	Haleakala (2, 24)
	Wailuku sandhills (3)
Oct.	Haleakala (3)
	Iao Valley (3)
Oct.	Travels from Maui to O'ahu (9)
Oct. 4–8	O'ahu: no apparent fieldwork (marriage) (20)
Oct.	O'ahu: fieldwork
	Mts Waianae (3)
	Waialua (2)
Nov.	Honolulu (21)
	Honolulu Mts (2, 3)
	SE Koolau Range (3)
Nov. 15–21	Waianae Mts with S. Wilder (20)
Dec.	Honolulu Mts (3)
	Waialua (3)
Dec.	Ceases to collect for the Joint Committee (20)

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BISHOP MUSEUM OCCASIONAL PAPERS 26: 47–51 MAY 1986

A New Lizard of the Genus *Emoia* (Scincidae) from Morobe Province, Papua New Guinea

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ABSTRACT

A new skink of the genus *Emoia* from the vicinity of Wau in the Bulolo River drainage, Morobe Province, Papua New Guinea, is described. Its relationship to the other species in the *E. submetallica* complex is discussed, and a key to the species of *Emoia* occurring in the Wau area is provided.

INTRODUCTION

Collections by the 2nd author from the vicinity of Wau on the upper Bulolo River drainage, Morobe Province, Papua New Guinea, include 7 sympatric species of the scincid lizard genus *Emoia,* 1 previously undescribed. The last, a distinctively colored species, is thus far recorded only from near Wau, whereas the others in the drainage system [*E. caeruleocauda* (de Vis), *E. jakati* superspecies, *E. loveridgei* Brown, *E. pallidiceps* superspecies, *E. physicae* (Dumeril & Bibron), and *E. submetallica popei* Brown] are all relatively widespread on the north and east side of the central mountain range in Papua New Guinea; *E. pallidiceps* and *E. physicae* are also found on the south side.

The new species described herein is probably most closely related to *E. submetallica popei* and *E. s. submetallica* (Macleay). The latter, however, unlike *popei,* is not sympatric with the new species in the Wau region; it occurs to the south in the Waria River drainage between the Chapman and Bowutu ranges, as well as in the mountains in Central Province west of the central mountain range.

The purpose of this paper is to describe the new species and to provide a diagnostic key to the 7 species of *Emoia* thus far recorded from the Wau area.

Emoia guttata Brown & Allison, **new species** Fig. 1

Emoia submetallica: Allison, 1982, p. 810 [not *submetallica* (Macleay)].

This species is a member of the *E. baudini* group (evolutionary line), a group of about 20 species mostly limited to New Guinea and nearby islands. The species of this section are mostly small to intermediate in size; have smooth scales; a short, high, anterior loreal; rounded subdigital lamellae, numbering not more than 50 under the 4th toe; and frontoparietals and interparietal fused into 1 shield.

Diagnosis. This species of *Emoia* is distinguished from congeners by the following combination of characters: (1) snout–vent length of mature specimens 51–73 mm; (2) midbody scale rows 33–38; (3) paravertebral scales between parietals and base of tail 49–58; (4) 4th-toe lamellae 35–43; (5) prefrontals moderately to widely separated; (6) 6th (rarely 5th) upper labial enlarged and beneath eye; (7) color pattern: dorsum olive to light

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Fig. 1. Photograph of adult *Emoia guttata.*

olive-brown with scattered black and whitish blotches on body and tail; upper lateral surface black, bordered below by an irregular white band; sides of neck and lower lateral surfaces marbled by scattered black and whitish blotches (Fig. 1).

Description. An intermediate sized *Emoia,* snout–vent length 51–73 mm for 407 adult males and 51–69 mm for 339 adult females (Allison 1979); snout moderately tapered, bluntly rounded, its length 43–50% of head breadth and 28–32% of head length; head breadth 63–73% of head length and 15–17% of snout-vent length; eye moderate, its diameter 58–74% of snout length and 25–36% of head breadth; ear diameter ⅓ to ½ of eye diameter; supranasals narrowly triangular, in contact with anterior loreal; rostral broader than high, forming long, relatively straight suture with frontonasal; prefrontals moderately to widely separated; frontal longer than wide, rounded posteriorly, somewhat shorter than to about as long as fused fronto-interparietal shield (rarely slightly longer), in contact with 1st and 2nd supraoculars; 4 large supraoculars; 7 supraciliaries; parietals in contact posteriorly; 1 pair of nuchals; anterior loreal shorter and higher than posterior, in contact with 1st and 2nd, 2nd or rarely 2nd and 3rd upper labials; usually 7 upper labials, 6th (rarely 5th) enlarged and beneath eye; 6 or 7 lower labials; dorsal scales smooth, scarcely larger than ventrals; midbody scale rows 33–38; paravertebral scales between parietals and base of tail 49–58; preanals slightly enlarged; limbs well developed, length of extended hind limb 95–117% (rarely < 100%) of axilla–groin distance and 46–54% of snout–vent length; 35–43 rounded lamellae beneath 4th toe (Table 1); 9–11 beneath 1st toe; rank of adpressed toes, from longest to shortest, 4, 3, 5=2, 1; tail longer than body.

Details of holotype. Snout–vent length 56.4 mm; axilla–groin distance 27.1 mm; hind limb length 27.3 mm; head length 11.8 mm; head breadth 8.2 mm; snout length 3.6 mm; eye diameter 2.1 mm; ear diameter 0.8 mm; tail length 79.5 mm. Thirty-five midbody scale rows, 58 paravertebral scales between parietals and base of tail, 38 fourth-toe subdigital lamellae.

Color. Dorsal ground color of live or freshly preserved specimens olive to light olive-brown. Top of head and anterior part of neck relatively unmarked except for a few blackish spots on supraoculars for some specimens. Body and tail marked by blackish blotches involving 1 to several scales and scattered whitish scales, the latter most frequent near dorsolateral line. Upper lateral surface marked by uneven black band (with a few whitish specks) 3–4 scale rows in breadth. This extends anteriorly as a narrow band through eye and along snout onto lateral margin of rostral. Below is a narrower, whitish band; this may be broken by scattered dark, transverse lines and is in turn bordered ventrally by a narrow, irregular blackish band or series of blotches. Sides of neck and lower lateral surfaces blotched with black and whitish patches. Venter greenish blue to light slate.

Type data. Holotype, adult ♀, PAPUA NEW GUINEA: Morobe Prov: 3.5 km NW of Wau, on lower slopes of Mt Kaindi at 1,300 m, 5 May 1980 (A. Allison) [Bernice P. Bishop Museum (BPBM) No. 8345]. Paratypes. Morobe Prov, general area of Wau and Mt Kaindi in the Bulolo Riv drainage, BPBM 8337, 8346–47, 8811–14, 8816, 8818–19, 8822, 8824–25, 8827, 8829, 8833, 8837, 8839, 8843, 8845, 8847–48, 8851, 8856, 8865, 8867, 8870–72, 8874, 8876–77, 8881, 8883, 8886–87, 8889, 8895–96, 8913, 8915–16, 8921–22, 8924, 8926–30, 8932–33, 8938, 8943–44, 8946–49, 9226, 9228–29, 9231–33, 9235–36, 9238, 9241, 9247–48, 9255–56, 9258–60, 9265, 9268, 9275–80, 9282, 9284, 9286–87, 9290–9303, 9305, 9325, 9335, 9970, 9974, 9989–90, 9992, 9999–10000, 10002, 10013–14, 10017–19, 10021, 10027–28, 10031, 10045, 10047, 10049, 10051–56, 10058, 10060–61, 10063, 10070, 10076, 10079, 10081–90, 10092–104, 10106–115, 10117, 10119–21, 10123–32, 10137, 10143–46, 10149–55, 10172, 10190, 10194, 10203, 10212, 10215–17, 10226–31, 10243, 10246, 10259, 10261–62, 10266–67, 10270–71, 10280–83, 10294–95, 10314, 10330–31, 10335, 10349, 10362, 10380, 10410, 10422, 10430, 10441, 10449, 10452, 10456, 10458, 10466, 10474, 10481–83, 10499–507, 10512–19, 10521, 10525, 10527, 10532, 10539, 10541; AMNH 126687–96; CAS 155986–95; MCZ 142638–39.

Etymology. The name *guttata* is Latin for "spotted" and refers to the numerous light spots and blotches on the lateral surfaces.

Reproduction. Allison (1979) studied reproduction in this species at Wau (1,230 m). Most individuals of both sexes reach sexual maturity (as judged by the presence of enlarged follicles or oviducal eggs in females, or by testicular or epididymal sperm in males) at 53 mm snout–vent length, although a few individuals are mature by 51 mm. Reproduction occurs throughout the year. No clear seasonal pattern is evident, although numbers of ovigerous females tend to increase during wet periods. As is true of other species of *Emoia* (Greer 1968), the new species is oviparous and has a clutch size of 2. The 2 eggs are laid in a shallow hole in the ground and take from 95 to 115 days to hatch ($n = 6$). Hatchlings range from 69 to 79 mm in total length and from 25 to 27 mm in snout–vent length ($n = 14$). Hatchlings closely resemble adults in coloration.

Ecology. The new species is terrestrial and occurs in early successional forest and disturbed areas (e.g., roadsides, garden clearings) from ca. 900–1,750 m elevation. It is virtually absent from primary forest and other densely shaded areas.

Individuals emerge in the early morning to bask and are active for about 2 h, foraging mainly in leaf litter. The diet consists mostly of soft-bodied prey (orthopterans, moths, lepidopteran larvae, and spiders). Juvenile lizards (including conspecifics) are occasionally taken. Hard-bodied prey such as beetles and ants are rare in the diet (Allison 1979, 1982, in prep.).

Ecologically the new species is very similar to *Emoia physicae,* which, although slightly larger, occurs in the same general area, is apparently active at the same time of day, and has a similar diet. Both species are abundant.

Range. This species has thus far been recorded only from the upper Bulolo River drainage, Morobe Prov, Papua New Guinea.

Comparisons with other species of *Emoia* found near Wau as well as the related *E. submetallica* are provided in the following diagnostic key and in Table 1.

Table 1. Scale counts and other pertinent characters for *Emoia guttata* and other related or sympatric species of similar size with which it might be confused.

	Snout–vent length at maturity (mm)	No. in sample for scale counts	$\bar{x}$ no. midbody scale rows (range)	$\bar{x}$ no. scale rows between parietals and base of tail (range)	$\bar{x}$ no. 4th-toe lamellae (range)	Large upper labial under eye
E. guttata	51.0–73.0	25	35.4 (33–38)	53.0 (49–58)	37.7 (35–43)	6th
E. submetallica popei	44.9–65.0	28	38.2 (34–42)	48.4 (45–52)	40.6 (37–44)	6th
E. s. submetallica	44.4–64.7	35	37.6 (34–41)	57.0 (54–62)	33.3 (30–37)	5th
E. pallidiceps	33.6–61.5	30	34.3 (30–36)	50.6 (46–55)	34.6 (32–41)	5th

Diagnostic Key to Species of *Emoia* in the Vicinity of Wau, Upper Bulolo River Drainage

1. Most dorsal and upper lateral scales with 3–5 moderate to sharp keels ...... **Emoia physicae**
   Dorsal and upper lateral scales smooth (rarely some scales of immature specimens with weak keels) 2
2. Sixth (rarely 5th) upper labial enlarged and under eye 3
   Fifth (rarely 6th) upper labial enlarged and under eye 4
3. Number of paravertebral scale rows between parietals and base of tail 45–52; upper lateral surfaces medium to dark brown, sometimes bordered ventrally by a pale white line; side of neck brown, marked by a prominent pale white spot (not a line from ear to forelimb) .... **Emoia submetallica popei**
   Number of paravertebral rows between parietals and base of tail 49–58; upper lateral surfaces dull black (fading to brown in preservative) marked by numerous, scattered pale white scales and usually bordered below by a narrow, broken light band and dark blotches .... **Emoia guttata, n. sp**
4. Number of lamellae under 4th toe 23–30 (rarely > 28); snout–vent length at maturity 29–48 mm; color in preservative medium brown to brown, nearly uniform or with a rather faint, narrow light line or row of small spots on lateral surface from ear to groin .... **Emoia loveridgei**
   Number of lamellae under 4th toe 30–38; other characters noted above variable 5
5. Number of midbody scale rows 28–32; dorsal ground color black to brown, nearly always with a narrow, pale brown to light-blue vertebral line (prominent or vague) continuous on head to tip of snout .... **Emoia caeruleocauda**
   Number of midbody scale rows 30–38 (rarely < 32 or > 36); narrow light vertebral stripe may or may not be present but never on head 6
6. Dorsal ground color green-brown to brown, with some dark spots widely separated or more or less fused (never a distinct light vertebral line); on lateral surface a pale white narrow line at limb level, extending from forelimb to ear but not anterior to ear .... **Emoia pallidiceps**
   Dorsal ground color a distinct striped pattern: a moderately narrow, light vertebral stripe bordered on either side by a wider, dark brown band followed by a narrow pale white dorsolateral line; on lateral surface, a pale white lateral line at limb level extending anterior to forelimb and passing over ear and along upper labials ...... **Emoia mivarti** superspecies

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Nonmarine Mollusks and Ecological Change at Barbers Point, O‘ahu, Hawai‘i

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ABSTRACT

Study of fossil nonmarine mollusks recovered from archaeological and paleontological sites at Barbers Point in the karstic ‘Ewa Plain of southwestern O‘ahu, Hawai‘i, demonstrates that prior to human occupation this arid region supported a fauna of 16 or more native terrestrial mollusk species. Although precise ecological data are lacking for most taxa represented, the composition of this fauna is consistent with botanical evidence that the region supported open-canopy dry forest and grassland prior to human settlement. Nonmarine mollusks were analyzed from 5 sites: 2 unmodified sinkholes, 2 human habitation sites, and 1 modified sinkhole (possible pit garden). At all but the last of these, a consistent pattern was observed in which now-extirpated native land snail taxa [species of *Orobophana* (Helicinidae), *Amastra* and *Leptachatina* (Amastridae), *Nesopupa* and *Pupoidopsis* (Pupillidae), and *Cookeconcha* and *Endodonta* (Endodontidae)] were replaced over time by ecologically tolerant native taxa that still persist in the region [*Lamellidea* and *Tornatellides* (Achatinellidae), *Succinea* (Succineidae), and to a lesser extent *Lyropupa* (Pupillidae)]; eventually, alien species introduced to the Hawaiian Islands during the prehistoric and historic periods [*Lamellaxis gracilis* (Subulinidae) and *Gastrocopta servilis* (Pupillidae), respectively] became prominent elements in the fauna. *Gastrocopta servilis* is now the dominant species in the litter fauna. At a single site (the possible pit garden), an aquatic species [*Assiminea nitida* (Assimineidae)] was extremely abundant, suggesting that this site may formerly have been an anchialine pool. Temporal changes in the composition of the land snail fauna of the Barbers Point region indicate drastic ecological disturbance, undoubtedly a result of human impact. The observed co-occurrence of prehistorically introduced mollusk and vertebrate taxa with extinct or locally extirpated native species of land snails and birds provides evidence in support of the conclusion that much of this ecological change, and many of the associated extinctions, resulted from the activities of the Hawaiians prior to the advent of European influence in A.D. 1778.

INTRODUCTION

The nature of prehistoric human impact on the Hawaiian ecosystem is a matter of considerable interest to archaeologists and biologists alike (Kirch 1982a,b; Olson & James 1982a,b, 1984). Archaeologists interested in the course of prehistoric cultural evolution in the Hawaiian Islands must consider the range of resources available for exploitation by the first colonizing Polynesians, as well as the complex process of anthropogenic ecological modification and cultural adaptation to the changing Hawaiian environment. Biologists studying Hawaiian plants and animals must consider the effects of some 1,600 years of human impact as they attempt to interpret the taxonomy, evolution, and ecology of the

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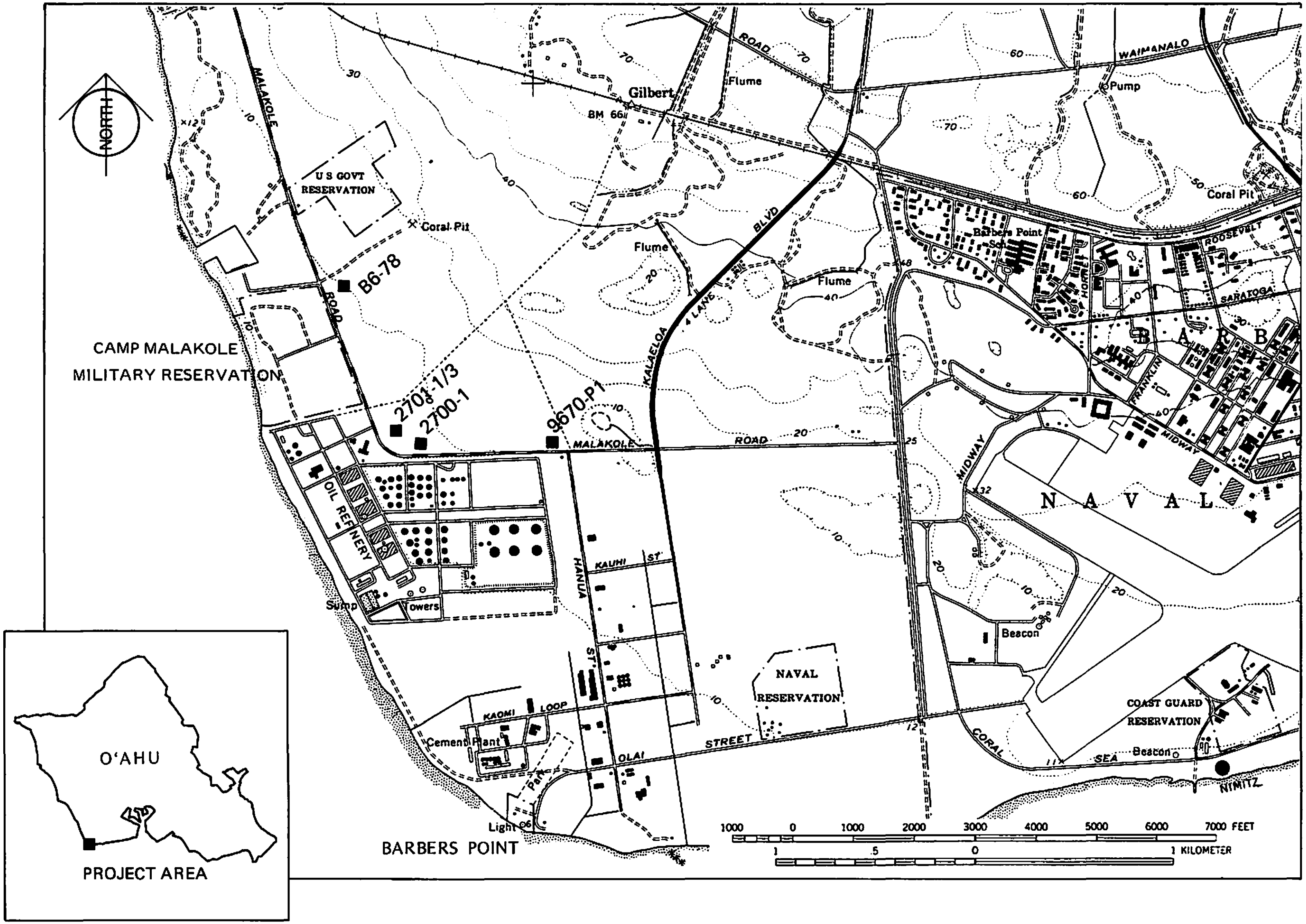
various elements of the modern biota. Several methods have been developed that aid in the task of paleoenvironmental reconstruction necessary for the interdisciplinary investigation of the interaction of the Hawaiians and their environment. One such technique is snail analysis, a process analogous to pollen analysis, in which temporal changes in the composition of nonmarine mollusk communities are used to interpret larger ecological changes. This technique has been used extensively by archaeologists and paleontologists in the reconstruction of ancient environments in Europe and North America (Kerney 1966; Evans 1972; Bobrowsky 1984). The potential value of fossil land snails as indicators of ecological change in Hawai'i has long been recognized, but although Henshaw (1904), Perkins (1913), and Zimmerman (1948) all referred to such evidence in discussions of ecological change, until recently little use was made of the technique in investigations of Hawaiian paleoenvironments. Kirch (1975) presented malacological evidence in support of conclusions regarding anthropogenic ecological change in Halawa Valley, Moloka'i. Additional studies are those of Christensen (1983, 1984) regarding fossil nonmarine mollusks from sites in South Kohala and North Kona, respectively, on the island of Hawai'i, and continuing studies of Barbers Point sites by Christensen et al. (in prep.).

In 1976 the Bishop Museum conducted an archaeological program of survey and test excavations at Barbers Point, in the karstic 'Ewa Plain of southwestern O'ahu (Sinoto 1976). Study of sediments found in solution sinkholes in emerged Pleistocene reef limestone revealed the presence of abundant avian remains. Material recovered then and subsequently included the bones of many extinct species, documenting a previously unsuspected diversity in the endemic avifauna of O'ahu (Olson & James 1982a,b, 1984). During a later salvage phase of the archaeological studies (Sinoto 1978), these sites were found to contain rich deposits of fossil nonmarine mollusks; a nonquantitative preliminary study (Kirch 1978) indicated that these were a potential source of information regarding paleoenvironmental change at Barbers Point and recommended that further investigations be undertaken.

In April 1980 we were requested by Dr. Hallett H. Hammatt, Archaeological Research Center Hawaii, Inc. (ARCH), to investigate nonmarine mollusks in archaeological and paleontological sites to be excavated under his direction (Fig. 1). This work was conducted under contract to the U.S. Army Corps of Engineers as part of environmental impact mitigation efforts for the Barbers Point Deep Draft Harbor. In cooperation with the ARCH field team (Hammatt and William H. Folk, II), we obtained column samples from a limestone sinkhole containing remains of extinct birds, from 2 human habitation sites, and from 1 small culturally sterile sink. In addition, we sampled the deep sinkhole (50-Oa-B6-78) previously excavated by Sinoto (1978). In all, 26 soil samples were analyzed, from which 21,376 shells were extracted, sorted, identified, and counted. One additional limestone sinkhole was sampled, but the material obtained was not analyzed owing to funding limitations. The present report contains the results of these analyses and is an expansion of a manuscript report (Kirch & Christensen 1980) prepared for ARCH under contract to the Department of the Army, Corps of Engineers, Pacific Ocean Division. The ARCH archaeological investigations undertaken concurrently with our malacological studies have been reported upon by Hammatt & Folk (1981). Additional archaeological studies in the Barbers Point region are those of Davis & Griffin (1978), Sinoto (1979), and Davis et al. (in prep.).

MATERIALS AND METHODS

This investigation was the first major application of quantitative snail analysis in Hawai'i, and therefore the methods used are described in detail.


NORTH
CAMP MALAKOLE
MILITARY RESERVATION
U S GOVT
RESERVATION
Coral Pit
B6-78
2701-1/3
2700-1
9670-P1
MALAKOLE
ROAD
MALAKOLE ROAD
Gilbert
BM 66
Flume
ROAD
WAIMANALO
Pump
Coral Pit
KALAELOA
4 LANE
BLVD
Barbers Point
Sch
ROOSEVELT
SARATOGA
FRANKLIN
MIDWAY
B A R B
N A V A L
OIL REFINERY
Sump
Towers
KAUHI
ST
HANUA
ST
NAVAL
RESERVATION
KAOMI
LOOP
Cement Plant
OLAI
STREET
Park
Light
BARBERS POINT
CORAL
SEA
Beacon
COAST GUARD
RESERVATION
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1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
O'AHU
PROJECT AREA

Site selection. Sites to be sampled for nonmarine mollusks were selected by ARCH personnel, with the exception of Site B6-78, which we chose for study because of the abundant avian remains recovered there during Sinoto's earlier excavations.

Sampling. Soil samples for snail analysis were taken as continuous columns (50 or 100 cm^2 in cross-sectional area) cut into exposed vertical stratigraphic sections. Columns were taken at points where the stratigraphic section appeared to be relatively complete and free of disturbance. Sampling intervals ranged from 2 to 10 cm and did not cross stratigraphic boundaries. At the time of sampling, notes were made on the stratigraphic profile, although detailed stratigraphic analysis was the responsibility of the ARCH personnel.

Extraction. In the laboratory each sample was air-dried and weighed on an Ohaus triple-beam balance. The sample was then wet-sieved using 4-mm, 1-mm, and 0.5-mm standard mesh screens (material passing through the 0.5-mm screen was discarded). The fractions retained were oven-dried, weighed, and bagged. The 4-mm and 1-mm fractions were hand-sorted under a low-power (7 ×) binocular microscope, and all countable specimens (complete shells and those fragments including the shell apex) and fragments of species not represented in a particular sample by countable apices were removed, as well as bones, marine shells, etc. Material retained by the 0.5-mm screen was examined for the presence of shells of species not otherwise represented in a particular sample, but it was not quantitatively analyzed. Although workers in other regions routinely separate all snails retained by a 0.5-mm mesh screen, the presence of heavy calcareous deposits on shells from the deeper samples of some of the Barbers Point sites, together with the difficulty of sorting and counting the often extremely abundant immature or broken shells that make up the bulk of the molluscan material retained by the 0.5-mm screen, made it impractical to treat this fraction quantitatively.

Counting. In quantifying frequencies of mollusk taxa, only intact shells or fragments containing the shell apex were counted to avoid double counting of broken shells. Identifiable nonapical fragments of species not otherwise represented in a particular sample, or those present only in the 0.5-mm fraction, are indicated in the data tables with a plus sign (+). A few living individuals of *Gastrocopta servilis* (Gould, 1843) found in subsurface samples are thought to be the result of contamination; these are identified in the data tables as numbers within parentheses.

Identification. Identification of terrestrial mollusks was accomplished with the aid of published reports and by comparison with identified specimens in the Bernice P. Bishop Museum. In most instances, identification was to species level; where the condition of the specimens (broken, immature, etc.) or the unsettled taxonomy of the group (as in *Tornatellides*) prevented precise identification, determination was to the generic or family level. A few shells too broken or immature even for family-level identification are listed in the data tables merely as "unidentified." Vertebrate remains were identified by Carla Kishinami, Division of Vertebrate Zoology, Bishop Museum.

Archaeological site designations. Two archaeological site designation systems have been used in the Barbers Point region. Bishop Museum site numbers assigned by Sinoto

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Fig. 1. Location map showing Sites B6-78, 9670-P1, 2700-1, 2701-1, and 2701-3 at Barbers Point, O'ahu (base map: 'Ewa, Hawai'i, quadrangle, U.S. Geological Survey 7.5' topographic series, 1962).

(1976, 1978, 1979) carry the prefix "50-Oa-" (example: 50-Oa-B6-78), while for State of Hawai'i site numbers designated by Davis & Griffin (1978) and Hammatt & Folk (1981) the prefix is "50-80-12-" (e.g., 50-80-12-2701-1) (in this report these prefixes are omitted from text except at first mention of a particular site designation in its site report). Hammatt & Folk (1981) assigned a 2nd state number to several sites. We will use Bishop Museum numbers where designated, as well as the original State of Hawai'i number assigned to a particular site; as the revised state numbers have been cited by Christensen (1982) and Olson & James (1982a,b), they are also noted.

Presentation of data. Brief site descriptions are presented for each site from which samples were analyzed. Raw counts recorded for shells of each taxon in each sample are presented. To permit comparison of density of shells for various samples, we present a concentration index (countable shells per 100 g sample weight) for the total number of shells (not including eggs) of all taxa for each sample. Graphical summaries are provided for each stratigraphic column; for each sample, the relative abundance of a particular taxon is indicated by the width of the vertical bar for that taxon (species making up less than 1% of the countable shells in a particular sample are represented by a "+"). To demonstrate discontinuities and the degree of grading within the stratigraphic columns of the 2 deepest sinks (B6-78 and 9670-P1), we have made use of paleoecological similarity matrices (Pielou 1979). Whittaker's (1952) Proportional Similarity Index was used to provide a measure of the similarity between the molluscan communities represented in any 2 samples. Discontinuities within the soil column can be detected through inspection of a matrix constructed of the similarity indices for all samples within the column. The extent to which the faunal sequence at a particular site matrix is graded is determined by the use of the ratio of Q, the grading index of Pielou (1979) for a particular similarity matrix, and Q_{max}, the maximal value of Q for a matrix of such dimensions (this ratio ranges from 0 to 1, low values signifying a well-graded matrix). Similarity matrices are presented graphically.

Ecological interpretations. Ecological data pertinent to the various species were abstracted from published sources, where available, or from records and collecting data associated with specimens in Bishop Museum. This ecological information is much less complete than that usually available for land snail taxa in Europe and the mainland United States, where snail analysis is a relatively refined method of paleoenvironmental reconstruction. Interpretation of the Barbers Point material is complicated by the fact that many of the species represented are universally extinct, and thus direct evidence of their ecology is not available. Because of the virtual destruction of native lowland habitats in the Hawaiian Islands, modern observations of extant populations of other native taxa may not reflect the full range of habitats in which these snails once occurred. Because of these deficiencies in available ecological data, we decided to categorize taxa of native terrestrial mollusks according to whether they still inhabit the study area (NL = Native, Extant) or are now locally or universally extinct (NE = Native, Extinct). Members of the NL group we interpret as being tolerant of ecological disturbance associated with human activities, while the NE group apparently includes anthropophobic taxa intolerant of such environmental change. Christensen & Kirch (1981) demonstrated the significance of prehistorically or historically introduced land mollusks as stratigraphic markers and as indicators of human ecological impact. These taxa are categorized here either as Introduced, Prehistoric (IP) for alien taxa introduced to the Hawaiian Islands prior to A.D. 1778 or Introduced, Historic (IH) for taxa introduced during the period following the European rediscovery of the islands. A single aquatic species (AQ) occurs in the Barbers Point sites.

SYSTEMATIC REVIEW

Family HELICINIDAE

Orobophana uberta (Gould, 1847)

According to Neal (1934), this species is precinctive to O'ahu, where it has been found over a wide altitudinal range. Neal reported that these snails live on the ground on dead leaves and twigs; little is known of their habitat preferences. *Orobophana uberta* was formerly more widely distributed than today, and fossil shells may be found in abundance in localities where, as at Barbers Point, the species is now extinct.

Family ASSIMINEIDAE

Assiminea nitida (Pease, 1865)

Assiminea nitida is an amphibious snail of wide distribution in the Indo-Pacific region (Abbott 1958). Maciolek & Brock (1974) found this euryhaline species to be a common inhabitant of anchialine ponds along the Kona coast of the island of Hawai'i, occurring over a salinity range of 2 to 30 parts per thousand.

Family ACHATINELLIDAE

Lamellidea spp.

Shells of this genus were abundant in all samples studied and are a major component of the modern litter fauna of the Barbers Point region. Considerable morphological variation within the fossil material obtained suggests the presence of more than 1 species of *Lamellidea,* but no specimens could be definitely attributed to any species other than *L. gracilis* (Pease, 1871). This species occurs throughout the Hawaiian Islands from sea level to 300 m elevation (Cooke & Kondo 1960) and is one of the few native land snails commonly found in association with non-native plant communities.

Tornatellides spp.

At least 3 species of *Tornatellides* are represented in this material. Because of the difficulty of identifying members of this genus, particularly when immature or broken shells are involved, no attempt has been made to differentiate the various species present. One, or possibly 2, species of this genus still inhabit the Barbers Point region, and for purposes of ecological analysis all *Tornatellides* found are classified as "native extant" taxa; we do not believe that this unavoidable oversimplification results in significantly overstating the importance of the "native extant" faunal element in any sample. Little is known of the ecological preferences of species of *Tornatellides,* although their persistence in this region of exotic vegetation is indicative of a rather broad tolerance of changing ecological conditions.

Family AMASTRIDAE

Amastra (Cyclamastra) umbilicata umbilicata (Pfeiffer, 1855)

A single shell fragment identifiable as this species was found in a sample from Site B6-78; additional shells were found at Site 9670-P1 in the backdirt piles of the ARCH excavations. *Amastra umbilicata* or closely related taxa have been reported from all main islands except Ni'ihau. "For the greater part, these were shells of the plains and low elevations, down to near sea level. With the passing of the low forests these Amastras have become extinct, with few exceptions" (Pilsbry & Cooke 1914–1916).

Leptachatina (Angulidens) cookei Pilsbry, 1914

Fossil shells of this extinct species have been found in a few scattered locations in the arid coastal regions of western O'ahu. *Angulidens,* the subgenus to which both of the Barbers Point *Leptachatina* belong, is represented by 1 or more species on each of the main islands of the Hawaiian Chain; most inhabited lowland areas, and nearly all are extinct (Pilsbry & Cooke 1914–1916).

Leptachatina (Angulidens) subcylindracea Cooke, 1911

Like the preceding species, this is an extinct lowland snail; it was formerly widely distributed on O'ahu and has also been reported from Moloka'i and Kaho'olawe (Pilsbry & Cooke 1914–1916).

Specimens listed in the data tables as "*Leptachatina* spp." are too fragmentary or immature for precise identification.

Family PUPILLIDAE

Lyropupa (Mirapupa) ovatula ovatula Cooke & Pilsbry, 1920

This snail is restricted to O'ahu, where it is known only as a fossil; a subspecies formerly occurred on Moloka'i and Hawai'i. Dextral species of *Lyropupa* (members of the subgenus *Mirapupa*) are generally restricted to arid low-elevation sites (Pilsbry & Cooke 1918–1920). Although *Lyropupa o. ovatula* occurs in some abundance in fossil deposits elsewhere in the Barbers Point region (Christensen, in prep.), only 8 shells from a single site (2700-1) were recovered during the present study.

Lyropupa (Mirapupa) perlonga (Pease, 1871)

This species occurs abundantly in the fossil deposits of coastal O'ahu; it has been found also on Kaua'i and Ni'ihau (Pilsbry & Cooke 1918–1920). Living individuals of *L. perlonga* are rarely encountered, and the only live-collected Bishop Museum lot for which habitat data are available (BPBM 21939) contains numerous specimens found in 1911 in *pili* grass (*Heteropogon*) at Koko Head, O'ahu. The species is common in fossil assemblages at Barbers Point, and small numbers of living individuals were found in leaf litter in the immediate vicinity of Site B6-78; the species is thus one of the few native snails tolerant of the disturbed vegetation now found in the study area.

Nesopupa (Nesopupilla) litoralis Cooke & Pilsbry, 1920

This extinct species is known only from fossil shells found in a few scattered localities on the O'ahu coastal plain (Pilsbry & Cooke 1918–1920).

Nesopupa (Limbatipupa) newcombi (Pfeiffer, 1852)

This species occurs on most of the main Hawaiian Islands. It is often present in lowland fossil assemblages, but it has also been reported from higher elevations. Its ecology is otherwise unknown. No living or freshly dead shells were found during this study, and the species is apparently extinct in the Barbers Point region.

Nesopupa (Nesodagys) wesleyana Ancey, 1904

Nesopupa wesleyana is a variable species reported from all of the main islands from Kaua'i to Hawai'i; the numerous localities from which Pilsbry & Cooke (1918–1920) recorded living or fossil examples indicate that the species once occupied diverse habitats. Only a single fossil shell was obtained during the present study.

Pupoidopsis hawaiiensis Pilsbry & Cooke, 1921

Fossil shells of *P. hawaiiensis* are often abundant in aeolian sandstones and other sedimentary deposits in the coastal lowlands of the main Hawaiian Islands, but the species is thought to be extinct throughout the state. On Christmas Island living snails of this species have been found on the bunchgrass *Lepturus,* a habitat thought by Cooke & Neal (1928) to be similar to that of Hawaiian *Pupoidopsis.* At Hao, Tuamotu Islands, *Pupoidopsis* has been found "on tree trunks and twigs" and "under *Tournefortia* [=*Messerchmidia*]" (BPBM 136562-3 and 136597-8, respectively).

Gastrocopta servilis (Gould, 1843)

This Neotropical species has been present in Hawai'i since the late 19th century (Ancey 1892, as *Pupa lyonsiana*). It has been transported throughout the islands of the Pacific by modern commerce and may occur also on islands in the Indian Ocean [*Gastrocopta seignaciana* (Crosse & Fischer, 1879), *G. microscopica* (Martens, 1898), and related taxa are very similar and may prove to be conspecific (Pilsbry 1916–1918)]. *Gastrocopta servilis* is the most abundant snail in the modern litter fauna at Barbers Point and is well represented in the uppermost levels of the sites examined (its apparent presence in deeper levels at Site B6-78 is undoubtedly due to contamination, as explained in the discussion of that site elsewhere in this report).

Family ENDODONTIDAE

Cookeconcha undescribed sp.?

The numerous specimens of *Cookeconcha* recovered probably represent an undescribed species of the *C. henshawi* group (as defined by Solem 1976), although until the many O'ahu species of this genus are fully reviewed the possibility cannot be excluded that the specimens may be referable to a known species. No representatives of the group now inhabit the Barbers Point region.

Pilsbry & Vanatta (1906) stated that species of *Cookeconcha* "live on dead stumps and logs, and under the bark of dead trees, but also under fallen leaves." Solem (1976) added that these snails "have also been found in heavy moss on large boulders and at low levels on tree trunks." These remarks are probably more relevant to species of the mountain forests than to those of arid low-elevation sites, most of which had become extinct prior to the activities of modern malacologists. Records of undescribed species of *Cookeconcha* living in *pili* grass at Koko Head, O'ahu (BPBM 21938), and in clumps of the bunchgrass *Eragrostis* on Nihoa, Northwestern Hawaiian Islands (Conant et al. 1984), may be more indicative of the preferred habitat of the Barbers Point species.

Endodonta kalaeloana Christensen, 1982

This extinct species has been recorded from several sites in the 'Ewa Plain (Christensen 1982). As with *Cookeconcha,* published ecological data are most pertinent to species of high elevations or other moist habitats. An exception is the report by Cooke (1928) of the occurrence of living *Endodonta* "in talus slopes of the Waianae Mountains, some of them in dry and exposed situations." An undescribed *Endodonta* occurs with *Cookeconcha* in bunchgrass on Nihoa (Conant et al. 1984), and the Barbers Point species may have existed under similar conditions.

Table 1. Stratigraphic profile for Site B6-78.

Layer	Depth (cm)	Description
I	0–5	Black (10YR 2/1) organic A_0 and A_1 horizons, relatively loose.
II	5–35	Brown (7.5YR 5/4) silt and sand with angular fragments of limestone; primary zone of bird bones.
III	35–85+	Reddish yellow (5YR 5/6) deposit of limestone breccia in a matrix of silt and sand.

Family SUCCINEIDAE

Succinea caduca Mighels, 1845

Succineids recovered from excavations at Barbers Point exhibit a considerable range of shell form but all appear referable to *S. caduca,* a native species found throughout the main Hawaiian chain at low elevations, often in extremely arid conditions. The species currently inhabits the study area, and estivating individuals can often be found in abundance, sealed to the undersides of limestone slabs.

Family SUBULINIDAE

Lamellaxis gracilis (Hutton, 1834)

This adventive species became established in several Pacific island groups during the prehistoric period (Christensen & Kirch 1981, unpubl. observ.; Hunt 1981; Sinoto 1983); Christensen (1984) demonstrated its presence in Hawai'i in the late prehistoric period.

Fossil snail eggs of the type produced by *L. gracilis* were obtained at Sites B6-78 and 9670-P1, always in association with identifiable shells of *L. gracilis.* We cannot exclude the possibility that some may be those of *Leptachatina,* however.

Kirch & Christensen (1980) erroneously identified some of the subulinids from Site B6–78 as *Pseudopeas tuckeri* (Pfeiffer, 1846). In fact, all are *L. gracilis.*

Site Descriptions

Site 50-Oa-B6-78

This site, a sinkhole with an opening 2.5 × 1.5 m and a depth of 1.9 m to the top of the deposit, was excavated by Sinoto (1978: 21–24). The sink's deposits yielded many fossil bird bones, particularly in the upper 35 cm. Fortunately, the previous excavators had left intact some of the upper levels of deposit near the walls of the sink, and half of the lower breccia zone remained unexcavated. Thus we were able to obtain a complete column of 9 samples, to 85 cm below the original floor of the sink. The modern terrestrial mollusk fauna of the site was sampled by counting all living snails recovered from leaf litter under vegetation immediately adjacent to the sinkhole opening.

The stratigraphy of the site was reported by Sinoto (1978: fig. 11, table 4) and was also the subject of a detailed sedimentological analysis by Morgenstein (1978). The 2 reports differ in terms of layer designations and thicknesses, although they generally agree in description of the sediments. Sinoto's "overburden" is essentially equivalent to Morgenstein's Layer I. Morgenstein's Layer II, stated by him to be the primary zone of bird-bone deposition, coincides with Sinoto's Layer I and part of Layer II (based on depth data presented in Sinoto's table 4). Morgenstein's Layer III is divided by Sinoto into Layers III and IV.

The depositional sequence is summarized in Table 1 (layer designations are from Morgenstein, but with depths as measured at the time of collection of the land snail sample). The results of snail analysis are given in Table 2 and are plotted in Fig. 2.

Table 2. Nonmarine mollusks recovered from Site B6-78.

	Sample no.									
	—	6	7	8	9	1	2	3	4	5
Layer	Litter	I	II	II	II	III	III	III	III	III
Depth (cm below surface)	—	0–5	5–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85
Sample weight (g)	—	247.9	354.6	460.0	176.3	419.0	351.7	500.0	707.9	230.0
Total snails counted	499	5,039	1,311	2,056	536	258	207	197	351	752
Shells/100 g sample weight	—	2,033	370	447	304	62	59	39	50	327
	No. specimens collected									
Orobophana uberta	0	376	203	325	91	55	45	40	60	109
Assiminea nitida	0	4	0	2	0	0	0	0	0	0
Lamellidea spp.	146	1,378	219	308	65	32	30	28	52	159
Tornatellides spp.	18	555	112	43	5	0	+*	1	4	9
Leptachatina cookei	0	22	18	32	3	3	0	0	7	12
L. subcylindracea	0	116	231	459	103	58	35	29	34	29
L. spp.	0	110	1	0	0	0	0	0	0	18
Amastra u. umbilicata	0	+	0	0	0	0	0	0	0	0
Lyropupa (Mirapupa) perlonga	16	490	55	15	3	2	0	3	9	48
Nesopupa litoralis	0	78	10	30	18	7	4	1	7	43
N. newcombi	0	1	0	0	0	0	0	0	0	0
N. wesleyana	0	0	0	1	0	0	0	0	0	0
Pupoidopsis hawaiiensis	0	39	2	2	1	0	0	0	0	0
Gastrocopta servilis	318	456	1	(5)**	(3)	(5)	(1)	(1)	(1)	(2)
Cookeconcha undescribed sp.?	0	181	273	586	180	69	53	59	91	190
Endodonta kalaeloana	0	103	137	236	60	32	40	34	87	132
Succinea caduca	1	781	44	12	7	0	+	1	0	2
Lamellaxis gracilis	0	349	5	4	0	0	0	0	0	0
Unidentified	0	0	0	1	0	0	0	1	0	1

* Plus sign indicates nonapical fragments of species not otherwise represented in a sample.

** Numbers in parentheses represent probable contaminants.

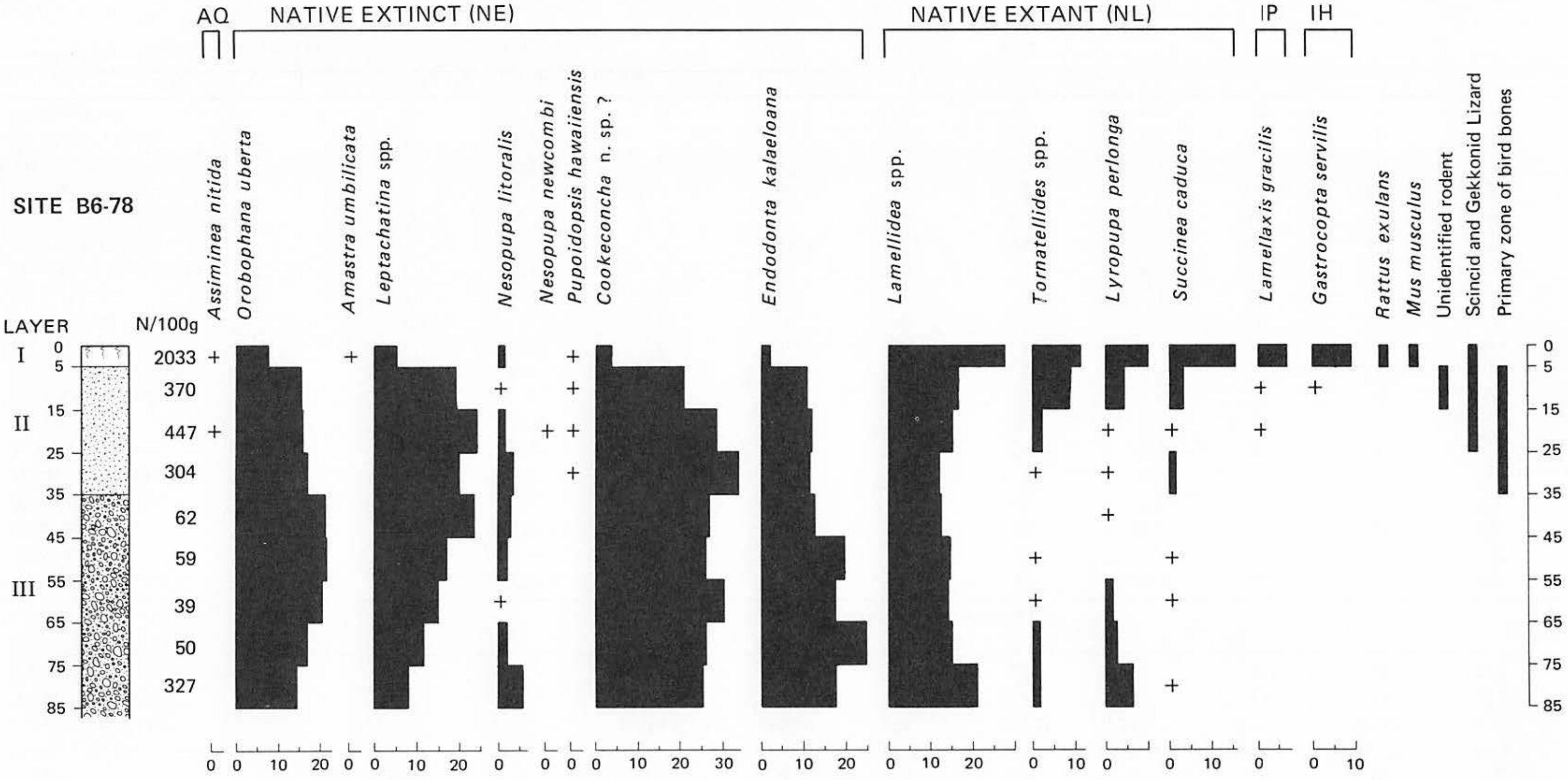

Fig. 2. Mollusk diagram for Site B6-78. Left to right: stratigraphic layer designations; depth below surface in cm; soil diagram; number of countable shells per 100 g sediment; percentage frequency histogram for nonmarine mollusk taxa (ecological groups: AQ = Aquatic; NE = Native, Extinct; NL = Native, Extant; IP = Introduced, Prehistoric; IH = Introduced, Historic; relative frequency values of less than 1% are plotted as a plus sign in the histogram); stratigraphic occurrence of vertebrate remains.

The Layer I faunal assemblage is the most divergent of the entire set, with significantly reduced quantities of the native genera *Orobophana, Leptachatina, Cookeconcha,* and *Endodonta.* Abundance of the historically introduced *Gastrocopta servilis* indicates that Layer I represents historic-period change. Vertebrate remains from this level (Sample 6) included *Mus musculus* (the House Mouse, a postcontact introduction), *Rattus exulans* (the Polynesian Rat), and scincid and gekkonid lizards (depending on the species, pre- or postcontact introductions).

Layer II (Samples 7–9) is clearly a zone of change. During the depositional span of this stratum there was a significant decrease in the abundance of *Cookeconcha* and increased abundance of *Lamellidea, Tornatellides, Lyropupa,* and *Succinea.* Most interestingly, *Lamellaxis gracilis* is present in the upper two-thirds of Layer II. This species was spread throughout the inner Pacific by prehistoric Austronesian peoples (cf. Christensen & Kirch 1981), and its presence in Layer II would suggest that humans were also active in the Barbers Point area by the time these sediments were deposited. Because Layer II is the principal zone of occurrence of avian fossils (Morgenstein 1978), including remains of extinct species, this indication of human activity is of considerable interest. Also noteworthy is the presence of remains of scincid lizards in Samples 7 and 8; additionally, remains of an unidentified rodent and of the seabird *Pterodroma phaeopygia* (Dark-rumped Petrel) were present in Sample 7. Vertebrate remains found in and below Sample 9 were not identifiable. Individuals of *Gastrocopta servilis* found at depths in excess of 15 cm below surface (Samples 8–9, 1–5) were either living or freshly dead. As the excavation had been open for some 2 years prior to our sampling, we believe these to be contaminants; they are undoubtedly recent shells that were living on the exposed face of the excavation, not true constituents of the fossil assemblage. For this reason these shells are listed in parentheses in Table 2 and are omitted from consideration in Fig. 2.

Layer III (Samples 1–5) shows a total absence of any introduced snail species (except *Gastrocopta servilis* as a contaminant, as discussed above), although there are changes in its faunal composition from top to bottom.

The extent to which the faunal sequence illustrated in Fig. 2 is graded can be tested with the use of a similarity matrix, as described above. Proportional similarity values for the B6-78 samples are plotted as a shaded matrix in Fig. 3. The grading index Q for this matrix is 123 ($Q = 0$ for a perfectly graded matrix). For a 9 × 9 matrix, as with B6-78, $Q_{max} = 546$. The Q/Q_{max} ratio for site B6-78 is thus 0.23, which indicates that the stratigraphic sequence is definitely nonrandom (Pielou 1979: fig. 3) and reasonably well graded. Examination of the shaded matrix also reveals (1) the divergence of the Layer I assemblage, and (2) a slightly higher internal clustering between samples from Layers II and III (i.e., a stepped sequence), thus supporting the interpretation of the faunal succession in terms of the observed stratigraphic units. That is, within Layer III, Sample 2 links most closely with Samples 1 and 3 (above and below it), and within Layer II, Sample 8 links most closely with Samples 9 and 1, both lower in the column.

In sum, the land snail sequence from Site B6-78 can be interpreted as a nonrandom, reasonably well-graded but stepped faunal succession. Gradual changes in Layer III may reflect local vegetational changes. More drastic change is indicated for Layer II (the zone of greatest abundance of fossil bird bones), and the possible role of humans is suggested by the presence of *Lamellaxis* and adventive vertebrates. Historic-period changes are clearly evident in Layer I.

Site 50-80-12-9670-P1

Site 9670-P1 (Site 50-80-12-2624 of Hammatt & Folk 1981) is a large sinkhole about 3 to 4 m in diam and 3 m deep. At the time of sampling for land snails, most of the deposit had been excavated for fossil bird bones by the ARCH team. The snail column was taken

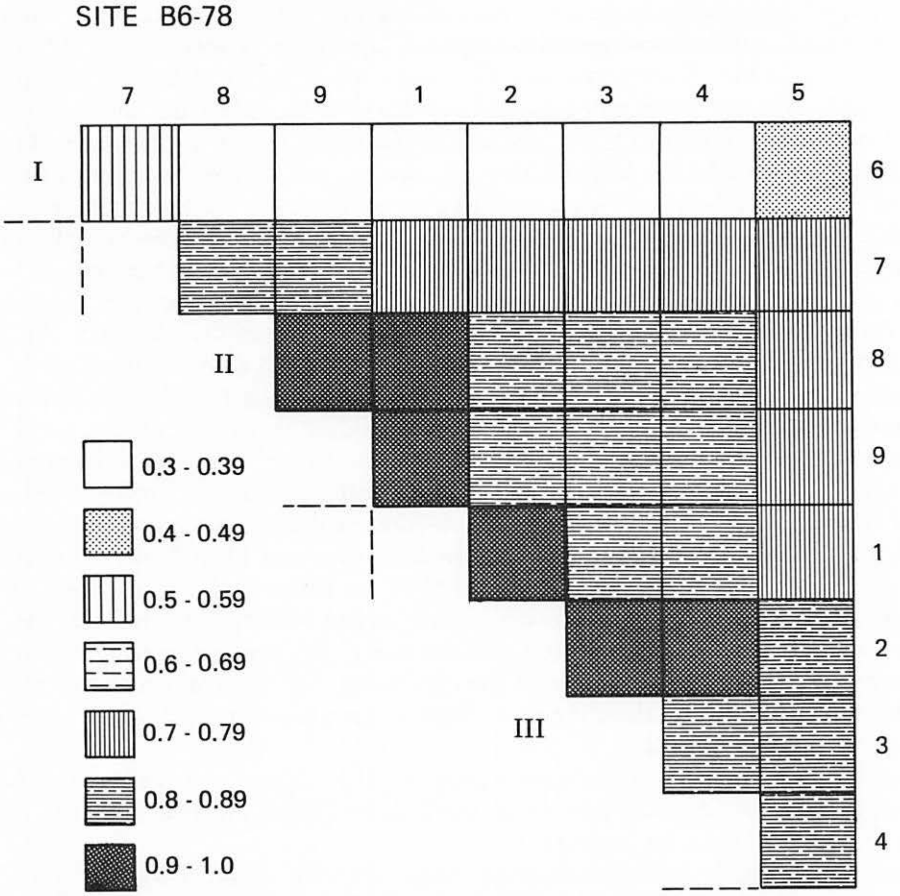

Fig. 3. Proportional similarity matrix for Site B6-78.

from an undisturbed face in the center of the sink, about 1 m from the limestone walls (adjacent to TP-4, E face). The stratigraphic profile is summarized in Table 3. Results of the snail analysis are given in Table 4 and plotted in Fig. 4. This series of samples represents a well-graded progression of faunal change. Most salient are the continual decreases in *Orobophana* and *Endodonta* and the increases in *Lamellidea, Tornatellides,* and *Succinea.* The historically introduced *Gastrocopta* increases in abundance in the upper 7 cm (the presence of 2 specimens in the 7–12-cm sample probably derives from the contact zone of Samples 2 and 3). Most significantly, the prehistorically introduced *Lamellaxis* is present in all samples, suggesting a potential human role in this sequence of faunal, and presumably vegetational, change. Vertebrate remains provide additional evidence: the Polynesian Rat

Table 3. Stratigraphic profile for Site 9670-P1.

Layer	Depth (cm)	Description
I	0–2	A_0 and A_1 horizons of organic matter and litter.
II	2–23/24	Silt-loam composed of aeolian material with fine limestone gravel. A reddish tint in the upper part of the deposit grades into a creamy color at the base.
III	23/24–27	Compacted deposit of unconsolidated limestone breccia in cream-colored silt matrix. Not sampled.

Table 4. Nonmarine mollusks recovered from Site 9670-P1.

	Sample no.					
	1	2	3	4	5	6
Layer	I	II	II	II	II	II
Depth (cm below surface)	0–2	2–7	7–12	12–17	17–22	22–23/24
Sample weight (g)	62.0	208.3	145.9	97.7	98.0	56.7
Total snails counted	373	1,599	1,758	1,559	889	260
Shells/100 g sample weight	602	768	1,205	1,596	907	459
	No. specimens collected					
Orobophana uberta	43	236	328	306	225	70
Assiminea nitida	1	1	1	1	0	2
Lamellidea spp.	68	349	339	305	147	36
Tornatellides spp.	53	346	330	291	93	15
Leptachatina cookei	0	0	8	9	3	0
L. subcylindracea	14	47	94	112	55	9
L. spp.	0	0	0	0	0	2
Lyropupa (Mirapupa) perlonga	21	60	115	87	33	12
Nesopupa litoralis	+*	10	4	16	12	2
N. newcombi	18	75	53	16	12	2
Pupoidopsis hawaiiensis	5	21	27	11	4	1
Gastrocopta servilis	46	69	2	0	0	0
Cookeconcha undescribed sp.?	18	52	85	73	64	9
Endodonta kalaeloana	52	168	297	304	216	93
Succinea caduca	20	120	63	26	22	3
Lamellaxis gracilis	14	45	10	2	3	3
Unidentified	0	0	2	0	0	1

* Plus sign indicates nonapical fragments of species not otherwise represented in a sample.

was present in Samples 2 and 3 and probably also in Samples 4 and 5 (the species of *Rattus* represented in the latter 2 samples could not be determined), and bones of lizards were also found (Gekkonidae in Samples, 1, 2, and 4, Scincidae in Samples 2–4). According to Olson & James (1982b: 27), "Bones of birds, including extinct species, occurred throughout these sediments [to a depth of 30–40 cm] but were more abundant in the upper 20 cm; extinct species were often found within the upper 5–10 cm." Those authors also remark on the co-occurrence of remains of *R. exulans* with those of extinct birds.

The interpretation of the 9670-P1 stratigraphic column as a well-graded series is borne out by matrix analysis (Fig. 5). The grading index Q for this matrix is only 3, and the Q/Q_{max} ratio of 0.04 (Q_{max} = 85) indicates a highly significant nonrandom pattern.

Site 50-80-12-2700-1

This site (Site 50-80-12-2712 of Hammatt & Folk 1981) is a late prehistoric/early historic Hawaiian habitation feature chosen for snail analysis to contrast the faunal assemblage of an open occupation site with those of the paleontological sink deposits. The main structural feature at the site was a nearly square enclosure (5 × 5 m) constructed of limestone boulders and cobbles (a plan of the site is given in Hammatt & Folk 1981: fig. 9). A cultural deposit (Layer I) up to 15 cm thick underlay the enclosure and extended out around the structure for an unspecified distance. Our snail column (taken after completion of the major excavations and dismantling of the enclosure walls) was cut from the E face of the SE quadrant of grid unit N1/E1. This point previously underlay the western wall of the enclosure and thus had been protected from historic-period land disturbance or contamination. The stratigraphic profile is summarized in Table 5. Results of the snail analysis are presented in Table

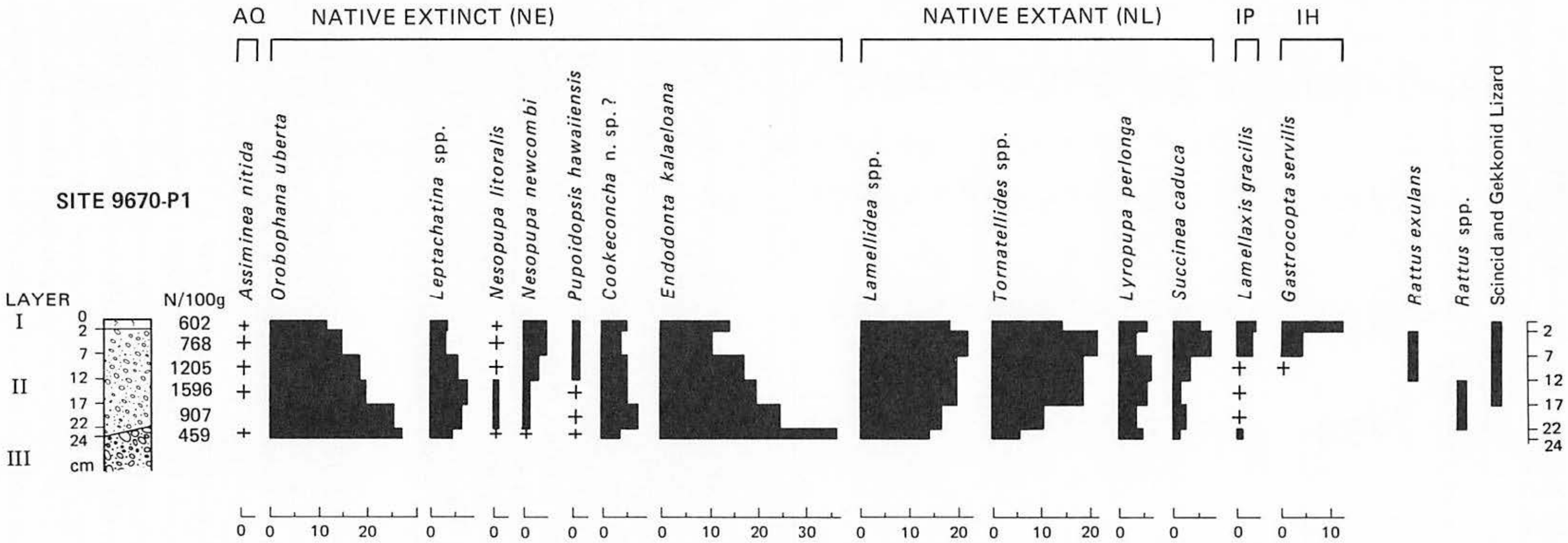

Fig. 4. Mollusk diagram for Site 9670-P1.

Table 5. Stratigraphic profile for Site 2700-1.

Layer	Depth (cm)	Description
—	0–3	A_0 horizon; organic litter.
—	3–6	A_1 horizon. Overburden of aeolian dust and organic matter. Very dark gray (5YR 3.1).
I	6–7/9	Gray to light gray (5YR 5–7/1) cultural deposit, color becoming lighter with increasing depth. Compacted, with marine shells and other midden material.
I/II	7/9–11	Irregular contact zone between layers I–II; land snails very abundant.
II	7/9–27	Culturally sterile, decomposed limestone; compacted; gravelly. Light gray (5YR 7/1).

6 and are plotted in Fig. 6. The faunal sequence indicates rather drastic changes beginning with the onset of human habitation. The Layer II assemblage correlates fairly closely with the upper part of Layer III at Site B6-78. With the beginning of habitation, there is a major decrease in *Orobophana* and *Leptachatina,* increases in *Lamellidea* and *Lyropupa,* and the significant addition of *Tornatellides* and *Succinea.* The Polynesian introduction *Lamellaxis* also appears (the presence of a few *Gastrocopta* is probably due to contamination from upper levels during sampling). Following abandonment of the habitation site, further change occurred, including continued increases in *Lamellidea* and *Tornatellides,* drastic decrease in *Orobophana,* extirpation of *Leptachatina,* and major increase in *Gastrocopta.* The influence of humans on the local ecology seems unquestionable in the present case. Interestingly, the pattern of change in this habitation site largely mirrors that in the upper portions of the 2 limestone sinks examined, where avian as well as molluscan remains were present.

Site 50-80-12-2701-1

This site (50-80-12-2723 of Hammatt & Folk 1981) is a small C-shaped shelter built of limestone slabs, with an interior floor area of ca. 4 m², on open limestone. A test pit, 50 ×

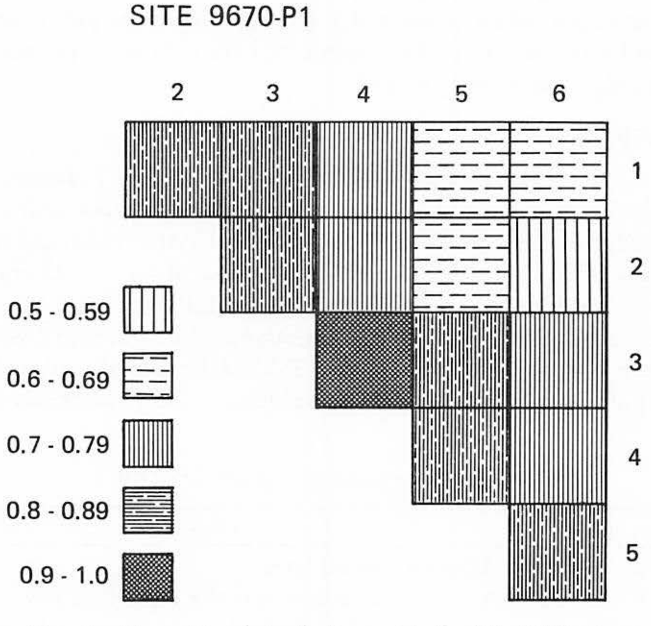

Fig. 5. Proportional similarity matrix for Site 9670-P1.

Table 6. Nonmarine mollusks recovered from site 2700-1.

	Sample no.				
	1	2	3	4	5
Layer	—	—	—	—	—
Depth (cm below surface)	0–3	3–6	6–7/9	7/9–18	18–27
Sample weight (g)	59.1	100.1	250.4	99.1	112.4
Total snails counted	227	133	318	183	33
Shells/100 g sample weight	384	133	127	185	29
	No. specimens collected				
Orobophana uberta	5	5	111	89	16
Lamellidea spp.	58	44	69	30	5
Tornatellides spp.	28	14	12	0	0
Leptachatina cookei	0	0	11	11	+*
L. subcylindracea	0	0	14	28	0
L. spp.	1	0	0	0	0
Lyropupa (Mirapupa) o. ovatula	0	0	1	3	1
L. (M.) perlonga	+	1	40	4	1
Nesopupa litoralis	+	+	6	1	3
Gastrocopta servilis	119	59	3	0	0
Cookeconcha undescribed sp.?	0	0	2	2	0
Endodonta kalaeloana	+	+	19	13	7
Succinea caduca	16	10	28	0	0
Lamellaxis gracilis	0	+	1	0	0
Unidentified	0	0	1	2	0

* Plus sign indicates nonapical fragments of species not otherwise represented in a sample.

50 cm, had been excavated by the ARCH team, exposing a thin cultural deposit with limited quantities of shellfish and bone midden. The stratigraphic column is summarized in Table 7. Results of snail analysis are reported in Table 8 and plotted in Fig. 7. The sequence of faunal change closely parallels that described for Site 2700-1. We doubt, however, that *Gastrocopta servilis* was actually associated with the prehistoric cultural layer, as the shallow and loose nature of the sediments here may have permitted some downwashing of empty shells or mixing of soil.

Site 50-80-12-2701-3

The final site chosen for snail analysis (Site 50-80-12-2725 of Hammatt & Folk 1981) is a small sinkhole 3 m in diam and 0.5 to 0.75 m deep, with a low wall of limestone slabs built up on the E edge of the sink. Davis (pers. comm., 13 Apr. 1984) believes this structure to have been a pit garden. The ARCH team had excavated a 25 × 25-cm test pit into the floor of the sink and had judged the feature to be culturally sterile. A column of 3 samples was taken for comparison with the deep sinks containing bird bones and with the habitation sites. The stratigraphic profile is summarized in Table 9. Results of snail analysis are reported in Table 10 and plotted in Fig. 8. This faunal sequence differs markedly from those from

Table 7. Stratigraphic profile for Site 2701-1.

Layer	Depth (cm)	Description
—	0–3	A_0 horizon; organic litter.
—	3–8	A_1 horizon and zone of cultural material; light gray.
—	8–13/20	Decomposed limestone distributed in pockets in the limestone bedrock.

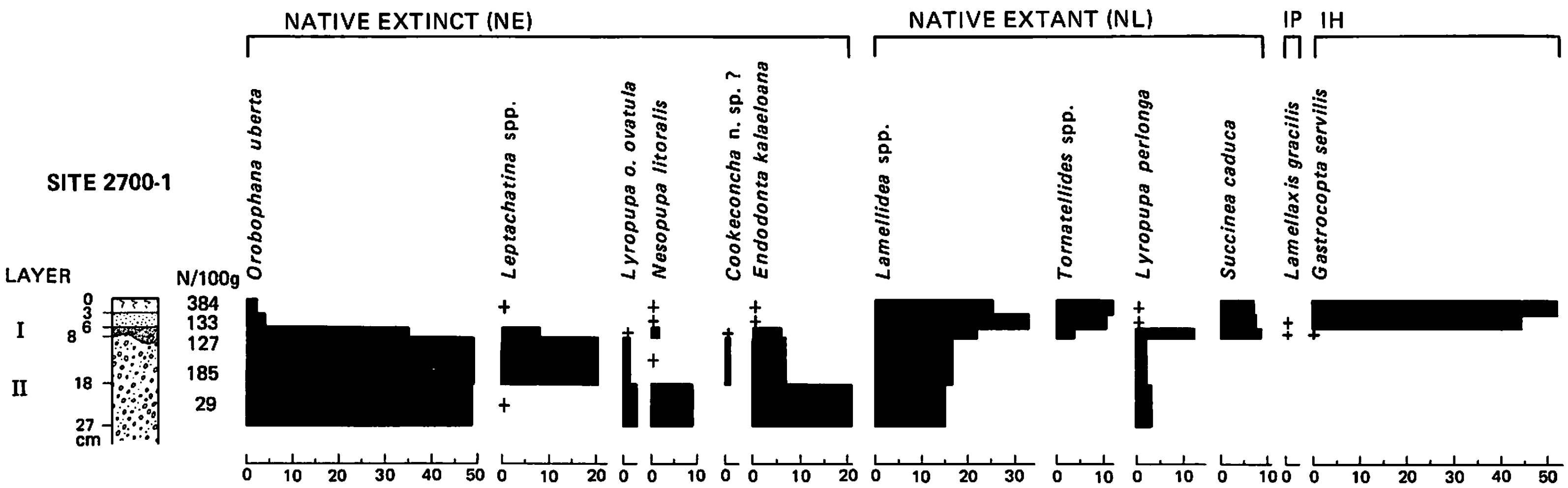

Fig. 6. Mollusk diagram for Site 2700-1.

Table 8. Nonmarine mollusks recovered from Site 2701-1.

	Sample no.		
	1	2	3
Layer	—	—	—
Depth (cm below surface)	0–3	3–8	8–13/20
Sample weight (g)	44.2	120.2	64.5
Total shells counted	164	605	112
Shells/100 g sample weight	371	503	174
	No. specimens collected		
Orobophana uberta	1	+*	12
Assiminea nitida	0	3	1
Lamellidea spp.	28	198	27
Tornatellides spp.	33	245	19
Leptachatina cookei	0	0	5
L. subcylindracea	0	0	4
L. spp.	0	+	0
Lyropupa (Mirapupa) perlonga	+	19	19
Nesopupa litoralis	0	+	+
Gastrocopta servilis	83	84	5
Succinea spp.	16	55	20
Unidentified	3	1	0

* Plus sign indicates nonapical fragments of species not otherwise represented in a sample.

all other sites, as 89–98% of each sample consisted of shells of *Assiminea nitida,* an aquatic or amphibious snail normally associated with brackish water environments. Kirch & Christensen (1980) hypothesized that the unusual abundance of this species was the result of transport of mud from a nearby brackish pond to improve soil quality for agriculture. Subsequent investigations in the area (Christensen et al., in prep.) suggest, however, that this sink may formerly have been an anchialine pool; in some nearby shallow sinks the top of the water table lies a short distance below the modern ground surface, while other sinks are permanently or intermittently flooded by brackish water under tidal influence (Davis & Griffin 1978; Miura & Sato 1978). The 2701-3 sinkhole was not observed to be subject to such flooding; however, prior to infilling by sediment, or under conditions of a slightly higher water table, this site may well have provided an environment suitable for *Assiminea.*

DISCUSSION

Having reviewed the specific results from each of the 5 sites studied, we now turn to a discussion of certain wider implications. Of particular concern are (1) temporal correlations between the stratigraphic columns; (2) the implications for patterns of ecological change in the Barbers Point area; and (3) the possible role of both prehistoric and historic man in initiating or hastening ecological change in the region.

Table 9. Stratigraphic profile for Site 2701-3.

Layer	Depth (cm)	Description
—	0–10	A_0 and A_1 horizons. Gravelly soil with charcoal flecks. Very dark gray.
—	10–16/17	Compacted, transitional zone from dark organic layer into decomposed limestone floor of sink.

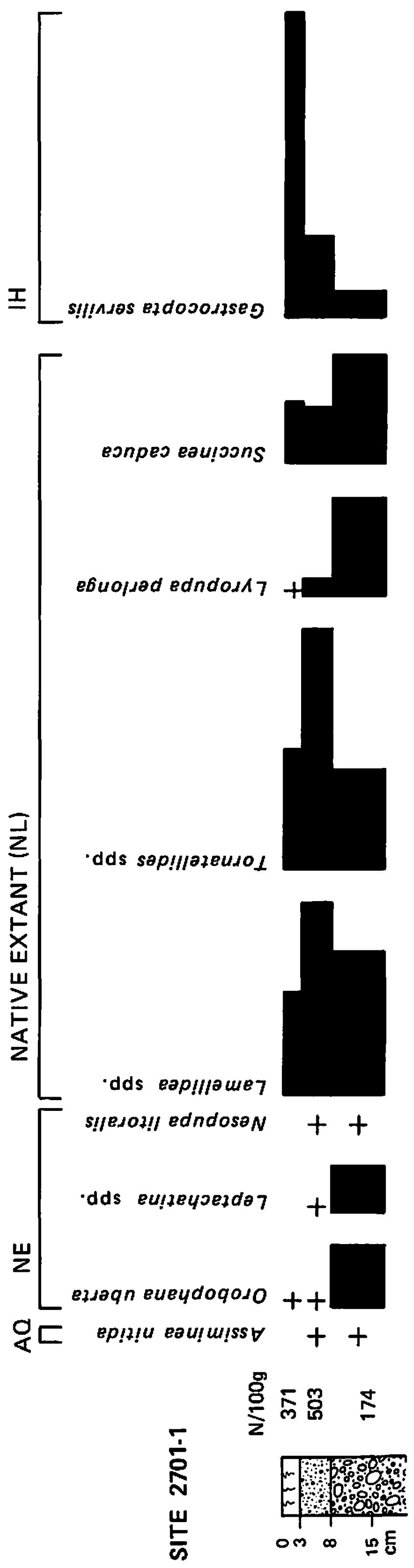

Fig. 7. Mollusk diagram for Site 2701-1.

Table 10. Nonmarine mollusks recovered from Site 2701-3.

	Sample no.		
	1	2	3
Layer	—	—	—
Depth (cm below surface)	0–5	5–10	10–16/17
Sample weight (g)	168.1	159.5	100.3
Total shells counted	365	893	1,180
Shells/100 g sample weight	217	560	1,176
	No. specimens collected		
Orobophana uberta	3	9	5
Assiminea nitida	321	818	1,162
Lamellidea spp.	6	21	8
Tornatellides spp.	22	26	3
Leptachatina cookei	0	1	0
L. subcylindracea	2	4	0
L. spp.	0	0	+*
Lyropupa (Mirapupa) perlonga	1	4	0
Nesopupa litoralis	+	+	+
Endodonta kalaeloana	+	+	0
Gastrocopta servilis	4	2	0
Succinea caduca	2	8	2
Unidentified	4	0	0

* Plus sign indicates nonapical fragments of species not otherwise represented in a sample.

Intersite correlations

Although there are differences in the stratigraphic columns of the sites studied, the overall pattern of faunal change is remarkably consistent and thus allows us to propose tentative temporal correlations between columns. Major time markers include (1) the onset of decreases in the relative abundance of *Orobophana, Leptachatina, Cookeconcha,* and *Endodonta,* and of corresponding increases in the abundance of *Lamellidea, Tornatellides, Lyropupa perlonga,* and *Succinea*; (2) the appearance of taxa known or believed to have been introduced prehistorically (the snail *Lamellaxis gracilis,* certain gekkonid and scincid lizards, and *Rattus exulans,* the Polynesian Rat); and (3) the appearance of historically introduced taxa (the land snail *Gastrocopta servilis,* the House Mouse *Mus musculus,* and species of *Rattus* other than *R. exulans*).

Figure 9 illustrates our proposed correlations between the stratigraphic columns, based solely upon evidence from our analysis of land snails and associated vertebrate remains [no radiometric or other "absolute" dates were obtained by Hammatt & Folk (1981) for sites examined by us]. Site B6-78 provides the longest stratigraphic sequence and is thus of critical importance in assessing long-term ecological change at Barbers Point. The column at Site 9670-P1 appears to correlate with the upper portion of the B6-78 sequence. The 2 habitation sites may span a lengthy time period, as suggested in the diagram, but their stratigraphic sections are greatly compressed and are less amenable to detailed interpretation than are the 2 sinkhole sequences.

Based upon the presence or absence of introduced taxa and the relative abundance of extinct and extant native taxa, it is possible to suggest that the temporal sequence shown in Fig. 9 spans 3 major time periods: (1) a period prior to the advent of human impact; (2) a period of prehistoric Polynesian use and/or occupation of the area; and (3) the recent historic period. Highly significant is the co-occurrence of prehistorically introduced mollusk

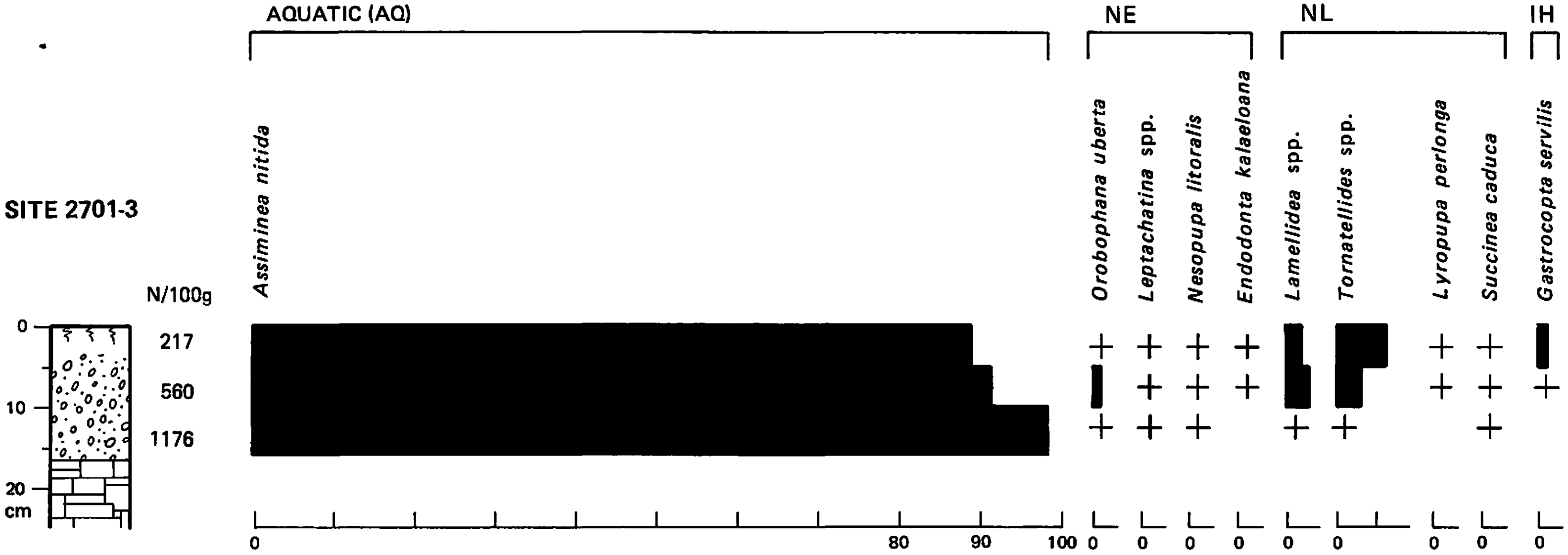

Fig. 8. Mollusk diagram for Site 2701-3.

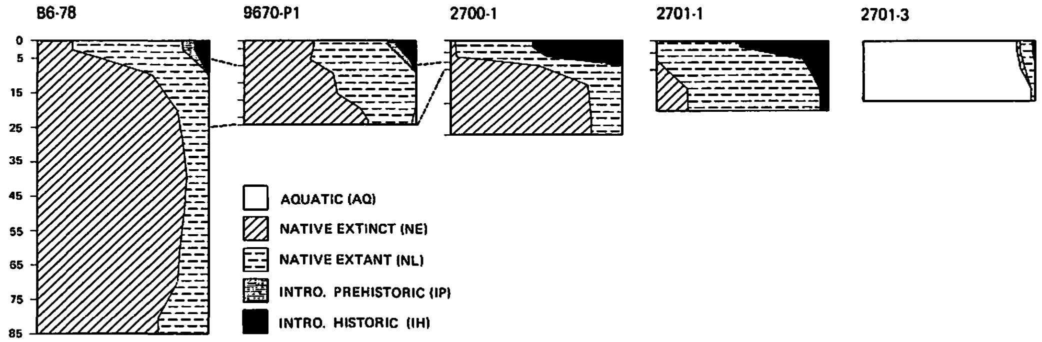

Fig. 9. Relative abundance of nonmarine mollusks by ecological group, including tentative stratigraphic correlations between Sites B6-78, 9670-P1, and 2700-1.

and vertebrate taxa and locally or universally extinct avian taxa, a finding that suggests that Polynesian man was present at the time when these avian remains were deposited and may indeed have played a role in the extinction of these birds. We stress that these tentative correlations are based solely on the stratigraphic evidence presented above, and have not been confirmed by results of radiometric analysis or other absolute dating techniques. While the consistent faunal succession revealed by our analysis gives us confidence in our proposed correlations, a program of careful excavation and precise stratigraphic control combined with quantitative faunal analysis and extensive dating would be required to more clearly determine the chronology of extinction and the extent of prehistoric or modern man's involvement.

Patterns of ecological change

The median annual rainfall recorded at stations in the Barbers Point region is generally 50 cm (20 in.) or less. Most rain falls in the winter months, and in most years the median monthly rainfall is 1.25 cm (0.5 in.) or less from May to September; months without rain may occur at virtually any time during the year (Taliaferro 1959). These conditions suggest the former presence of a native dry-land vegetation community. Char & Balakrishnan (1979) surveyed the modern vegetation of the ʻEwa Plain and offered an interpretation of the presumed original (prehuman) vegetation of the region, based upon analysis of relict native plants and other evidence; a portion of their remarks is quoted here:

> Inland, the vegetation on the coralline plains may have consisted of an open savannah with scattered trees of *Erythrina sandwichensis* (wiliwili) and *Sapindus oahuensis* (aulu). *Santalum ellipticum* (ʻili-ahi-a-loʻe), *S. freycinetianum* (iʻili-ahi) and *Myoporum* probably occurred as small trees in the more sheltered areas, or as large shrubs. Smaller shrubs such as *Abutilon incanum* (koʻoloa), *Gossypium sandwichense* (maʻo), the two varieties of *Euphorbia skottsbergii* (ʻakoko), *Achyranthes, Capparis sandwichiana* (maiapilo), *Sida* spp. and *Plumbago zeylanica* (ʻilieʻe) could occasionally have formed thickets between the trees. Such grasses as *Eragrostis paupera, Panicum torrida* (kakonakona), perhaps several other native *Panicum* spp., and probably *Heteropogon contortus* (pili) would occur in the herb layer. Vines such as *Sicyos microcarpus* (kupala), *Cocculus ferrandianus* (huehue), *Ipomea congesta* (koali-aʻawania), *Cassytha filiformis* (kauna-ʻoa pehu) and probably a few species of *Canavalia* (ʻawikiwiki) probably were climbing over the shrubs and trees. In areas with a thin layer of alluvium and that were subject to occasional flooding during the rainy season there would be patches of the fern *Marsilea villosa* and perhaps *Ophioglossum concinnum* (pololei). The ravines and gulches farther inland probably would have supported

> a number of larger trees and much more vegetation as they are wetter. (Char & Balakrishnan 1979: 60)

Paleoecological interpretation based upon the occurrence of land snails in the earliest levels of the Barbers Point excavations (i.e., those presumed to antedate human impact in the region) is hindered by our incomplete knowledge of the ecological requirements of the various species present. Several of the species common in these early levels are now extinct, making direct observation of their habitat preferences impossible. Data on other species are often incomplete. Malacological studies of Hawaiian terrestrial mollusks have focused almost exclusively upon taxonomy, while the ecology of these snails has received only passing consideration. In general, however, those inferences that can be drawn are consistent with the paleobotanical conclusions of Char & Balakrishnan. Of particular importance is the fact that snails characteristic of moist forest conditions are absent from the fossil assemblages studied here. Such taxa as *Achatinella, Auriculella, Amastra* (excluding the xerophilous subgenus *Cyclamastra*), *Laminella,* sinistral *Lyropupa,* low-spired Succineidae (principally the genus *Catinella*), and *Philonesia* are absent or virtually so,[3] although all of these occur (or formerly occurred) in forested locations in the nearby Waianae Mountains. Several of these (*Achatinella, Catinella,* and *Philonesia*) are abundantly represented in coastal deposits in windward O'ahu, where they presumably indicate that moist forest conditions formerly extended to considerably lower elevations than at present (cf. Perkins 1913: xxxvi–xxxvii).

In contrast, the assemblage of native land snail species present in the Barbers Point sites is indicative of a relatively arid environment and, to the extent that the limited ecological data available can be used to infer vegetation associations, is consistent with the inference by Char & Balakrishnan (1979) of the former presence of a plant community characterized by native grasses, shrubs, and sparse, open-canopy dry-forest tree species. *Leptachatina cookei, L. subcylindracea, Amastra u. umbilicata,* and *Nesopupa litoralis* are universally extinct, and their ecological preferences are therefore not directly observable, although their occurrence only in low-elevation fossil deposits, including those of the dry leeward coast of O'ahu, indicates a preference for arid conditions. *Cookeconcha* undescribed sp.? and *Endodonta kalaeloana* are likewise extinct, but closely related living species found at low elevations are recorded only from grasses in arid locations. *Pupoidopsis hawaiiensis* was probably restricted to grasses and strand vegetation. The species is now extinct in Hawai'i but inhabits clumps of bunchgrass (*Lepturus* sp.) on Christmas Island (Cooke & Neal 1928) and occurs in strand vegetation in the Tuamotus (BPBM collection). *Orobophana* has been collected on dead leaves and twigs (Neal 1934), but additional data are lacking.

Nesopupa newcombi and *N. wesleyana* are extinct in the Barbers Point region but probably persist elsewhere on O'ahu; *Tornatellides* is represented in the modern Barbers Point fauna by 1 or possibly 2 species, and *Lamellidea* now inhabits the region. All of these are tolerant of a broad range of environments, but their presence is consistent with the postulated arid, grassland–parkland conditions.

In later stratigraphic levels, individuals of now-extinct taxa are reduced in numbers; land snail assemblages at these depths are dominated by native taxa tolerant of disturbed conditions (as evidenced by their presence in the modern fauna of the area), such as *Lamellidea, Tornatellides, Lyropupa (Mirapupa) perlonga,* and *Succinea caduca.* The first 2 of these frequently inhabit areas of disturbed vegetation (Cooke & Kondo 1960). Species of *Lyropupa (Mirapupa)* are tolerant of very arid conditions, and Pilsbry & Cooke (1918–1920: 259) remarked, "In

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[3] Christensen (in prep.) has recovered shell fragments of *Achatinella mustelina* Mighels, 1845, a single immature shell of a sinistral *Lyropupa,* and a few specimens of *Amastra (Metamastra)* sp. from recently excavated sites at Barbers Point.

every case where the junior author found living examples they were taken in open country under dead sticks and stones." *Succinea caduca* is also highly tolerant of aridity and environmental disturbance. We hypothesize that this change in the land snail assemblage reflects a reduction in vegetative cover and a concomitant decrease in availability of moisture resulting from human-induced environmental modification.

In the upper levels exotic snails also appear, becoming dominant in the topmost levels. This transition from a fauna exclusively of native taxa, many of them now extinct in the Barbers Point area, to a fauna in which exotic forms predominate or are at least prominent, may be recognized in all but 1 of the sites studied (*Assiminea nitida,* an aquatic snail, is dominant in the highly aberrant Site 2701-3 assemblage). In the absence of chronometric data indicating the contemporaneity of this transition with the advent of human occupation, it can be argued that it is perhaps premature to conclude with certainty that the Polynesians were responsible (through forest clearance and agriculture) for the extinction of much of the native land snail fauna (and avifauna?). We believe, however, that such data, when available, will be consistent with that conclusion.

In sum, the overall patterns of ecological change suggested by land snail analysis are of (1) an original grassland–parkland vegetation, giving way to (2) decreased vegetative cover and resultant decrease in the availability of moisture, probably due to prehistoric Polynesian interference, and finally (3) a drastic change in local flora and fauna in historic times.

CONCLUSIONS

Stratigraphic analyses of land snail assemblages from both paleontological and cultural sites at Barbers Point demonstrate a consistent pattern of faunal succession. The sequence begins with a snail fauna containing a full range of endemic taxa, proceeds through a phase of marked decrease in certain native taxa that do not now inhabit the site and of increase in more resilient extant native taxa, and ends with a modern assemblage characterized by the presence of abundant non-native synanthropic species. It is significant that the phase of major change in the mollusk fauna corresponds, in the sinkhole sites, with the zone of heaviest concentration of bones of extinct or locally extirpated birds. This zone unquestionably represents a period of local environmental change, and it is furthermore highly likely that the extirpation of the Barbers Point avifauna was directly related to this ecological disturbance and change.

The occurrence of shells of the synanthropic land snail *Lamellaxis gracilis* and bones of rats and gekkonid and scincid lizards in the same stratigraphic zone with the fossil bird bones provided the first direct evidence that the extinct Barbers Point avifauna persisted into the period of human occupation of the island. All of these synanthropic species are known to have been transported by early Pacific island peoples (Stejneger 1899; Tate 1951; Christensen & Kirch 1981; Christensen 1984). Thus Polynesians were clearly present in the leeward O'ahu region at the time that the Barbers Point area was undergoing the phase of major environmental change revealed in the sinkhole deposits.

The further implication of this demonstrated contemporaneity of Polynesian occupation and local environmental change is, of course, the attribution of causality on the part of the human population. The role of Oceanic peoples in the modification of island ecosystems has been increasingly demonstrated in recent archaeological studies (Kirch 1982a,b, 1984). In our view, the Barbers Point evidence offers clear support for the hypothesis of substantial anthropogenic modification of lowland Hawaiian ecosystems in the centuries following initial Polynesian colonization of the archipelago. Such human-induced modification of local biota and landscapes was effected by both direct and indirect processes, including the transport and introduction of exotic animal and plant species (such as *Lamellaxis, Rattus exulans,* and gekkonid and scincid lizards), hunting and collecting of native fauna and flora for subsistence and other uses, forest clearance for agriculture and settlement, repeated firing of vegetation, initiation of local erosion, and other processes. At Barbers Point, the archaeological evidence to date (Davis et al., in prep.) suggests that long-term human settlement did not occur until after about A.D. 1200 and was not substantial until perhaps the 16th or 17th centuries. We know from a variety of other sites on O'ahu, however, that Polynesians were established on the island by the 5th century, and that expansion into leeward regions was well underway by A.D. 1000 (Kirch 1985). Thus, it is likely that the Barbers Point area and the 'Ewa Plain in general began to be subjected to human activities and ecological modification by the 11th century, even prior to the local establishment of permanent settlement.

Despite the demonstration of a significant faunal succession and of its co-occurrence with human occupation, the attribution of causality for ecological change (including avifaunal and other extinctions) to the Polynesians remains a hypothesis that, while highly plausible, requires additional research. The discovery of a fantastically rich former avifauna in the Hawaiian Islands and of massive avian extinctions has generated worldwide interest (Olson & James 1982a,b, 1984; Boag 1983; James & Olson 1983). Demonstration that extinct animal species co-occurred with prehistoric Hawaiians, while extremely important in itself, does not *prove* that prehistoric Hawaiian activities were the cause of extinction, even though this is a highly probable and favored hypothesis. Alternative hypotheses, particularly those of naturally occurring extinction owing to climatic change and of anthropogenic extinction occurring primarily since the arrival of Europeans, must also be addressed. Unfortunately, few reports of the sort needed to resolve the matter (quantitative faunal analysis coupled with precise stratigraphic and, ideally, chronological control) have yet been published for paleontological or archaeological sites in the Hawaiian Islands.

In New Zealand, where prehistoric extinctions of moas and other birds provide a situation analogous to the Hawaiian case, the controversy regarding climatic change vs. prehistoric human impact as a cause of recent extinctions has apparently been resolved in favor of the latter explanation (Anderson 1984; Trotter & McCulloch 1984). In Hawai'i, Olson & James (1982b) noted that there is little to support the hypothesis that these are natural extinctions resulting from climatic change. While naturally occurring climatic fluctuations have undoubtedly taken place since initial human settlement of the Hawaiian Islands, there is no evidence to suggest that such fluctuations were more extreme than those to which the Hawaiian biota was subjected during the Pleistocene.

Less easily dismissed is the contention that extinctions in Hawai'i have been primarily a result of Western influence in the period since Cook's expedition of 1778–1779. Until recent paleontological and archaeological findings demonstrated the true diversity of the original Hawaiian avifauna, the dominant view of extinctions was that these were almost exclusively a feature of the modern era, the Hawaiians having had little impact on the biota (see discussion in Kirch 1982a). Although this interpretation still has adherents, we believe it is highly unlikely that such conspicuous animals as flightless geese and ibises could have persisted into the historic period without leaving evidence in the form of specimens or ethnological references. Similarly, the great seabird colonies formerly present at Barbers Point must have been extirpated prehistorically. The status of some other members of the Hawaiian avifauna is less certain. As Olson & James (1982b, 1984) point out, it is possible that several of the extinct species represented in fossil deposits at Barbers Point and elsewhere may have persisted into the historic period. In an analysis of ornithological observations by members of Cook's expedition, Medway (1981: 107, 109–10) cites reports of a brown hawk observed on Kaua'i and of a large, whitish pigeon and a dark-green dove seen on Hawai'i Island. Doubts have been expressed about the accuracy of one of these reports [the "whitish pigeon" may actually have been the White Tern, *Gygis alba* (Medway 1981: 109)], and none of them have been confirmed by other historical accounts or by recent fossil discoveries. Nevertheless, these observations may record island populations that became extinct during the period between A.D. 1778 and the initiation of serious ornithological collecting in the Hawaiian Islands in the later 19th century. This was clearly a time of extensive ecological disturbance, and it would be surprising if some avian species did not die out during this period without having attracted the attention of naturalists; extinction and reduction in range are known to have occurred at this time in O'ahu tree snails of the genus *Achatinella* (Hadfield 1986). Nonetheless, we consider the older view that the prehistoric Hawaiians had only a minimal impact on lowland habitats of the archipelago to be without foundation and in conflict with a wealth of recent archaeological, geomorphological, and paleoenvironmental data. We believe that human interaction with the native plants and animals of Hawai'i, with the resulting extinction of many elements of the native biota, is a process characteristic of both the prehistoric and historic periods, and we anticipate that study of the ecological consequences of human activities in these islands will be of continuing interest to both anthropologists and biologists; we hope that recent discoveries in this area will usher in a period of intense cooperative effort between students of these and other disciplines to elucidate the nature and chronology of this complex interaction.

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Redescription of *Stenopus devaneyi* and *Stenopus earlei* from the Indo-West Pacific Region (Decapoda: Stenopodidae)

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ABSTRACT

Preliminary diagnoses and color plates of 2 new species of *Stenopus* Latreille from the Indo-West Pacific region were presented by Goy & Randall (1984). Detailed redescription of the holotypes and morphological variations in the paratypes are presented. Specimens of *Stenopus devaneyi* Goy & Randall, 1984, were collected from the Marquesas Is and Sri Lanka and specimens of *Stenopus earlei* Goy & Randall, 1984, were collected from the Hawaiian Is and Grand Comoro I. These species are easily distinguished by differences in morphology and color pattern. A key to the 6 described species of *Stenopus* from the Indo-West Pacific is included.

INTRODUCTION

Collections over several years in the Indo-West Pacific region have yielded numerous interesting specimens of new stenopodidean shrimps from deep and shallow water habitats. For the shallow water species in the family Stenopodidae, color pattern is an invaluable diagnostic field tool. Color patterns are highly consistent throughout the range of a given species; however, the shade and intensity of color may vary from locality to locality. The discovery of 2 new species in the genus *Stenopus* Latreille from the Indo-West Pacific region was facilitated by their distinctive color patterns. Preliminary diagnoses and color plates of these 2 new species were presented by Goy & Randall (1984). The present paper provides detailed redescriptions of the holotypes and morphological variations in the paratypes.

Specimens of *Stenopus devaneyi* Goy & Randall, 1984, have been collected from the Marquesas Is and Sri Lanka. Specimens of *Stenopus earlei* Goy & Randall, 1984, have been collected from the Hawaiian Is and Grand Comoro I in the Indian Ocean. The 2 species are closely related to *S. tenuirostris* DeMan, 1888, and *S. scutellatus* Rankin, 1898, respectively, but both are easily distinguished by numerous morphological differences as well as striking differences in coloration. A key to the 6 described species of *Stenopus* from the Indo-West Pacific is included below. Specimens treated herein are deposited in the Bernice P. Bishop Museum (BPBM), Honolulu, Hawai'i, the California Academy of Sciences (CAS), San Francisco, California, and the Senckenberg Museum (SMF), Frankfurt, West Germany. All redescribed material recorded below is from the type series.

SYSTEMATICS

Stenopus devaneyi Goy & Randall, 1984: 117. Fig. 1–4

Diagnosis. Small stenopodid shrimp, body subcylindrical, densely covered with spinous processes; last 3 pairs of pereiopods more robust than in other members of the genus;

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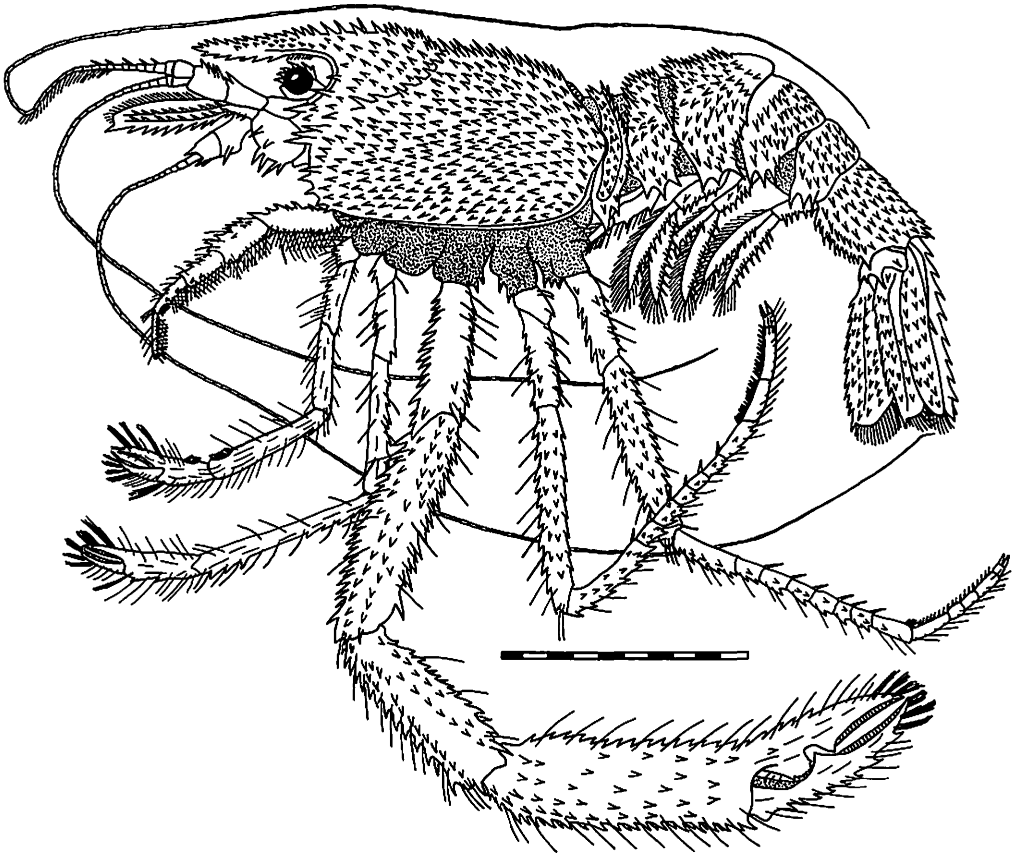


Fig. 1. *Stenopus devaneyi*, holotype, ♂. Increments of scale in mm.

distoventral extremity of 4th and 5th pereiopod carpi with 2–6 acute movable spinules; uropodal exopodite with dorsal bifurcated median ridge; body generally whitish with bilobed bright red spot on sides of abdomen.

Description. Holotype (♂, BPBM S8045). Rostrum (Fig. 1) broad at base, tapering and compressed anteriorly; extending slightly past end of last antennular peduncle segment; dorsal margin with 13 spines, distal spine not reaching tip. Ventral margin with 6 spines in distal ½, numerous proximal setae. Lateral margins with row of 6 spines in proximal ½, directed obliquely upwards and forward; carinae fairly developed.

Carapace (Fig. 1, 2A) densely covered with spinules not noticeably elongated and not in distinct longitudinal rows. Cervical groove distinct with 9 spines. Orbit without supraorbital spine; inferior orbital angle bearing small anterior and larger posterior spines. Large antennal spine present; small hepatic spine at lower end of cervical groove. Branchiostegal spine preceded posterodorsally by 2 spines of equal length, followed by large spine slightly overlapping anterior edge of pterygostomial region and 4 smaller pterygostomial spines. Ventrolateral angle somewhat rounded, only slightly produced anteriorly while posterolateral angle of branchiostegite straight.

First 3 abdominal somites (Fig. 1, 2B) with forwardly directed spinules similar to those on carapace. Spinous region of 1st abdominal somite dorsally and laterally about ⅓ breadth of same region of 2nd somite. Pleura of 1st somite ending in 1 strong, 1 weak obliquely

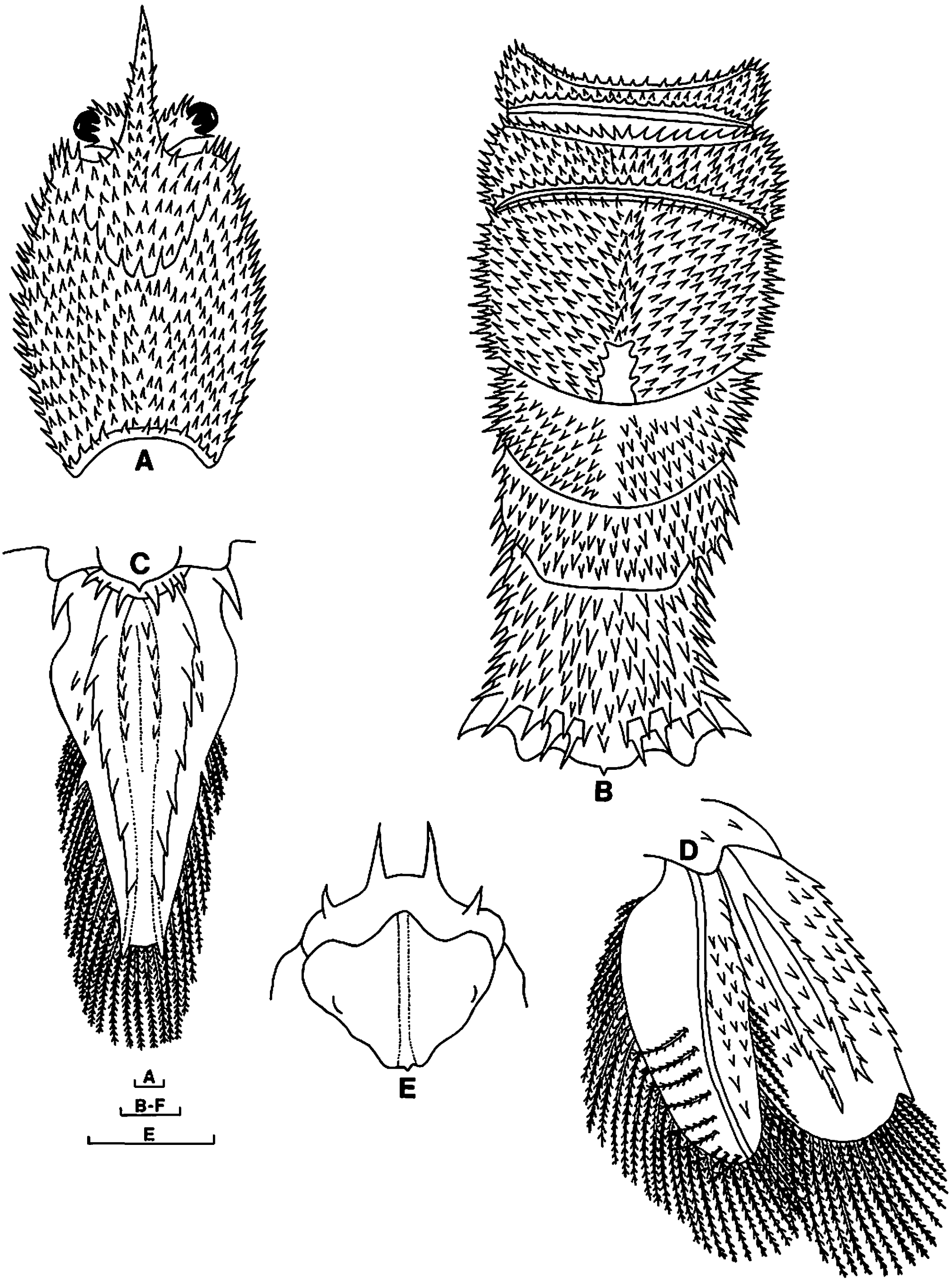


Fig. 2. *Stenopus devaneyi*, holotype, ♂: **A**, carapace, dorsal view; **B**, abdominal somites, dorsal view; **C**, telson; **D**, uropods; **E**, epistome and labrum, ventral view. Scale bars represent 1.0 mm.

directed posterior tooth; pleura of 2nd to 5th somites truncate, each ventrolateral margin with 3 equal teeth. Third somite broadly produced, posterior medial edge, without spines near entire edge; spines on this somite more or less laterally directed. Fourth somite with large area of anterior and medial regions lacking spinules. Last 3 somites with distolateral

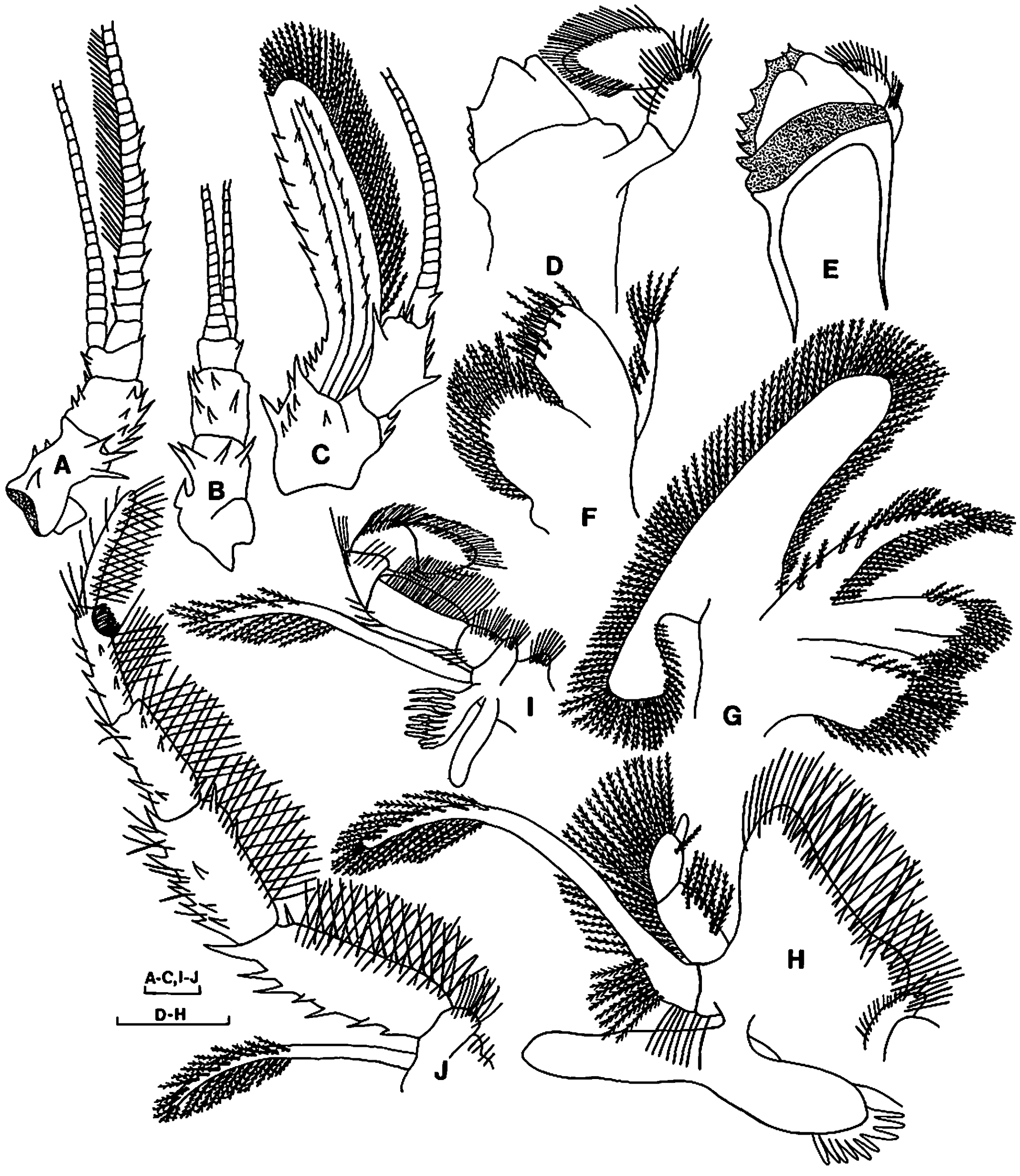


Fig. 3. *Stenopus devaneyi*, holotype, ♂: **A**, right antennule and antennular peduncle, ventrolateral view; **B**, left antennular peduncle, dorsal view; **C**, antenna and scaphocerite, dorsal view; **D**, right mandible, ventral view; **E**, same, dorsal view; **F**, maxillule; **G**, maxilla; **H**, 1st maxilliped; **I**, 2nd maxilliped; **J**, 3rd maxilliped. Scale bars represent 1.0 mm.

spinules depressed and posterolaterally directed, arranged in somewhat transverse rows. Each abdominal somite except 6th bearing strong ventral median spine; that of 1st, 4th, and 5th somites posteriorly directed, latter somite flanked by a shorter spine on each side, that of 2nd and 3rd somites anteriorly directed; ventral surface of 6th somite also densely covered with short spinules.

Eyes well developed, with peduncle slightly longer than cornea. Ophthalmic peduncle dorsomedially with 3 short spinules and anteromedially with 2 longer spinules; 5 spinules extending over cornea, 3 dorsally and 2 anterolaterally; proximodorsal side with 2 short spinules extending over cornea.

Telson (Fig. 2C) somewhat lanceolate, with median groove flanked by 2 distinct longitudinal carinae. Carinae with 8 strong, posteriorly directed spines, last spine overlapping rounded posterior telsonal margin. Base of telson with 4 pairs of spaced spines, lateral pair most strongly developed, middle pair weakest. Between each carinae and median groove, row of 6 small spinules; 2 or 3 spinules outside each carinae in anterior ½. Lateral margins with strong spine about midway, provided with plumose setae along posterior ⅔.

Uropods (Fig. 2D) well developed with endopodite not exceeding telsonal tip and slightly narrower and shorter than exopodite. Basal segment with 5 or 6 ventral spinules, 2 dorsomesial spinules. Exopodite bearing 10–11 acute teeth on outer margin, with distinct gap between penultimate and ultimate teeth. Dorsal surface bearing anterior median ridge that bifurcates longitudinally at about proximal ¼ of its length, creating median groove. Two distinct rows of 5–6 and 9–10 spinules outside external longitudinal ridge; ridge bears 8–9 outer, 1–3 inner spinules. Three spinules midway on median groove; internal longitudinal ridge bears 3–4 inner, 4–5 outer spinules; 2 rows of 5–6 and 2–3 spinules outside internal ridge. Ventral surface with distinct longitudinal row of 13 spinules on outer portion, 23–24 spinules dispersed on inner portion. Outer proximal margin of endopodite bearing 5 teeth. Dorsal surface bearing distinct median ridge with 3 rows of 5–7 outer spinules, inner row of 9 plumose setae. Ventral surface without spinules. Unarmed margins of exopodites, endopodites with long plumose setae.

Epistome (Fig. 2E) triangular anteriorly with 2 stout submedian spines next to slightly rounded median area. Two smaller spines present laterally; labrum normally developed. Paragnath moderately bilobed, lobes separated by small median fissure, bordered by short setae. Thoracic sternites narrow with 2 submedian spinules on segments 4–6, 8 submedian spinules on segments 7–8.

Antennular peduncle (Fig. 3A,B) short, extending to less than ½ of scaphocerite. Basal, middle segments nearly same length, distal segment considerably shorter. Basal segment about 2× as long as wide with short rectangular process on inner proximodorsal margin; small, acute stylocerite on outer margin; outer distodorsal angle with scale bearing 3 spines, dorsomedially 2 small spines; interior ventral angle with 2 strong spines. Middle segment with 5 spines on ventral margin, 3 dorsal submesially, 5 large spines extending out dorsally. Distal segment with very weak ventral and strong dorsal spines. Upper flagellum well developed with proximal part bearing 39 aesthetascs beginning on 6th article and ending on 24th. From article 3 to 14, 8 dorsal spines; articles 2–5 with weak ventral spines. Lower flagellum not as strongly developed as upper.

Antenna (Fig. 3C) with strong basicerite bearing at least 10 spines on enlarged proximoventral portion, 6 small spinules on dorsoexternal side. Carpocerite with 6 small dorsomedial spinules, 1 large and 1 small dorsodistal spinule and 2 ventral spinules. Antennal flagellum well developed with dorsal spinules on segments 1 and 2, extending beyond tip of telson. Scaphocerite well developed, reaching more than ½ its length beyond tip of rostrum. Outer margin moderately concave proximally with 4 spines decreasing in size distally; distal part bearing 8–11 teeth, followed by short nonserrate distance to final small blunt tooth. Dorsal surface with 2 distinct longitudinal carinae, inner carina bearing row of 13 close-set spinules nearly to distal margin, outer carina with row of 8 spinules widely spaced, not extending as far distally. Inner margin with long plumose setae. Ventral surface with 2 longitudinal rows of spinules away from lateral margins; external row of 4–7 smaller and internal row of 15–18 larger curved spinules, latter extending further distally. Lamina only slightly tapering distally, its greatest width slightly proximal to ½ its length; narrowing to about ½ its maximum width proximally with convex median and concave outer sides.

Mandibles (Fig. 3D,E) robust with short, fused molar and incisor processes. Molar surface nearly smooth, incisor bearing 3 strong teeth medially, central one longest, 4 short lateral teeth. Palp well developed, 3-segmented. Proximal segment shortest; middle segment setose distolaterally and medially, broadest distally, 2× longer than proximal segment; distal segment broadest basally, tapering distally, densely setose laterally and distally.

Maxillule (Fig. 3F) with slender, undivided endopodite bearing 9 plumose setae mostly on distolateral border, a few mesiolaterally. Proximal endite broad, truncated distally with seta laterally, numerous compound spinose setae distally. Distal endite of equal size, rounded distally, bearing numerous plumose setae along most of its margins.

Maxilla (Fig. 3F) with following setation on coxal and basal endites; numerous plumose setae on both coxal lobes with fringe of setae below distal margins of lobes, forming double row together with marginal setae distally; proximal lobe 2× as broad as distal lobe; plumose setae along distal edge of both lobes of basal endite; proximal lobe about ¾ breadth of distal lobe and slightly shorter. Endopodite not exceeding anterior margin of scaphognathite, slender, gradually narrowing distally, bearing 20 lateral, 10 distal, 9 inner marginal plumose setae. Scaphognathite long, narrow, about 5× longer than maximum breadth, with numerous plumose setae along margin.

First maxilliped (Fig. 3H) bearing 3-segmented endopodite. Proximal segment slightly longer than broad, with 10 long plumose setae laterally on outer margin, 9 shorter setae on inner margin. Middle segment about ½ length of proximal segment, with 15 long plumose lateral setae on outer margin, seta on inner margin. Distal segment slender, unarmed, less than ½ length of middle segment. Basipodite large, rounded anteriorly, slightly concave near middle, with outer border and area adjacent to this on both inner and outer sides proximally bearing dense fringe of long setae. Coxopodite lobed with numerous moderately long setae. Exopodite well developed, flagellum arising from complete peduncle, which bears 3 simple setae. Flagellum with 5 simple, 8 plumose long proximal setae, 20 longer plumose setae distolaterally. Large epipod with slender proximal and distal lobes approximately equal in length and slightly more than 2× as long as broad.

Second maxilliped (Fig. 3I) with 5-jointed endopodite. Dactylus suboval, about as long as broad, with dense fringe of comb setae along distodorsal margin, 3 short setae along distoventral margin with others scattered on inner surface, and 7 longer simple setae in rows on outer surface medially. Propodus equal to length of dactylus, comb setae in broad band dorsally and onto inner side, row of 6 longer setae dorsomedially, up to 10 setae near distal edge on outer side; 3 short setae on ventral margin. Carpus short, triangular, about ½× length of propodus, with numerous long and short simple setae on distal border; few very short setae on inner surface. Merus about 2× length of dactylus, 2½× longer than broad; inner border with 4 short, widely spaced distal simple setae; outer border slightly convex, with fringe of many long simple setae. Ischium and basis not fused, each with dense fringe of mesial setae as coxa; 4 short simple setae at inner proximal edge of ischium. Exopodite long, slender, undivided distal ½ bearing 18 long plumose setae. Small, elongate epipod present.

Third maxilliped (Fig. 3J) endopodite strongly developed, well calcified, 5-segmented. Dactylus slender, tapering, about 6× longer than basal width, 4 simple setae on outer margin, numerous long simple setae mesially and on inner margin. Propodus slightly shorter than dactylus but about 4× longer than broad, bearing 1 acute spine, 7 long and short setae on distal margin; 2 spines submesiad; setiferous organ distally; numerous long simple setae on inner margin. Carpus equal in length to propodus, about 3× longer than broad, with 3 spines, 3 setae on outer margin; small spine proximally supramediad, 2 distal, 1 proximal submesiad spines; numerous long simple setae on inner margin. Merus robust, about ⅓×

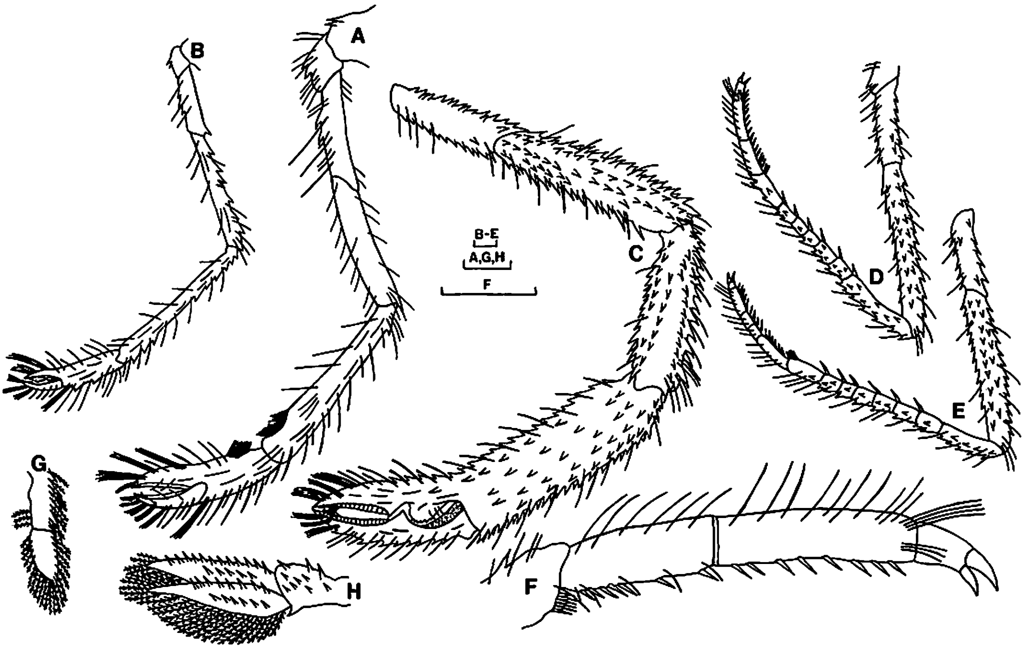


Fig. 4. *Stenopus devaneyi,* holotype, ♂: **A**, 1st pereiopod; **B**, 2nd pereiopod; **C**, 3rd pereiopod; **D**, 4th pereiopod; **E**, 5th pereiopod; **F**, dactylus and propodus of 4th pereiopod; **G**, 1st pleopod; **H**, 2nd pleopod. Scale bars represent 1.0 mm.

longer than carpus, with 7 large spines, 7 long setae on outer margin; 2 proximal supramesiad, 1 more distal mesiad spine; 2 acute large spines at distal extremity, long setae densely covering inner margin. Ischium robust, about ⅕× longer than merus, with 7 spines of various sizes on outer margin; small acute ventral spine at distal extremity; dense fringe of long setae on inner margin; row of shorter setae mesiad of inner marginal fringe on both dorsal and ventral sides. Basis short, rounded, with long setae on inner margin, laterally bearing well-developed exopodite ⅓× longer than ischium, with 26 plumose setae on distal ½. Coxa short, with 4 short setae on inner margin, laterally bearing short, bluntly rounded epipod.

First pereiopod (Fig. 4A) small, slender, when stretched reaching just past scaphocerite, all segments generally glabrous. Palm of chela somewhat compressed, rounded dorsal and ventral sides about 3⅓× longer than deep. Dactylus less than ½ length of propodus. Fingers slightly compressed, having somewhat hooked tips. Cutting edges indistinct, both dactylus and propodus bearing chitinous ridges along inner margins. Dactylus covered with numerous, widely scattered, long simple setae; propodus covered with numerous short and long simple setae. Fingers and distodorsal extremity of palm bearing small tufts of long setae. Distoventral part of carpus and proximoventral part of propodus with setiferous organ. Carpus longest segment about ½× longer than propodus, narrowing slightly proximally, bearing widely scattered long and short simple setae, with small proximal spine on outer margin. Merus almost equal to carpal length, with acute spine at distal extremity of outer margin, few short simple setae. Ischium almost as long as merus, with 2 small proximal spines on inner margin, few long and short simple setae. Basis short, with 2 small spines and few simple setae on inner margin. Coxa stout, with 2 spines on inner margin, laterally small epipod.

Second pereiopod (Fig. 4B) built similarly to 1st, but longer, stronger. No setiferous organ present. Finger tips not as strongly hooked as those of 1st, cutting edges each with small rounded proximal tooth, larger dactylar tooth slightly in advance of one on propodus; edges bearing chitinous ridges. Fingers and distodorsal extremity of palm bearing small tufts of long setae; numerous scattered simple setae on propodus and dactylus; outer dactylar margin with 4 simple setae. Propodus with 1 or 2 minute spines on proximodorsal margin, surface covered with numerous short and long simple setae. Carpus about ½× longer than propodus, slightly longer than merus, bearing 6 proximal, 2 or 3 distal small dorsal spines, with only few scattered long simple setae on outer side, absent on inner side. Merus almost 2× longer than ischium but shorter than carpus, with 8 small spines along dorsal margin, most distal at carpal-meral junction; small spine proximoventrally; few long setae on surface. Ischium with several long and short scattered setae, 3 recurved spines along ventral margin, 1 acute distodorsal spine. Basis short, with 2 small ventral spines. Coxa stout, with 3 distal spines; bearing small epipod.

Third pereiopod (Fig. 4C) strongest, robust, moderately calcified, slightly longer than entire length of body, extending beyond scaphocerite by length of carpus and chela. Palm of chela longest segment with 2 to 4 irregular rows of 16–18 forwardly directed robust spines, numerous blunt-tipped spines on both inner and outer surface in irregular rows, ventral surface with somewhat alternating row of 14 robust but blunt spines; few simple setae only adjacent to some spines. Ventral margin slightly concave at distal ⅓, with row of 20 spines. Fingers elongate, ⅔× length of palm, with sharp hooked crossing tips. Dactylus with 8 dorsal acute spines; numerous long simple setae. Dactylar cutting edge bearing proximal large sharp tooth, distal row of stout, slightly posteriorly directed peglike teeth separated by rectangular chitinous lamellae. Cutting edge of propodus with proximal large rounded projection dorsally, with 6 denticles, followed by acute tooth merging into row of peglike teeth even with and separated by chitinous lamellae. Fingers distally bearing small tufts of long setae. Carpus about ⅔× length of propodus, narrowing proximally. Dorsal margin with 14 spines increasing in size distally, 2 rows of 4 and 9 spines dorsomesially, row of 3 medial spines; ventral margin with 11 spines, less distinct row of 4–5 small spines on outer border, 2 rows of 7 and 7 spines ventromesially. Between dorsal, ventral marginal spines, numerous long simple setae. Merus about ⅛× length of propodus, with 13 dorsal spines, 2 rows of 7 and 7 spines dorsomesially, indistinct row of 5 small inner border spines, 2 rows of 9 and 15 spines dorsomedially. Ventral margin with 11 large spines, 2 irregular rows of spines ventromesially. Numerous long setae interspaced between dorsal, ventral marginal spines. Ischium short, about ¼× length of propodus, with 12 short dorsal spines, 5 spines dorsomesially; 12 short ventral spines, distal spine ventromesially, few long simple setae. Basis and coxa short, with coxa bearing 2 small spines on ventral margin, small epipod.

Fourth and 5th pereiopods (Fig. 4D,E,F) long, stout, very similar. Dactylus of 4th biunguiculate with unguis and accessory spine nearly of equal length, latter slightly shorter, both clearly separated from dactylar corpus. Propodus subdivided into 2 segments bearing 15 movable ventral spines, 12 dorsal long setae, various short setae dorsally and ventrally. Carpus straight, longest segment of pereiopod 2$\frac{7}{10}$× length of propodus, subdivided into 7 segments, proximal segment 3×, distal segment 2× longer than each of 5 middle segments; dorsal margin with 15 small acute recurved spines, 12 long setae, 2 rows of 12 and 4 small dorsomedial spines; each segment with acute distoventral movable spine, distoventral edge of most distal segment with group of 6 acute movable spines (Fig. 4F). Merus long, ⅔× length of carpus, stocky, with 10 small spines, 9 long setae dorsally, 2 rows of 8 and 9 dorsomesial spines, 8 small spines, 3 long setae ventrally. Ischium $\frac{7}{10}$× length of merus, with 6 small spines, 2 long setae dorsally, 2 distal dorsomesial spines on each side, 6 small spines, 4 long setae ventrally, 2 proximal ventromesial spines. Basis with small ventral spine, 4 long setae; coxa ventrally with 2 small spines. Fifth pereiopod with dactylus similar to 4th. Propodus subdivided into 4 segments bearing 15 movable ventral spines, 14 long and short dorsal setae. Carpus 2½× length of propodus, subdivided into 8 segments, proximal segment slightly shorter than that of 4th pereiopod and lacking distoventral movable spine; dorsal margin with 13 small, recurved spines, 16 long setae, irregular row of 13–15 dorsomesial spines, proximal 4 segments each with small ventromesial spine, each segment with acute distoventral movable spine, distoventral extremity of last segment with 5 acute movable spines. Merus 7/10× length of carpus, with 10 spines dorsally, irregular row of 13 and 7 spinules on each side dorsomesially, 9 slightly recurved spines ventrally, and irregular row of 7 spinules on one side, 3 on other side of ventral series. Ischium with 4 small dorsal spines, posterior 3 recurved, proximal and distal dorsomesial spines, proximal ventromesial spine, 5 small recurved spines, 3 long setae ventrally. Basis unarmed; coxa bearing 3 ventral spines.

First pleopod (Fig. 4G) uniramous, 2nd (Fig. 4H) to 5th biramous, all lacking appendices. First pleopod smallest, with exopodite equal in length to basipodite. External margin of basipodite with 4 spines, 2 proximal broader and larger than distal ones, with long plumose setae; dorsal margin with 3 distal long plumose setae. Exopodite lanceolate, with plumose marginal setae except in proximal region. Rami of 2nd pleopod more than 2× length of basipodite. External margin of basipodite bearing 3 spines, 6 spinules on ventral surface, large acute spine on distal edge of internal margin. Ventral surface of exopodite bearing 2 rows of 5 and 12 elongate acute spines, numerous plumose marginal setae; that of endopodite with 2 rows of 7 and 8 elongate acute spines, numerous plumose marginal setae. Third to 5th pleopods generally similar, decreasing in size and spinulation posteriorly.

Branchial formula as follows:

	Maxillipeds			Pereiopods				
	I	II	III	I	II	III	IV	V
Pleurobranchs	–	–	1	1	1	1	1	1
Arthrobranchs	1	1	2	2	2	2	2	–
Podobranchs	–	1	–	–	–	–	–	–
Epipods	1	1	1	1	1	1	1	–
Exopods	1	1	1	–	–	–	–	–

Measurements (in mm). Postorbital carapace length, 8.6 (3.0, 9.4). Rostral carapace length, 13.9 (5.5, 14.2). Total length, ca. 32.9 (22.2, 34.8). Length of 3rd pereiopod, 35.2 (25.1, 36.6). Numbers in parentheses represent measurements of paratypes.

Coloration. Carapace yellow-brown, eyestalks, antennular peduncle, antennal scale, rostrum, and 3rd maxillipeds faintly pale orangish to whitish. Antennal flagella, 1st, 2nd, 4th, and 5th pereiopods all completely opaque white. Third pereiopods banded as follows: basis, coxa, ischium opaque white; proximal ⅔ of merus opaque white, distal ⅓ with red-orange band distally becoming white; proximal ½ of carpus whitish, distal ½ red-orange; propodus with proximal and distal red-orange bands with white between; proximal band of propodus ending at white finger; dactylus white. Abdominal somites from 1st to middle of 5th whitish, with bilobed or trilobed bright red spots dorsolaterally on 2nd and proximal ½ of 3rd, distal ½ of 5th and all of 6th abdominal somites pale orangish. Telson, uropods also pale orangish. (See color plate IA,C,E.)

Paratypes. Male paratype collected in same area as holotype but from greater depth (22.9 m) shows considerable variation from holotype; generally, reduction in spination probably attributable to smaller size. Rostrum long, extending well beyond end of last antennular peduncle segment and to end of scaphocerite, with 10 dorsal, 3 ventral widely spaced spines occurring on anterior ½ and row of 5–6 lateral spines on posterior ½. Carapace less densely covered with spinules, with distinct cervical groove bearing 10 spinules; dorsal postrostral area with row of 5 pairs of forwardly curved spines, single spine posteriorly. Abdomen also less densely covered with spinules, shield-shaped area on dorsal side of 3rd abdominal somite bearing only 2 lobes on each side. Spination of telson similar except only 2 pairs of spines at base, only 7 carinal spines, only 2 intercarinal spinules anteriorly, none external to carina. Outer margin of uropodal exopodite and endopodite, respectively, bearing 12 and 3 spines, otherwise dorsal and ventral surfaces with fewer spines than holotype. Scaphocerite with only 1 large proximal, 1 smaller spine on outer margin distally; proximal portion with 9 nonoverlapping teeth followed by moderately long nonserrate portion to final distal tooth; dorsal surface with 2 rows of very short spines near center, 1 spine subdorsally; ventral surface also less spinous than that of holotype, with 1 row of spines centrally. Mouthparts show no major differences, except 3rd maxilliped bearing following spinulation: dactylus, propodus without spinules; merus with 3 dorsal spinules; carpus with 4 spinules subdorsally on external lateral surface; ischium with 3 dorsal, 1 ventral spinule. Spinule patterns for 1st to 3rd pereiopods as follows. 1st: dactylus, propodus, carpus without spinules; distodorsal extremity of merus formed into acute spinule; ischium with 1 distodorsal spinule. 2nd: dactylus, propodus without spinules; 6 dorsal spinules on carpus; 5 dorsal spinules on merus; ischium with distodorsal spinule. 3rd (heavily calcified): dactylus without spines; propodus with dorsal row of 5 spines on proximal ½, 1–3 smaller subdorsal spines on inner and outer sides proximally; carpus with 3 dorsal rows (2 dorsomedial) of 11–12 spines, mesial row of 7–8 spines, ventral and ventromesial rows of 4 spines; merus with 11 ventral spines, mesial row of 7–10 spines, dorsal and dorsomesial row of 7–10 spines; ischium with 6 dorsal, 6 ventral spines. Fourth pereiopod with dactylar unguis and accessory spine unequal; propodus indistinctly subdivided into 4 segments with 14 movable ventral spinules; carpus indistinctly subdivided into 8 segments with 12 dorsal spinules (5,1,1,2,1,1,1,0 arrangement on proximal to distal subsegments), 6 movable ventral spinules, 2 acute movable spinules at distoventral extremity; merus with 7 short ventral, 8 dorsal spines plus 1 and 2 subdorsal spines on each side proximally; ischium with 7 ventral, 1 proximodorsal, 3 distodorsal spinules. Fifth pereiopod with dactylar unguis and accessory spine subequal; propodus undivided, bearing 16 movable ventral spinules; carpus indistinctly subdivided into 9 segments with 12 dorsal spinules (3,0,2,1,2,1,1,1,1 arrangement on proximal to distal subsegments), 8 movable ventral spinules, cluster of 4 acute movable spinules at distodorsal extremity; merus with 9 dorsal spinules, 4 mediolateral spinules externally, 8 mediolateral spinules on internal side, 7 ventral spines; ischium bearing 5 ventral, 1 proximodorsal, 3 distodorsal spinules.

Paratype taken from Sri Lanka slightly larger than holotype but similar in body spination. Main differences as follows: rostrum with 10 dorsal, 4 ventral, row of 5 lateral spines on each side; telson median carinae with 7 spines; and outer margin of uropod with only 5 and 8 spines on left and right exopodites, respectively.

Material examined. FRENCH POLYNESIA: MARQUESAS IS: NUKA HIVA I: outer portion of Taiohae Baie, W side of islet, Sentinelle de l'Est, depth 6.2 m, 11.V.1971, Quinaldine poison (J.E. Randall) (BPBM S8045, ♂ holotype); W side of Sentinelle de l'Est, depth 22.9 m, 17.V.1971, Quinaldine poison (Randall & D. Cannoy) (BPBM S8496, ♂ paratype). SRI LANKA: donated by Hofmann (SMF 12200, ♂ paratype).

Type-locality. French Polynesia: Marquesas Is: Nuka Hiva I, outer portion of Taiohae Baie.

Habitat. The species is very retiring, having been observed only in recesses of the coral reef. It was found in close association with the moray eel *Gymnothorax breedeni* (see color plate IF) first observed at Vaitahu Baie, Tahuata (personal observation of Dennis M. Devaney, Nov. 1967). Other species of cleaner shrimp, including *Lysmata amboinensis,* were often present with the new *Stenopus.*

Etymology. The specific name is in honor of Dr. Dennis M. Devaney, who contributed greatly to this paper and whose tragic death in 1983 is a major loss to the scientific community. His contributions to various taxocenes of the Pacific marine environment have been innumerable and invaluable.

Stenopus earlei Goy & Randall, 1984: 117. Fig. 5–8

Diagnosis. Small stenopodid shrimp, with slender, compressed body; moderately covered with spinous processes; abdominal somites with numerous squamous spinules, those of last 3 somites arranged in distinct transverse rows; 3rd somite with suboval bare medial posterior area encircled by small squamous spinules; ventral surface of 6th somite sparsely covered with spinules; background color of body white with lateral red stripes extending from posterior carapace along sides of abdomen converging at telson; 3rd pereiopods reddish except tips of fingers.

Description. Holotype (♂, BPBM S10007). Rostrum (Fig. 5, 6A) long, extending to middle of last antennular peduncle segment. Dorsal margin with 6 spines, distal one little more than its length from tip, this space occupied by 4 stout hairs. Ventral margin slightly concave proximally, with 5 spines distally. Lateral margins without spines, carinae well developed.

Carapace (Fig. 5, 6A) densely covered with spinules placed in somewhat distinct longitudinal rows. Cervical groove distinct with 12 spines along upper margin. Orbit with both supraorbital and infraorbital spines. Large antennal spine present, moderate hepatic spine at lower end of cervical groove, large branchiostegal and pterygostomial spines also present. Ventrolateral angle somewhat rounded, only slightly produced anteriorly while posterolateral angle of branchiostegite slightly concave.

First 3 abdominal somites (Fig. 5, 6B) with forwardly directed spinules similar to those on carapace. First somite with 2 transverse rows of squamous spinules, anterior margin with small conical spine on distal ⅓, pleuron ending in 3 stout spines. Second somite with 3 transverse rows of squamous spinules. Pleura of 2nd, 3rd, 4th, and 5th somites truncate, ventrolateral margins ending in 5, 4, 3, 3 strong spines, respectively. Third somite broadly produced, with posterior medial bare suboval area surrounded by 22 small squamous spinules. Last 3 somites with distodorsal squamous spinules with upturned tips arranged in distinct transverse rows. Anterior margins of 4th and 5th somites with articular knobs. Abdominal somites 1–5 bearing strong ventral median spine, those of 1–3 directed anteriorly, those of 4–5 directed posteriorly. Ventral surface of 6th somite smooth.

Eyes well developed, with peduncle slightly longer than cornea. Ophthalmic peduncle dorsally with 3–4 spinules, 2 mediodorsal and 1 proximodorsal spinules, some extending over cornea.

Telson (Fig. 6C) lanceolate, ca. 2× longer than 6th abdominal somite, 2⅖× longer than anterior (maximum) width, median groove flanked by 2 distinct longitudinal carinae. Outer margins of carinae with 6 strong, posteriorly directed spines, last spine overlapping rounded posterior margin of telson; inner margins with row of 3 weaker spines in anterior ½, 1 sometimes 2, long setae at base of carinal spines. Base of telson with pair of lateral spines. Lateral margins with strong spine about anterior ⅓; also with plumose setae along posterior ⅔.

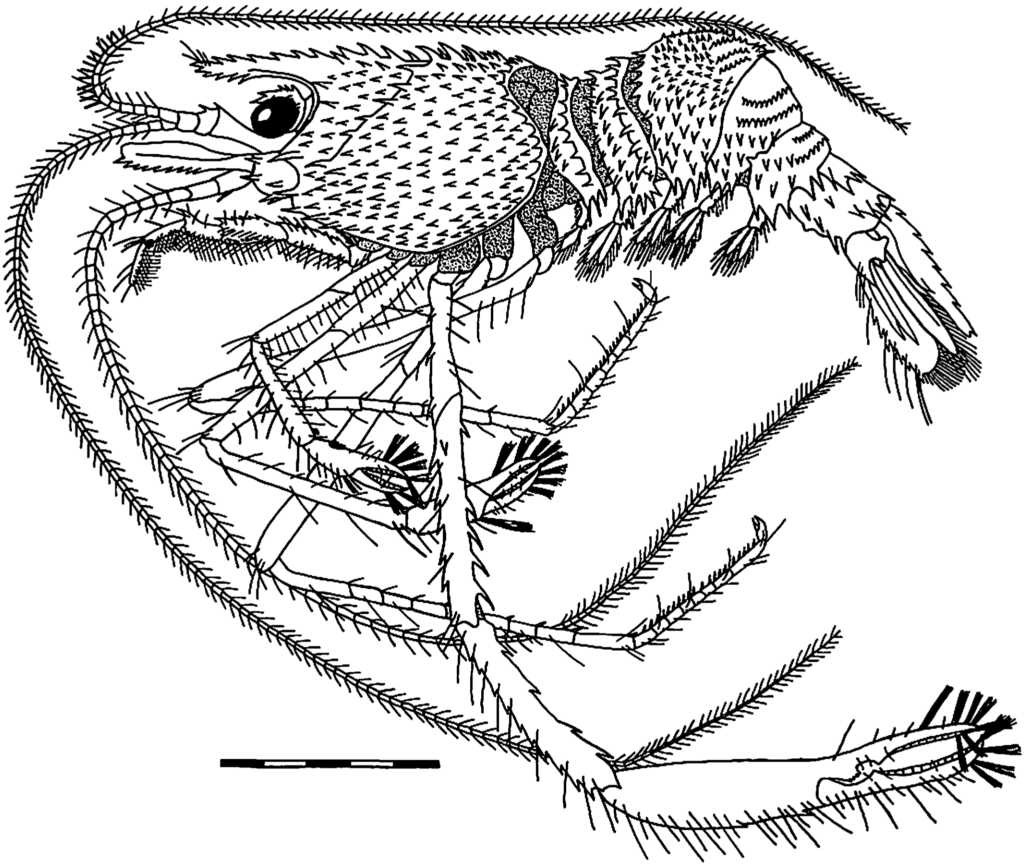
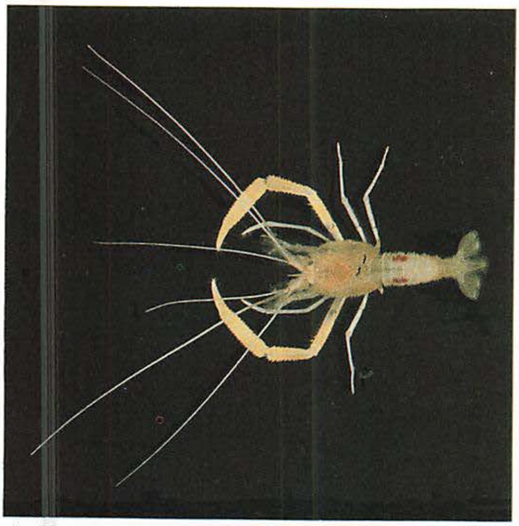


Fig. 5. *Stenopus earlei,* holotype, ♂. Increments of scale in mm.

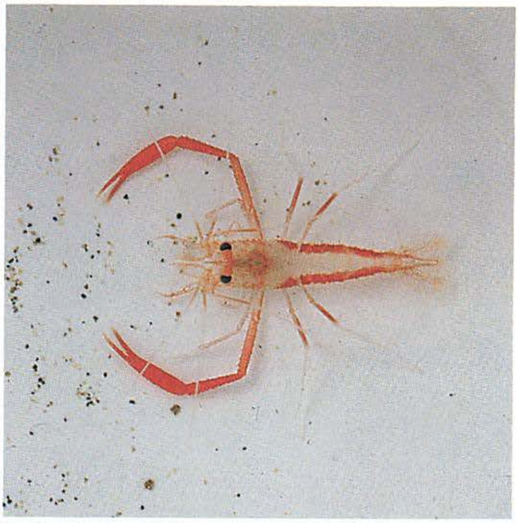
Uropods (Fig. 6D) well developed with endopodite equal to telson length and narrower but slightly longer than exopodite. Basal segment with medial central spinous process. Exopodite bearing 6 equally spaced teeth on distal ⅔ of outer margin, 7 long plumose setae; dorsal surface bearing 2 longitudinal carinae, 1 extending slightly past midlength; ventral surface unarmed. Outer proximal margin of endopodite bearing 2 teeth, 5 long plumose setae. Dorsal surface bearing distinct median ridge; ventral surface unarmed. Unarmed margins of exopodites, endopodites with long plumose setae.

Epistome (Fig. 6E) triangular anteriorly, with 2 submedian spines, 2 smaller spines present laterally; labrum normally developed. Paragnath (Fig. 6F) moderately bilobed, lobes separated by median fissure. Thoracic sternites narrow, 2 submedian spinules on segments 4–6, 6 submedian spinules on segments 7–8.

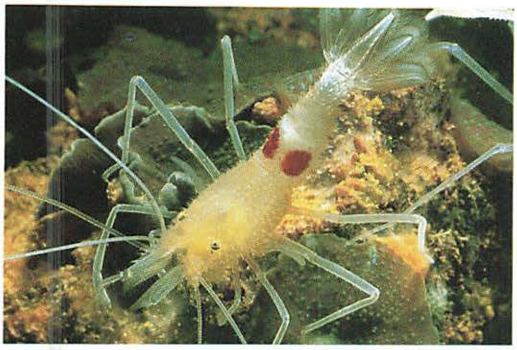
Antennular peduncle (Fig. 7A,B) short, extending to middle of scaphocerite. Basal segment almost 2× as long as wide, short rectangular process bearing small median knob on inner proximodorsal margin; small, elongate stylocerite on outer margin; dorsomedially 2 small spines, 5 plumose setae; distodorsally with appressed rounded process bearing small conical marginal spines. Middle segment with 2 strong spines at distodorsal angle; 2 spines anteriorly mesiad; 3 small spines dorsomedially. Distal segment with strong spine at distodorsal angle. Upper flagellum well developed, proximal part bearing 14 groups of aesthetascs beginning on 6th article ending on 14th. Lower flagellum not as strongly developed



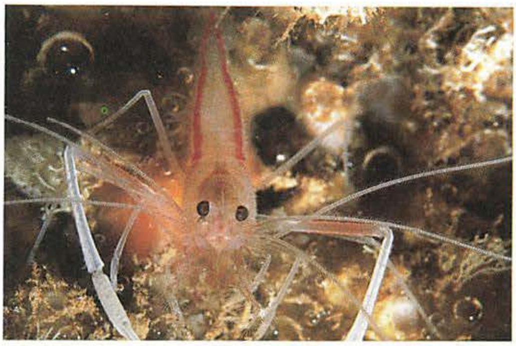
A. Holotype of *Stenopus devaneyi,* Nuku Hiva, Marquesas Islands. Photo by John E. Randall.



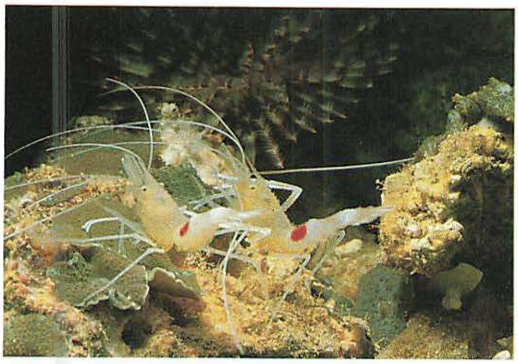
B. Holotype of *Stenopus earlei,* O'ahu, Hawaiian Islands. Photo by John L. Earle.



C. *Stenopus devaneyi,* Sri Lanka. Aquarium photo by Helmut Debelius.



D. *Stenopus earlei,* O'ahu, Hawaiian Islands. Underwater photo at night by Scott Johnson.



E. A pair of *Stenopus devaneyi,* Sri Lanka. Aquarium photo by Helmut Debelius.

F. *Stenopus devaneyi* and the moray *Gymnothorax breedeni,* Tahuata, Marquesas Islands. Underwater photo by John E. Randall.

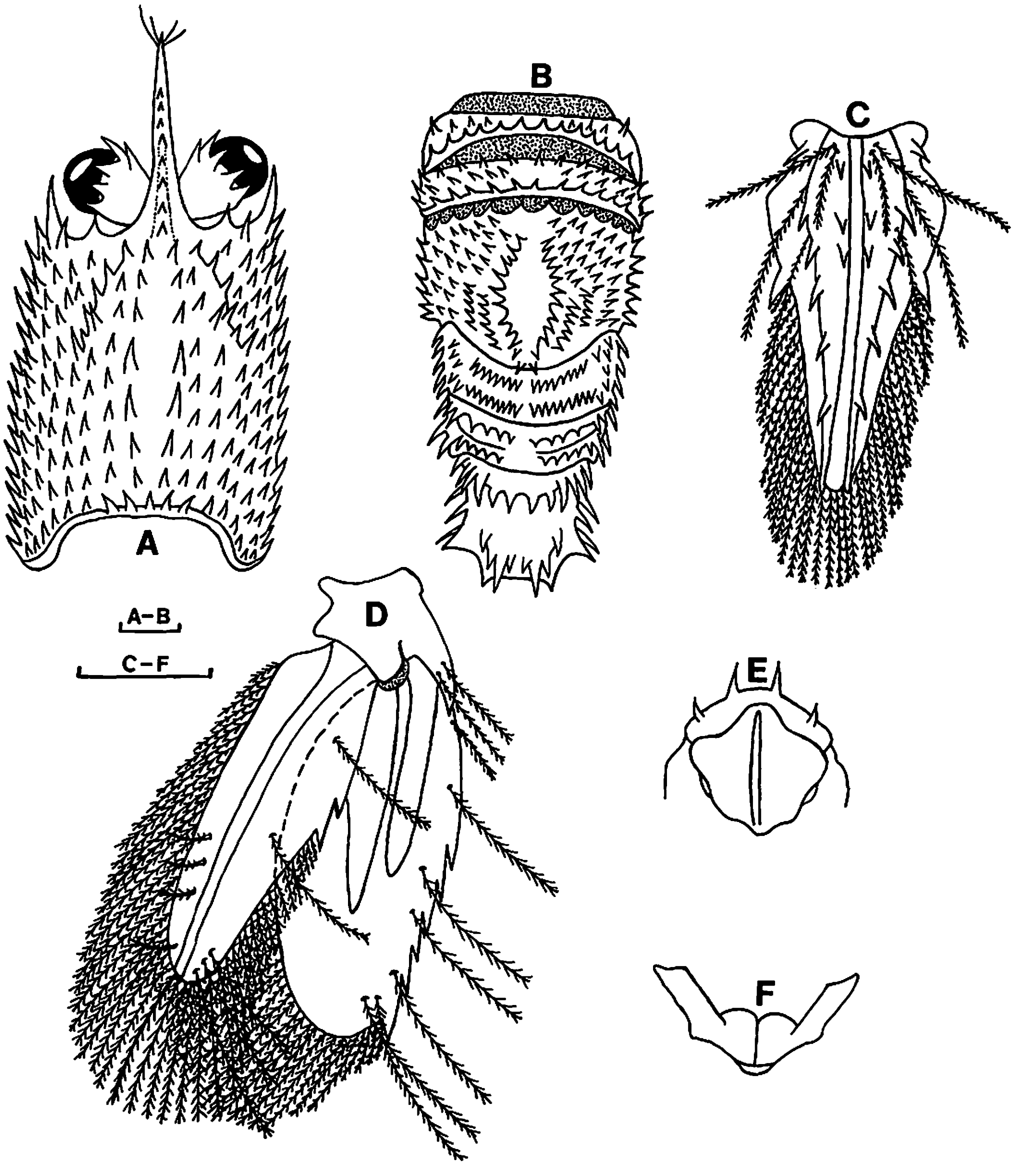


Fig. 6. *Stenopus earlei*, holotype, ♂: **A**, carapace, dorsal view; **B**, abdominal somites, dorsal view; **C**, telson; **D**, uropods; **E**, epistome and labrum, ventral view; **F**, paragnath. Scale bars represent 1.0 mm.

as upper. Articles of both flagella with delicate short setae placed on all sides along entire length.

Antenna (Fig. 7C) with strong basal segment bearing 2 strong ventral, 1 ventrolateral spines. Scaphocerite well developed, reaching about ½× beyond tip of rostrum. Outer margin moderately concave proximally with 2 small spines; distal part bearing 9 stronger teeth equally spaced to tip. Dorsal surface with 2 distinct longitudinal carinae, without spinulation. Inner margin with long plumose setae. Ventral surface without spinules but with widely spaced long setae. Antennal flagellum well developed, extending beyond tip

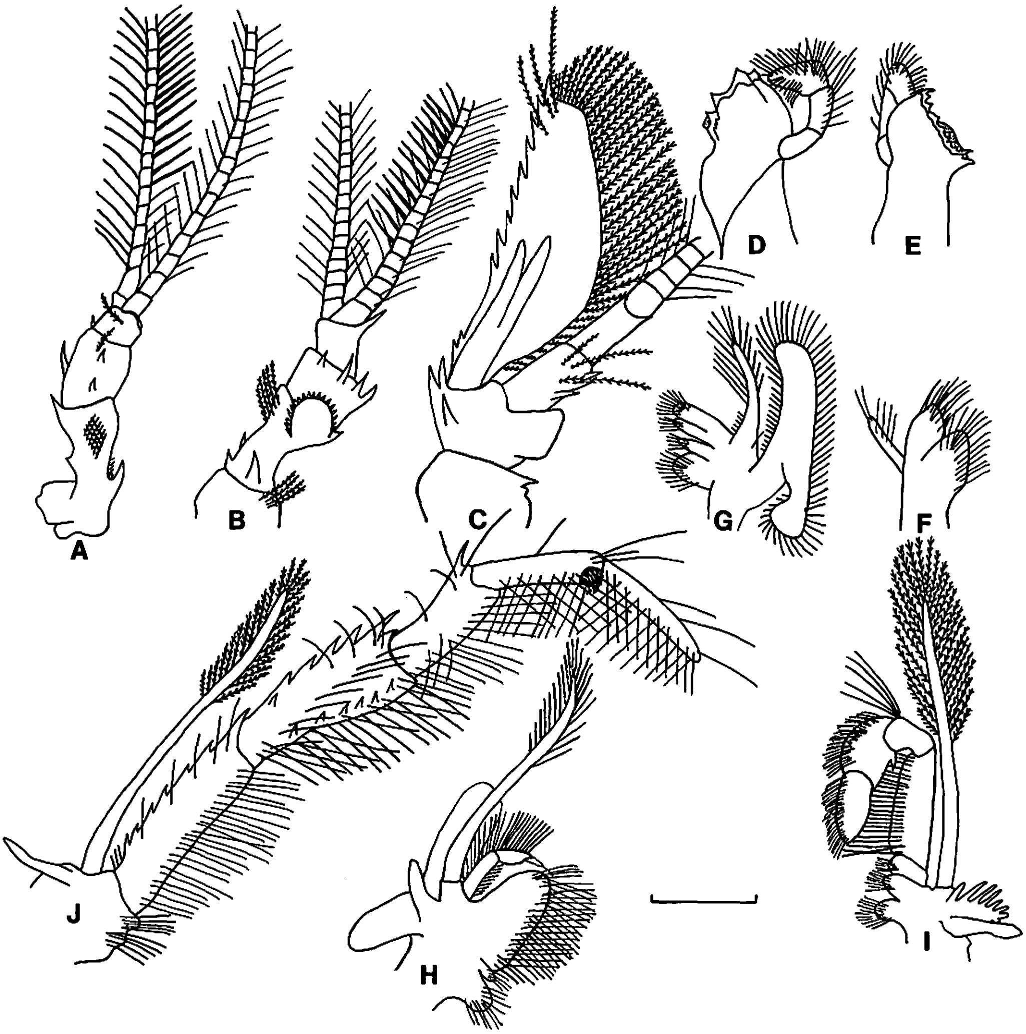


Fig. 7. *Stenopus earlei*, holotype, ♂: **A**, left antennule and antennular peduncle, dorsal view; **B**, right antennule and antennular peduncle, ventral view; **C**, antenna and scaphocerite, dorsal view; **D**, right mandible, ventral view; **E**, left mandible, dorsal view; **F**, maxillule; **G**, maxilla; **H**, 1st maxilliped; **I**, 2nd maxilliped; **J**, 3rd maxilliped. Scale bar represents 1.0 mm. Setules on some plumose setae not shown for clarity.

of telson; basal segment with 3 dorsal spines, 1 larger spine distoventrally; all flagellar articles with delicate setae around entire length of flagellum.

Mandibles (Fig. 7D,E) robust with short, fused molar and incisor processes. Molar surface nearly smooth, incisor bearing 10 minute medial teeth. Palp well developed, 3-segmented; proximal segment lacking setae; middle segment more than 2× as broad as proximal segment, setose on outer surface; distal segment broad, flattened, setose along edges and outer surface.

Maxillule (Fig. 7F) with slender, undivided endopodite bearing 4 plumose setae laterally, 2 distally. Proximal endite moderately broad, slightly broader distally than proximally with 1 slender seta laterally, about 15 robust simple setae in more than 1 row distally, fringing slender setae on inner edge. Distal endite slightly broader, tapering distally, simple setae dense.

Maxilla (Fig. 7G) with following setation on coxal and basal endites: 11 on proximal lobe, 5 on distal lobe of coxal endite; 5 on proximal lobe, 9 on distal lobe of basal endite. Endopodite long, slender, exceeding anterior margin of scaphognathite, with 5 small simple setae on basal portion of inner margin, 15 long plumose setae around distal ½. Scaphognathite long, narrow, little more than 4× longer than breadth at center with plumose setae along margin.

First maxilliped (Fig. 7H) with 3-segmented endopodite. Proximal segment longer than broad, with 10 long plumose setae laterally along outer margin, 9 shorter setae on inner margin. Middle segment about ½ length of proximal segment, with 11 long plumose setae along outer margin. Distal segment slender, tapering, slightly less than ½ length of middle segment, with minute simple terminal seta. Basipodite large, auriculiform, with straight outer border bearing dense fringe of long simple setae. Coxopodite bilobed, each lobe bearing numerous short setae. Exopodite well developed, flagellum with 22 long plumose distolateral setae. Large epipod with proximal lobe distinctly longer, larger than distal lobe.

Second maxilliped (Fig. 7I) with 5-jointed endopodite. Dactylus suboval, 1⅔× longer than greatest breadth, dense fringe of short setae along distodorsal margin. Propodus equal to length of dactylus but broader, densely setose on dorsal margin, ventral margin bearing stout proximal tooth. Carpus short, almost as long as propodus, with 5 long simple setae at distodorsal angle, several shorter setae on upper surface. Merus about 2× length of dactylus, 2½× longer than broad; outer border compressed, slightly convex, with many long simple setae. Ischium and basis not fused, each with dense fringe of mesial setae as for coxa, ventral aspect of ischio-basis bearing small setose knob. Exopodite long, slender, undivided in distal ½, bearing 28 long plumose setae. Small, elongate epipod present; arthrobranch and podobranch also present.

Third maxilliped (Fig. 7J) endopodite strongly developed, 5-segmented, with coxa and basis fused. Dactylus slender, tapering, about 6½× longer than basal width, with 3 simple setae on outer margin, 10–11 simple setae in mesial row and 11 along inner margin. Propodus same length as dactylus but about 5× longer than broad, with 4 simple setae on outer margin; setiferous organ reduced to 10 stout short setae distally, row of 8 long simple setae mesially and row of 6 on inner margin. Carpus slightly shorter than propodus, about 4× longer than broad, with large distodorsal spine, 4 setae on outer margin; numerous long setae mesially on inner margin. Merus long, slightly robust distally, about 1⅓× longer than carpus, with 6 dorsal spines increasing in size distally, 4 simple setae on outer margin; row of 6 low, curved, small spines subdorsally along proximal ¾ of segment, above numerous long simple setae medially and mesially on inner margin. Ischium long, slender, about ⅓× longer than merus, with 7 spines, 8 setae on outer margin; dense fringe of long setae on inner margin and row of simple setae on central part of medial side together with some scattered setae.

First pereiopod (Fig. 8A) small, when stretched almost reaching past scaphocerite, all segments glabrous. Dactylus equal to ½ length of propodus. Fingers slightly compressed, having somewhat hooked tips. Cutting edges distinct, both propodus and dactylus bearing small, stout, peglike teeth separated by rectangular chitinous lamellae. Dactylus with few scattered simple setae, tufts of longer setae around distal part; propodus with few scattered short simple setae, pair of long setae (branched towards their tips) on distodorsal extremity, tufts of long setae around distoventral area. Distoventral part of carpus and proximoventral part of propodus with setiferous organ. Carpus longest segment about 2× longer than palm, narrowing slightly proximally, bearing scattered long and short simple setae. Merus

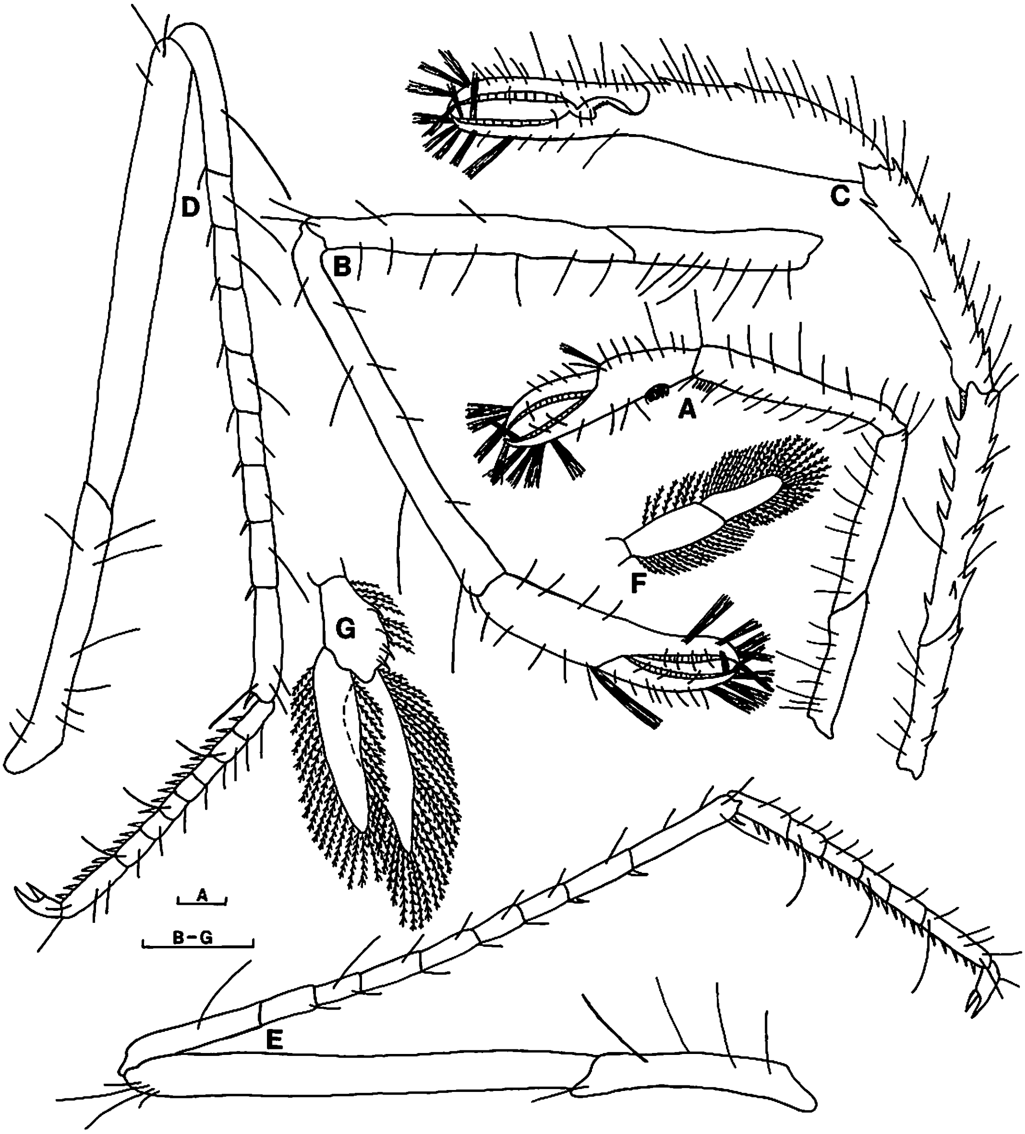


Fig. 8. *Stenopus earlei*, holotype, ♂: **A**, 1st pereiopod; **B**, 2nd pereiopod; **C**, 3rd pereiopod; **D**, 4th pereiopod; **E**, 5th pereiopod; **F**, 1st pleopod; **G**, 2nd pleopod. Scale bars represent 1.0 mm.

almost equal to carpal length, with numerous long and short simple setae, especially on ventral margin. Ischium about ⅓× shorter than merus, with few long simple setae on ventral margin. Basis short, with few simple setae on inner margin. Coxa short, with few simple setae on inner margin, laterally small epipod.

Second pereiopod (Fig. 8B) built similarly to 1st but longer, stronger, all segments glabrous. No setiferous organ present. Finger tips more strongly hooked than those of 1st, cutting edges with small, stout, peglike teeth separated by rectangular chitinous lamellae. Fingers and distodorsal extremity of palm bearing small tufts of long setae; outer dactylar margin with 8 simple setae. Widely scattered short to medium simple setae over surface of palm, pair of long fused setae at distodorsal extremity. Carpus longest segment just over

3× longer than palm, with several long and short simple setae on margins. Merus about 2× longer than ischium, with few long and short simple setae, especially on ventral margin. Basis and coxa unarmed, coxa with small epipod.

Third pereiopod (Fig. 8C) largest, strongest, longer than entire length of body, extending beyond scaphocerite by length of carpus and chela. Palm of chela equal in length to carpus, with 2 small spines centrally on outer dorsal surface together with long simple setae along dorsal margin of entire propodus. Fingers elongate, with sharp hooked crossing tips. Dactylus with numerous long and short dorsal simple setae; cutting edge bearing proximal large sharp tooth, distal row of 10 stout peglike teeth separated by rectangular chitinous lamellae. Cutting edge of propodus with proximal large rounded projection dorsally, with 4 denticles followed by acute tooth merging into row of 10 stout peglike teeth separated by chitinous lamellae. Fingers distally bearing small tufts of long setae. Carpus about ½ length of propodus. Dorsal margin with 10 forwardly directed spines increasing in size proximally, 9 long simple setae; ventral margin with 4–6 smaller spines; dorsomesial edge produced into blunt spinelike process. Merus equal to length of carpus; 5 small spines, 5 long simple setae on dorsal margin; distomesial edge produced into large rounded knob; ventral margin with 5–6 spines increasing in size distally. Ischium about ½× shorter than merus, with 2 or 3 curved dorsal marginal spines along proximal ½ of segment, most proximal spine largest, 0–1 smaller spine and scattered simple setae on ventral margin. Basis and coxa short, coxa bearing few simple setae, small epipod.

Fourth and 5th pereiopods (Fig. 8D,E) long, slender, very similar. Dactylus of 4th biunguiculate with unguis long, curved, not clearly separated from dactylar corpus; accessory spine about ⅔ length of unguis. Propodus subdivided into 8 segments bearing 20 movable spines, 3 long setae ventrally; numerous shorter dorsal setae, except only 1 long seta at distodorsal extremity. Carpus slender, straight, longest segment of pereiopod slightly more than 2× meral length, subdivided into 9 smaller segments with 4 small spines on distoventral margin of distal 4 segments, other 5 segments bearing short simple seta distoventrally; dorsal margin with 9 long simple setae. Merus slender, elongate, about ½× length of carpus, unarmed except for 3 long simple setae distodorsally. Ischium, basis, coxa unarmed except for few long setae. Fifth pereiopod with dactylus similar to 4th, slightly more slender. Propodus subdivided into 6 segments bearing 23 movable spines; 3 long setae ventrally; 13 shorter dorsal setae and several on inner margin. Carpus slightly more than 2× propodal length, subdivided into 9 segments, all other segments except proximal bearing short simple seta distoventrally; dorsal margin with 9 long simple setae. Merus slender, ⅔× length of carpus, unarmed except for 4 long simple setae distoventrally. Ischium, basis, coxa unarmed except for few long setae.

First pleopod (Fig. 8F) uniramous, 2nd (Fig. 8G) to 5th biramous, all lacking appendices. First pleopod smallest, with exopodite slightly shorter than basipodite. Ventral margin of basipodite with long plumose setae; dorsal margin with 6 long plumose setae; exopodite with plumose marginal setae. Ventral margin of 2nd pleopod basipodite bearing 4 spines, 8 plumose setae; dorsal margin unarmed; rami lanceolate, about 2× length of basipodite. Exopodite and endopodite with plumose marginal setae. Third to 5th pleopods generally similar, except 3rd with only 3 spines on ventral margin, decreasing in size, setation posteriorly.

Branchial formula. Same as for *S. devaneyi* given above.

Measurements. Measurements of the holotype are included in Table 1 and compared with other specimens examined.

Coloration. Dorsal and lateral surfaces of carapace with numerous tiny, diffuse, reddish-

Table 1. Meristic data and comparison between carapace, 3rd pereiopod, and total length in *Stenopus earlei* (measurements in mm).

Lengths	Specimen					
	BPBM S10012a	BPBM S10012b	BPBM S10007 (holotype)	CAS 030069	CAS 031662	BPBM S8573
Total (T)	15.7	16.5	17.2	19.2	20.2	22.5
Rostral carapace (RC)	6.0	5.8	7.1	8.6	8.2	8.7
Postorbital carapace (PC)	4.2	4.0	4.0	4.8	4.7	5.3
Chela of 3rd pereiopod (C)	5.0	5.4	8.1	—	—	10.0
3rd pereiopod (P)	14.3	14.0	18.5	—	—	27.0
Ratios P/PC	3.4:1	3.5:1	4.6:1	—	—	5.1:1
P/RC	2.4:1	2.4:1	2.6:1	—	—	3.1:1
P/T	0.9:1	0.8:1	1.1:1	—	—	1.2:1
T/RC	2.6:1	2.8:1	2.4:1	2.2:1	2.5:1	2.6:1

orange chromatophores; many spines in this area red from base to tip; concentrated dark red spot at posteriolateral edge of carapace; anterior to this and medially, clear area with spines unpigmented. Rostrum, eyestalks light red. Edges of antennal and antennular peduncle, scaphocerite, ischium and merus of 3rd maxillipeds outlined in red. Carpus, propodus, dactylus of 3rd maxillipeds reddish. Flagella of antennule, antenna reddish proximally but white for greater part of their length. Lateral red stripe on each side of abdomen converging and narrowing distally, merging at telson, but abdominal pleura and dorsal region mainly white. First and 2nd pereiopods with light reddish ischia, meri, and carpi; chelae white. Third pereiopods reddish except tips of chelae white. Fourth and 5th pereiopods with red meri and reddish ischia; carpi, propodi, and dactyli white. Pleopods with reddish basipodites, rami outlined in light red. Telson reddish, only central area somewhat lighter anteriorly. Uropods with endopodite outlined in red becoming more diffuse centrally; exopodite reddish on outer edge, clear elsewhere. (See color plate IB.) Paratypes similar in coloration of holotype, except carpi, propodi and dactyli of 3rd pereiopods whitish. (See color plate ID.)

Paratypes. The new species is variable in the number of body and appendage spines. Rostrum with 5–7 dorsal, 1–5 ventral spines. Scaphocerite with 1–2 proximal spines, 7–9 distal spines on outer margin. Ischium of 3rd maxilliped with 2–7 dorsal spines; merus with 4–6 dorsal spines. One specimen with 5 dorsal meral spines, 6 dorsal carpal spines on 2nd pereiopod. Spination on 3rd pereiopod very variable: ischium bearing 4–5 dorsal spines; merus with 5–10 dorsal, 5–7 ventral spines; carpus with 10–14 dorsal, 1–5 dorsomesial, and 4–8 ventral spines; and propodus bearing 2–13 dorsal spines. Ventral surface of 6th abdominal somite sparsely covered with spinules in some specimens. Outer margin of uropodal endopodite with 2–3 teeth; outer margin of uropodal exopodite with 6–10 teeth. We could not find any correlation between the number of spines and the size or sex of the animals, but some of these differences may reflect allometric growth changes and normal variation in the species.

Material examined. HAWAIIAN IS: O'AHU I: off Mākua, depth 36.5 m, 12.IV.1981 (John Earle) (BPBM S10007, ♂ holotype); off Mākua, depth 39.6 m, under flat slab nr reef dropoff, VII.1979 (Earle) (BPBM S8573, ♀ paratype); KAUA'I I: off Lāwa'i, depth 15.2 m, under *Porites* slab, 4.X.1981 (Earle) (BPBM S10012, ♂,♀ paratypes). INDIAN OCEAN: GRAND COMORO I: Mozambique Channel, N of Hotel Itsandra in front of Coelacanth Grotto, depth 20–30 m, 20.II.1975 (McCosker et al.) (CAS 031662, ♀ paratype; CAS 030069, ♂ paratype).

Type-locality. Hawaiian Is: O'ahu I, off Mākua.

Habitat. Most of the specimens were taken under ledges on well-developed coral reef systems in depths greater than 20 m. The new species has long, prominent, white antennal flagella, and even though it was not found in association with any fishes, it may enter into cleaning symbiosis with cooperating fishes, much like its congeners in the genus *Stenopus.*

Etymology. This new species is named for Mr. John Earle, who first drew our attention to the animal. He not only provided the holotype and some of the paratypes but also provided color slides of these specimens. This enabled us to give an extensive morphological, as well as color, description of the species.

Key to the Described Indo-West Pacific Species of *Stenopus*

1. Lateral marginal spines absent on telson; carapace and abdomen white in life; antennal flagella white; abdominal somites with broad middorsal red stripe .... **S. pyrsonotus** Goy & Devaney, 1980
   Lateral marginal spine present on telson; abdominal somites otherwise pigmented 2
2. Rostrum not exceeding middle segment of antennular peduncle in length; without ventral spines; with 1 or more lateral spines 3
   Rostrum exceeding middle segment of antennular peduncle; with 1 to 5 ventral spines, but no lateral spines 4
3. Third abdominal somite without bare area posterodorsally; carapace white in life; antennal flagella white; abdomen with red transverse bands on 3rd and 6th somites .... **S. hispidus** (Olivier, 1811)
   Third abdominal somite with bare area posterodorsally; carapace golden yellow in life; antennal flagella red; abdomen with oval red patches on sides of 2nd and 5th somites .... **S. zanzibaricus** Bruce, 1976
4. Outer margin of scaphocerite serrate up to final (terminal) tooth; carapace reddish white in life; antennal flagella white; lateral red stripes extending from posterior of carapace along sides of abdomen, converging at telson; 3rd pereiopods reddish white except finger tips .... **S. earlei** Goy & Randall, 1984
   Outer margin of scaphocerite with considerable nonserrate space before final (terminal) tooth; rostrum exceeding antennular peduncle, with both ventral and lateral spines; carapace and abdomen otherwise pigmented; 3rd pereiopods banded in red, white, and orange 5
5. Distoventral carpal extremity of 4th and 5th pereiopods with 2 to 6 acute movable spines; carapace yellow-brown in life; antennal flagella white; abdomen with bilobed red spot on 2nd and 3rd somites .... **S. devaneyi** Goy & Randall, 1984
   Distoventral carpal extremity of 4th and 5th pereiopods without movable spines; carapace purplish blue in life; antennal flagella white; abdomen with red transverse bands on 3rd and 5th somites .... **S. tenuirostris** DeMan, 1888

DISCUSSION

Both *Stenopus devaneyi* and *S. earlei* closely follow the definition of the genus *Stenopus* given by Holthuis (1946). *Stenopus devaneyi* is generally more robust than other members of the genus, especially in having stouter appendages. In this regard, it is most closely related to *S. tenuirostris,* but differs in color and in being less spinous on the carapace, abdomen, and appendages. *Stenopus earlei* has squamous spinules on the abdominal somites in contrast to the usually erect spinules in other members of the genus. It is most closely related to *S. scutellatus* from the Western Atlantic, but differs in color and in the spination of the rostrum, scaphocerite, and 3rd maxilliped.

The only stenopodidean shrimp collected from the Marquesas Is is *S. devaneyi,* but *S. tenuirostris* has been photographed at Nuka Hiva I (BPBM photo #188, D.M. Devaney).

Also, both *S. hispidus* (Olivier, 1811) and *S. tenuirostris* have been recorded from other islands of French Polynesia (Holthuis 1946). *Stenopus hispidus* has been the only stenopodid besides *S. devaneyi* reported from Sri Lanka (Müller 1887).

Four species of stenopodidean shrimps have been reported from the Hawaiian Is: *Stenopus hispidus* (Rathbun 1906; McNeil & Ward 1930; Edmondson 1946; Tinker 1965; Hobson & Chave 1972; Titcomb 1979); *Spongicola henshawi* (Rathbun 1906); *Stenopus pyrsonotus* (Goy & Devaney 1980); and *Spongicoloides hawaiiensis* (Baba 1983). *Stenopus earlei* becomes the 5th stenopodid species collected in the Hawaiian Is. It is also reported herein from Grand Comoro I in the Indian Ocean. *Stenopus hispidus* collected from Grand Comoro I has been examined by one of us (JWG) (CAS 03-0067, CAS 030070, CAS 030071, and CAS 030073). A large (70.7 mm total length) *Stenopus pyrsonotus* (CAS 030068) also was found from Grand Comoro I. *Stenopus earlei* was photographed near Kilifi, Kenya, under a boulder inside a cave at a depth of 16 m (H. Debelius, IKAN photograph collection).

The Indo-West Pacific region occupies a large geographic area extending longitudinally more than halfway around the world and latitudinally through about 60° (Briggs 1974). In the east, this region's farthest outposts are the Hawaiian Is, the Marquesas Is, and the Tuamotu Archipelago, while in the west, the east coast of Africa provides a natural boundary (Ekman 1953). It is very interesting zoogeographically that 3 recently discovered species in the genus *Stenopus* (*S. pyrsonotus, S. devaneyi,* and *S. earlei*) have been found in these outposts. More extensive sampling in the Indo-West Pacific region will probably lead to records of these species and other stenopodidean shrimps from other localities throughout this tropical marine region.

ACKNOWLEDGMENTS

This paper would not have been possible without the extensive aid and comments of the late Dr. Dennis M. Devaney. We therefore dedicate this work to him. We are extremely grateful to Dr. Michael Türkay (Senckenberg Museum) and Mr. Robert Van Syoc (California Academy of Sciences) for the opportunity to examine and describe paratypes of *S. devaneyi* and *S. earlei,* respectively. We also would like to thank Mr. Helmut Debelius (IKAN Unterwasser-Bildarchio, West Germany) for providing color photographs of different stenopodid specimens. We are grateful to the Charles Engelhard Foundation for financial support for the color plates.

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Contributions to the Flora of Hawai'i
I. Acanthaceae—Asteraceae

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ABSTRACT

This paper, covering the families Acanthaceae, Amaranthaceae, Apiaceae, Apocynaceae, Asclepiadaceae, and Asteraceae, is the first of a series providing new records and other information pertinent to species naturalized in the Hawaiian Islands. Also presented are new species or combinations of native plants to make them available prior to the publication of the *Manual of the Flowering Plants of Hawai'i*. Discussion or comments on both native and naturalized species are provided where pertinent. The following new records of naturalized species are reported: *Alternanthera caracasana, Amaranthus lividus, Baltimora recta, Bidens gardneri, Blumea sessiliflora, Erigeron bellioides, Palafoxia callosa,* and *Zinnia palmeri.* Previously misidentified species, those that have had nomenclatural changes, or those that have been difficult to identify in Hawai'i are found in the following genera: *Hemigraphis, Ruellia, Alternanthera, Amaranthus, Hydrocotyle, Torilis, Asclepias, Ambrosia, Anthemis, Calyptocarpus, Conyza, Crassocephalum, Crepis,* and *Gnaphalium. Wedelia trilobata* is reported as becoming a sexually reproducing naturalized species. The new combination and new status *Gnaphalium sandwicensium* var. *hawaiiense* is made for the plants previously known as *G. hawaiiense.* Additional commentary is provided for the following native genera: *Rauvolfia, Gnaphalium, Lipochaeta,* and *Remya.* We conclude that *Alternanthera menziesii* and *Senecio sandvicensis,* previously considered to be endemic to the Hawaiian Is, actually represent *A. echinocephala* and *S. hydrophilus,* and that their previous inclusion in the Hawaiian flora is the result of faulty label information.

INTRODUCTION

It has been nearly a century since the last complete flora of Hawai'i was published (Hillebrand 1888). This has left the Hawaiian flora, doubtless one of the most interesting in the United States, without any significant modern inventory of its plants. A project initiated in 1982 by S.H. Sohmer and funded by the Irwin Charity Foundation of San Francisco is now underway at the Bishop Museum to produce the *Manual of the Flowering Plants of Hawai'i* (Wagner, Herbst & Sohmer, in prep.). The intent of the *Manual* is to bring together, with a uniform taxonomic treatment, the existing knowledge of the native and naturalized flowering plants pertinent to their identification, classification, distribution, and status. The project has invited knowledgeable specialists to contribute treatments of specific groups to the book and has encouraged scientists to initiate more detailed research programs on difficult Hawaiian genera. The completion of this project will be a significant step towards an overall evaluation of the native and naturalized flowering plants of the

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Hawaiian Archipelago; however, it should be followed by more detailed studies, especially in systematics, pollination ecology, autecology, genetics, and population biology.

The present series of notes is intended to bring out, prior to the publication of the *Manual,* new records of naturalized species, incorrectly identified naturalized species, and notes or comments on native and naturalized species. For some genera, new combinations or new species will be published in this series, since no new combinations or species will be published in the *Manual.*

Under each species discussed, a single collection is cited for each island on which it occurs. Also, the earliest known collection for naturalized taxa is given after the discussion of its presently known distribution in Hawai'i. References to original publications of names of naturalized species are not given, since they are available elsewhere, and the discussions of them here are more informal. However, references to original publications are given for all native Hawaiian taxa, since sources for infraspecific names are not given in standard references such as the Kew Index or St. John's checklist (1973).

ACANTHACEAE

Hemigraphis

The 2 species of *Hemigraphis* naturalized in Hawai'i have long been confused. We thank Dieter Wasshausen, Smithsonian Institution, for verification of the determinations. The following key distinguishes them.

Key to the Species of *Hemigraphis* in Hawai'i

1. Leaves cordate; floral bracts ovate, on stalks 1–2 mm long; plants sterile, no capsules produced .... **H. alternata**

   Leaves oblong-elliptic to narrowly ovate, the base truncate or rounded; floral bracts spatulate, on stalks 6–7 mm long; plants fertile, capsules narrowly ellipsoid, 6–7 mm long . . . **H. reptans**

Hemigraphis alternata (N.L. Burm.) T. Anderson

Ruellia alternata N.L. Burm.; *R. colorata* Blume; *Hemigraphis colorata* (Blume) H. Hall.

The native range of this species, known as red ivy or red-flame, is unknown, but it probably is originally from the Malay Archipelago. In Hawai'i the species is cultivated as a ground cover; it is propagated vegetatively and sometimes spreads in Honolulu lawns. A label on *Wilder s.n.* collected in 1930 (BISH) states that it was brought to Hawai'i by him from Fiji in 1927.

Hemigraphis reptans (G. Forster) T. Anderson

Ruellia reptans G. Forster.

The native range of this species also is unknown, but it was originally described from Aru I off the coast of New Guinea; in Hawai'i it is a lawn weed in Honolulu, O'ahu. First collected on O'ahu in 1957 (*Potter & Miyashiro s.n.*; BISH).

Ruellia

Three species of *Ruellia* are naturalized in Hawai'i: *R. brittoniana* Leonard, *R. graecizans* Backer, and *R. prostrata* Poir. The last species was previously misidentified in Hawai'i as *Ruellia repens* L., which differs from *R. prostrata* in its narrowly lanceolate to linear-lanceolate leaves and capsules only 1.2–1.5 cm long. *Ruellia repens* does not appear to be naturalized in Hawai'i.

Ruellia prostrata Poir.

Dipteracanthus prostrata (Poir.) Nees.

Prostrate perennial herbs; stems often rooting at the nodes. Leaves green, conspicuously paler on the lower surface, ovate, 2–10 cm long, (0.9–)1.5–4.5 cm wide, sparsely strigose, especially on the upper surface, petioles 5–30 mm long. Flowers solitary in the leaf axils, subtended by oblanceolate to ovate bracts, 15–23 mm long; calyx 5-lobed, the lobes linear, 6–10 mm long; corolla violet blue to occasionally nearly white, 2.4–3.2 cm long, the lobes slightly spreading. Capsule clavate, 1.5–2.0 cm long, densely puberulent. Native of Java; in Hawai'i it is a weed of urban areas in Honolulu, O'ahu. First collected on O'ahu in 1944 (*Neal s.n.*; BISH).

AMARANTHACEAE

Alternanthera

Alternanthera menziesii St. John was described from a single Menzies collection presumed to be from the Hawaiian Is (St. John 1957). According to Fosberg (1966) and Mears (1977), the type collection actually was made in the Galapagos Is, where Menzies did visit. The type is *A. echinocephala* (J.D. Hook.) Christopherson, which is endemic to the Galapagos Is. We have seen no evidence of *A. echinocephala* in the Hawaiian Is and agree with Fosberg and Mears that the type of *A. menziesii* was collected in the Galapagos Is. St. John (1973) included *A. menziesii* as a synonym of *A. echinocephala* and suggested that perhaps it is naturalized in Hawai'i. Subsequently, St. John (1977) resurrected *A. menziesii* and maintained that the type was indeed collected in Hawai'i and that it represents an endemic species distinct from *A. echinocephala.*

In the past there has been some confusion regarding the number of naturalized species of *Alternanthera* in Hawai'i and their correct names. There are 4 species of *Alternanthera* naturalized in Hawai'i; the following key can be used to separate them. Nomenclature and interpretation of native ranges follows Mears (1977). We are grateful to U. Eliasson for confirming our determinations of the *Alternanthera* species and providing the analysis for *A. brasiliana.*

Key to the Species of *Alternanthera* in Hawai'i

1. Scandent shrubs 1.5–4.0 m tall; inflorescences long-pedunculate, each flower on a short pedicel .... **A. brasiliana**
   Perennial herbs; inflorescences sessile in the leaf axils, each flower sessile 2
2(1). Outer sepals and bracts spine-tipped; hairs multicellular and appearing barbed 3
   Outer sepals and bracts not spine-tipped; hairs smooth or multicellular and appearing barbed 4
3(2). Inflorescences sparsely pubescent; bracts and outer sepals with spines usually > 2 mm long; outer sepals 4–5 mm long .... **A. pungens**
   Inflorescences densely pubescent; bracts and outer sepals with small spines < 1 mm long; outer sepals 3.5–4.2 mm long .... **A. caracasana**
4(2). Leaves spatulate to oblong; outer sepals 3-nerved, brown at base; hairs barbed .... **A. tenella**
   Leaves linear-lanceolate to obovate; outer sepals 1-nerved or indistinctly 3-nerved toward base, white throughout; hairs smooth .... **A. sessilis**

Alternanthera brasiliana (L.) Kuntze

Gomphrena brasiliana L.

Native from Mexico to Brazil and the West Indies; in Hawai'i known from a single collection from 300 m, ridge between Hālawa Iki and Lamaloa gulches, north side of Hālawa Valley, Moloka'i, in 1973 (*Pekelo s.n.*; BISH) where it appears to be naturalized.

According to Eliasson (pers. comm.) the detailed distribution of *Alternanthera brasiliana* in the Americas is not presently known due to a frequent confusion with *A. flavescens* H.B.K., a species with proportionally shorter bracts and bracteoles and without a dorsal crest on the bracteoles. The exact identity of the nominate variety of *A. brasiliana* is doubtful (Mears 1977); no attempt to assign the Hawaiian specimen to a variety is made. The frequently cited name *Alternanthera ramosissima* (Mart.) Chod. is a synonym of *A. brasiliana* var. *villosa* (Moq.) Kuntze. The latter variety is especially common in eastern South America (Mears 1977); the Hawaiian collection is definitely not this variety.

Alternanthera caracasana H.B.K.

A. peploides (Willd. ex Roem. & Schult.) Urban.

Alternanthera caracasana has been a weed in Hawai'i since at least the early 1920s; it has been consistently confused with *A. pungens* [*A. repens* sensu Degener (1938)]. Native to Africa, the Canary Is, and the Western Hemisphere; in Hawai'i it is a weed of dry areas such as roadsides, lawns, and beach parks on Kaua'i, O'ahu, Moloka'i, Lāna'i, and Maui. It was first collected on O'ahu in 1925 (Honolulu, *Degener 8670*; BISH).

Representative specimens examined. HAWAIIAN IS: KAUA'I: Lihu'e airport, 1938, *Lyons s.n.* (BISH); Moloka'i, Maunaloa Post Office, 1944, *Collins s.n.* (BISH); LĀNA'I: Lāna'i City, *Degener & Degener 28544* (BISH); MAUI: Pu'unēnē, 1940, *Judd s.n.* (BISH).

Alternanthera pungens H.B.K.

Achyranthes repens L.; *Alternanthera repens* (L.) Link (this combination often attributed to Kuntze), non J.F. Gmelin.

Alternanthera pungens has long been confused with *A. caracasana* in Hawai'i. Known as khaki weed, it is native to the Neotropics and is now widely naturalized in many parts of the world (Mears 1977). In Hawai'i it is a common weed of beach parks and other low-elevation, dry, disturbed sites; it is probably on all of the main islands, but we have seen specimens only from O'ahu, Moloka'i, and Hawai'i. It frequently grows with *A. caracasana.* First collected on O'ahu in 1959 (Punchbowl, *Uehara s.n.*; BISH).

Representative specimens examined. HAWAIIAN IS: MOLOKA'I: Kaunakakai, Pau Hana Inn, *Hobdy 2306* (BISH); HAWAI'I: Honaunau, *Higashino et al. 10254* (BISH).

Alternanthera sessilis (L.) DC.

Gomphrena sessilis L.; *Alternanthera ficoides* P. Beauv., non (L.) Sm.; *A. repens* J.F. Gmelin, non (L.) Link nec (L.) Kuntze.

Widespread in tropical and subtropical areas; in Hawai'i it is a common weed on O'ahu and probably on at least some of the other islands, although we have not seen any collections from the latter. First collected on O'ahu in 1935 (Kailua, *Fosberg 10928*; BISH).

Alternanthera tenella Colla

A. amoena (Lem.) Voss; *A. bettzichiana* (Regel) Voss; *A. bettzichiana* Nicholson, nom. subnud.; *A. ficoides* (L.) Sm. var. *bettzichiana* (Regel) Backer; *Telanthera bettzichiana* Regel.

Widespread in the Neotropics; in Hawai'i it is commonly cultivated and often found persisting, presumably vegetatively, around old homesites. Our plants are the cultivar of *A. tenella,* previously referred to as *A. bettzichiana.*

Amaranthus

This is a taxonomically difficult genus of about 50 species chiefly of warm temperate and subtropical regions of the world; a number of species are cosmopolitan weeds. The naturalized species in Hawai'i are greatly in need of further collection, and the distributions stated below most likely do not reflect the full geographical ranges of the species. Most BISH material was lost while on loan, and thus the dates of first collection, as well as distributions, probably are inaccurate. We thank C.C. Townsend, Royal Botanic Gardens, Kew, for determinations on BISH material and for comments on the manuscript. Nomenclature follows Townsend (pers. comm.).

Key to the Species of *Amaranthus* in Hawai'i

1. Leaf axils with paired spines .... **A. spinosus**
Leaf axils without paired spines 2
2(1). Fruit dehiscent, with circumscissile lid 3
Fruit indehiscent or rupturing irregularly at maturity 4
3(2). Staminate flowers usually only at apex of spikes, rarely scattered among pistillate flowers; capsule lid wrinkled near line of dehiscence .... **A. dubius**
Staminate flowers intermingled with pistillate flowers along length of spikes; capsule lid smooth .... **A. hybridus**
4(2). Leaves linear; fruit 0.8–1.0 mm long .... **A. brownii**
Leaves deltoid-ovate, ovate, or rhombic-ovate; fruit 1.2–2.5 mm long 5
5(4). Flowers primarily in terminal, paniculate spikes with some small axillary clusters; fruit strongly rugose, slightly compressed to globose; seeds conspicuously reticulate under high magnification .... **A. viridis**
Flowers primarily in axillary and terminal spikes, rarely paniculate; fruit smooth to sometimes wrinkled when drying, distinctly compressed; seeds inconspicuously reticulate under high magnification .... **A. lividus**

Amaranthus brownii Christophersen & Caum

Amaranthus brownii (Christophersen & Caum 1931) is endemic to Nihoa, occurring at 120–215 m. This rare species is not presently common anywhere on the island. It was collected most recently in 1980 (*Herbst & Takeuchi 6545*; BISH); however, roughly a dozen plants were observed by W. Gagné, Bishop Museum (pers. comm.), on a field trip to Nihoa in 1983.

Amaranthus dubius Mart. ex Thell.

Native to tropical areas of the Old World; in Hawai'i naturalized in low-elevation, disturbed sites on O'ahu, Lāna'i, and Hawai'i. The earliest collection we have seen was made on O'ahu in 1972 (Kahana Val, *Herat & Wirawan 212*; BISH), although Fosberg (pers. comm.) states that he was aware of its presence in Hawai'i as early as the 1930s.

Representative specimens examined. HAWAIIAN IS: LĀNA'I: Keōmuku, *Herbst & Spence 4022* (BISH); HAWAI'I: Pōhakuloa State Pk, state bird propagating facility, *Herbst 5946* (BISH).

Amaranthus hybridus L.

Apparently native to the New World; in Hawai'i the green amaranth is very sparingly naturalized at low elevations on O'ahu and Maui. It was first collected on O'ahu in 1930 (Kāne'ohe, *Wilder s.n.*; BISH). Our plants can be referred to subsp. *hybridus,* which is distinct in that the bracteoles of the pistillate flowers are usually 1.5–2.0 × longer than the perianth and the fruit has a distinct inflated neck.

Representative specimens examined. HAWAIIAN IS: MAUI: Kahakuloa, *Handy 34.15* (BISH).

Amaranthus lividus L.

A. blitum L.

A native of warm temperate and tropical regions throughout the world; in Hawai'i it apparently is sparingly naturalized in disturbed areas on O'ahu and Hawai'i. Not previously reported for the state. The earliest collection we have seen was made on O'ahu in 1971 (Mānoa Val, *Nagata 910*; BISH, HLA). Our plants can be referred to subsp. *polygonoides* (Moq.) Probst, which is distinct in having smaller leaves (rarely more than 4 cm long), usually prostrate to decumbent stems, and fruit 1.2–1.8 mm long.

Representative specimens examined. HAWAIIAN IS: HAWAI'I: Ka'ū Dist, Ka'ū Sugar Mill, *Herbst & Ishikawa 5517* (BISH).

Amaranthus spinosus L.

Cosmopolitan in the warmer regions of the world, perhaps of American origin; in Hawai'i the spiny pigweed is naturalized and often common in low-elevation, disturbed sites on Kure Atoll, Kaua'i, O'ahu, Moloka'i, Maui, Kaho'olawe, and Hawai'i, perhaps also on Ni'ihau and Lāna'i. Naturalized prior to 1928 (Neal & Metzger 1928).

Representative specimens examined. HAWAIIAN IS: KURE ATOLL: Green I, *Lamoureux 2804* (BISH); KAUA'I: Lāwa'i Val, *Herbst 2024* (BISH); O'AHU: Queen's Beach, *Wagner et al. 4813* (BISH); MOLOKA'I: Hālawa Val, *Ishikawa 136* (BISH); MAUI: SE of Lāhainā, *Ishikawa 155* (BISH); KAHO'OLAWE: Smuggler's Cove, *Char 78.077* (BISH); HAWAI'I: Hawai'i Volcanoes Natl Pk, Halapē Beach, *Herat et al. 861* (BISH).

Amaranthus viridis L.

A. gracilis Desf. ex Poir.; *A. lineatus* sensu Hillebr.; *Euxolus lineatus* sensu Hillebr.

Cosmopolitan in tropical and subtropical regions; in Hawai'i it is the most common naturalized species of *Amaranthus*, occurring in low-elevation, disturbed habitats on Ka'ula, Kaua'i, O'ahu, Lāna'i, Maui, Kaho'olawe, and Hawai'i. Naturalized prior to 1871 (Hillebrand 1888).

Representative specimens examined. HAWAIIAN IS: KA'ULA, *Herbst 6215* (BISH); KAUA'I: Lāwa'i Val, *Wagner et al. 5141* (BISH); O'AHU: Queen's Beach, *Wagner et al. 4808* (BISH); LĀNA'I: W Lāna'i, nr pineapple station, *Spence 167* (BISH); MAUI: Paeahu, *Herbst & Ishikawa 5400* (BISH); KAHO'OLAWE: Moa'ula, *Char 78.026* (BISH); HAWAI'I: Hawai'i Volcanoes Natl Pk, Hilina Pali, *Herat & Higashino 903* (BISH).

Charpentiera

In the revision of *Charpentiera* (Sohmer 1972) a neotype was selected for *C. elliptica* (Hillebr.) A. Heller; however, it has come to our attention that syntype material is available and thus a lectotype must be selected. Hillebrand cited 2 collections, one from Kaua'i and another from Maui, as well as the illustration in *Indigenous Flowers of the Hawaiian Islands* (Sinclair 1885). Hillebrand's original material was destroyed in Berlin during WW II, but a duplicate of the Maui collection and the illustration are both available for lectotypification; therefore, the neotype is not necessary. The Maui collection is *C. obovata* and thus has no relevance to the Kaua'i endemic long known as *C. elliptica*. Thus, to retain the epithet "*elliptica*" for the Kaua'i species we designate the Sinclair illustration (**pl. 44**) as lectotype of *C. elliptica* [based on *C. obovata* Gaud. var. *elliptica* Hillebr., Fl. Hawaiian Isl. 375. 1888. TYPE: **Pl. 44** in Sinclair, 1885, *Indigenous Flowers of the Hawaiian Islands,* lectotype, here designated].

APIACEAE

Hydrocotyle

Plants described by Degener & Greenwell (1956a) as *Hydrocotyle sibthorpioides* Lam. var. *oedipoda* Degener & Greenw. from Kilauea, Hawai'i, were thought to represent a naturalized taxon probably from Asia. L. Constance & J.M. Affolter, as part of their treatment of Apiaceae for the *Manual* (submitted), have determined this to be *H. bowlesioides* Math. & Const., a species native to Costa Rica.

Hydrocotyle bowlesioides Math. & Const.

H. sibthorpioides Lam. var. *oedipoda* Degener & Greenw.

Stems slender, creeping, hirsute. Leaves not peltate, roundish-reniform with a sinus at the base, excluding the petioles 10–20 mm long, 15–30 mm wide, shallowly 5-lobed, the lobes obtusely triangular, crenate, subequal, both surfaces hirsute, petioles slender, 1–12 cm long, reflexed-hirsute especially above. Umbels not proliferous, 2–10-flowered, globose, peduncles much shorter than leaves, axillary, slender, 2–12 mm long. Fruit ellipsoid, ca. 1 mm long, 1.5 mm wide, sessile, finely hispidulous in the intervals, ribs conspicuous, acute, subequal. Native to Costa Rica; in Hawai'i naturalized in open, sunny sites on O'ahu and Hawai'i. First collected on Hawai'i in 1943 (*Degener & Wiebke 3002*; UC).

Representative specimens examined. HAWAIIAN IS: O'AHU: Honolulu, *Herbst 8550* (BISH).

Torilis

Torilis japonica (Houtt.) DC. was recorded as naturalized in Hawai'i by St. John (1973); however, we have seen no evidence of this. The single collection known to us of *Torilis* made in Hawai'i in 1911, near Kanahāhā, Kona, Hawai'i (*Forbes 272.H*; UC), represents *T. nodosa*. There are no known recent collections of this species, and it may not be part of the naturalized flora. Determination and description of the following species as well as comments on the situation are based on Constance & Affolter (submitted).

Torilis nodosa (L.) Gaertn.

Tordylium nodosum L.

Plants slender, decumbent, 1–6 dm tall, hispid throughout, the branches spreading. Leaves oblong in general outline, 1–2-pinnately compound, the ultimate divisions linear to filiform, 1–2 mm wide, entire or lobed, acute. Peduncles 0–2.5 cm long, shorter than the leaves, involucre usually absent, involucel of 6–8 linear-lanceolate, acute bractlets longer than the pedicels, rays 2–3, short to absent. Fruit ovoid, 3–5 mm long, 1–2 mm wide, the outer mericarps bristly, the inner ones warty or bristly externally. Native to Europe; in Hawai'i apparently sparingly naturalized and known from a single collection near Kanahāhā, Kona, Hawai'i.

APOCYNACEAE

Rauvolfia

Rauvolfia sandwicensis A. DC.

Ochrosia sandwicensis A. DC.; *Rauvolfia degeneri* Sherff; *R. forbesii* Sherff; *R. helleri* Sherff; *R. mauiensis* Sherff; *R. molokaiensis* Sherff; *R. m.* var. *parvifolia* Degener & Sherff; *R. m.* var. *typica* Sherff; *R. remotiflora* Degener & Sherff; *R. sandwicensis* var. *subacuminata* Sherff; *R. s.* var. *typica* Sherff.

Rauvolfia sandwicensis is the only member of the endemic sect. *Ochrosioides.* Rao (1956) states that *Rauvolfia sandwicensis* is related to members of the New World sect. *Macrovolfia*; however, in the smooth backs of the anthers, *R. sandwicensis* resembles the African sect. *Afrovolfia.*

As treated here, *Rauvolfia sandwicensis* is a widespread, variable species found on all of the main islands except Kaho'olawe, primarily on ridges, slopes, and gulches in mixed mesophytic forest, but also scattered in relatively low-elevation, open, dryland sclerophyll forest remnants, *Lantana* thickets, and, rarely, in open margins of low-elevation rain forest. It is also found on lava flows on Maui and Hawai'i, 100–500(–800) m.

Sherff (1947) and St. John (1980) recognized 7 species in Hawai'i. Our study of over 150 collections of this genus suggests that there is but 1 variable species in Hawai'i. The 7 species described by Sherff are based largely on leaf variation and, to some extent, calyx size and relative congestion of the inflorescence. When carefully compared these features seem to vary in a rather continuous fashion; however, 2 modally distinct groupings can be identified as follows:

Group 1 (*R. degeneri*) is distinctive because of its large calyx (4–)6–8(–10) mm long.

Representative specimens examined. HAWAIIAN IS: O'AHU: Wai'anae Mts, Pu'uku'ua, *Takeuchi et al. Waianae-134a* (BISH).

Group 2 (*R. forbesii, R. helleri, R. mauiensis, R. molokaiensis, R. remotiflora,* and *R. sandwicensis*) is characterized by the calyx 1–5 mm long. It is widespread, occurring on Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i. This group is highly variable in calyx length, leaf size, peduncle length, and to some degree, fruit length and width. This variation correlates somewhat with geography; e.g., plants from Maui tend to have small leaves, but they grow in dryer habitats than most populations from the other islands, suggesting that the difference is largely ecological. The 2 groups intergrade to some degree on O'ahu.

Representative specimens examined. HAWAIIAN IS: KAUA'I: Kōke'e State Pk, Nonou Trail, *Herbst 1084* (BISH); O'AHU: Mānoa Cliff Trail, *Stone 3116-A* (BISH); MOLOKA'I: Wailau Val, *Degener & Nitta 9795* (BISH); LĀNA'I: head of trail Maunalei, *Munro 71* (BISH); MAUI: Auwahi, *K. Nagata 1935* (BISH); HAWAI'I: Kealakomo, Puna, *Stone 3016* (BISH).

At present we do not want to formally treat these entities as subspecies without detailed study.

ASCLEPIADACEAE

Asclepias

One of the 2 naturalized species here placed in *Asclepias* was previously known in Hawai'i as *Gomphocarpus physocarpus* E. Mey. The African species of *Asclepias,* which usually lack the internal horn in the hood, have been segregated in the past as the genus *Gomphocarpus.* According to Brown (1904) this genus should be included in *Asclepias. Asclepias physocarpa* (E. Mey.) Schlechter is native to South Africa; in Hawai'i it is naturalized in low-elevation, dry habitats occasionally up to 800 m on Kaua'i, O'ahu, Lāna'i, Maui, Kaho'olawe, and Hawai'i. According to Degener & Greenwell (1956b) it was originally introduced as a fiber crop on O'ahu, where it was first collected in 1919 (Halawa Val, *Gouveia s.n.*; BISH).

Representative specimens examined. HAWAIIAN IS: KAUA'I: Lāwa'i Val, *Herbst 2014* (BISH); MAUI: W of Maunawainui, *Wagner et al. 4771* (BISH); LĀNA'I: Lāna'i City, *Degener & Degener 28621* (BISH); KAHO'OLAWE: Moa'ula, *Clarke 415* (BISH); HAWAI'I: Hawai'i Volcanoes Natl Pk, *Herat et al. 822* (BISH).

ASTERACEAE

Ambrosia

Ambrosia artemisiifolia L.

A native of the United States and southern Canada; in Hawai'i it is naturalized in low-elevation, dry, disturbed habitats, especially along roadsides and in pastures, 0–900 m, on O'ahu, Moloka'i, Maui, and Hawai'i. It has been naturalized at least since 1854 (Hillebrand 1888).

Representative specimens examined. HAWAIIAN IS: O'AHU: Waialua, Hale'iwa Pt, *Fosberg 27129* (BISH); MOLOKA'I: 'Ualapu'e, *Degener 5594* (BISH); MAUI: Waipi'o, Kīpapa Gulch, *Hosaka 1277* (BISH); HAWAI'I: junction of Māmalahoa Hwy and Saddle Rd, *Herbst & Spence 5313* (BISH).

Franseria strigulosa Rydb. (= *Ambrosia confertiflora* DC.) does not occur in Hawai'i as has long been assumed (Degener 1937; St. John 1973). The BISH specimens labeled as "*Franseria strigulosa*" are fruiting specimens of *A. artemisiifolia,* while those labeled as *A. artemisiifolia* are all immature specimens.

Anthemis

Anthemis cotula L.

A native of Europe; in Hawai'i it is sparingly naturalized in scattered localities on Kaua'i, Lāna'i, and Hawai'i. First collected on Hawai'i in 1909 (Parker Ranch, *Rock 3372–3374*; BISH).

Representative specimens examined. HAWAIIAN IS: KAUA'I: Waimea drainge basin, *Forbes 1056.K* (BISH); LĀNA'I: Kō'ele, *Munro 174* (BISH).

Some plants of this species from the island of Hawai'i have been misidentified previously as *Matricaria chamomilla* L., which differs from *Anthemis* in that the receptacle is naked. *Matricaria* is not known to be naturalized in Hawai'i.

Baltimora

We thank W. Arthur Whistler, Pacific Tropical Botanical Garden, for pointing out this recently naturalized species.

Baltimora recta L.

Erect annual herbs up to 1(–3) m tall; stems many-branched, strigose throughout. Leaves simple, opposite, ovate, 2.5–18.0 cm long, 1.5–12.0 cm wide, both surfaces strigose and scabrous, margins crenate-serrate, apex long-acuminate, base truncate to broadly cuneate, petioles 1–7 cm long. Heads usually in large panicles, rarely racemes, peduncles 8–33 mm long; involucral bracts 3–6, in 3 series, base ± scarious, tips herbaceous, 3.5–6.0 mm long, weakly strigose and ciliate at the apex; receptacle chaffy throughout, the bracts conduplicate, membranous, lanceolate, 3.5–4.2 mm long; ray florets 3–8 per head in a single series, pistillate and fertile, rays yellow, 3.8–5.5 mm long; disk florets 16 or sometimes more per head, functionally staminate, corollas 5-lobed, yellow, ca. 1.5 mm long, style undivided; pappus appearing to be absent, but present as a very small crown of minute scales. Achenes developing only from ray florets, thick, 3-angled, 2.4–3.2 mm long, apex truncate, angled, ± winged, puberulent. Native from Chiapas and Yucatan, Mexico, southward throughout Central America; in Hawai'i very sparingly naturalized at Makapu'u, O'ahu. First collected in 1984 (*Whistler s.n.*; BISH).

Bidens

Bidens alba (L.) DC., *B. cynapiifolia* H.B.K., and *B. pilosa* L. have been the only species of *Bidens* known to be naturalized in Hawai'i. Here we report a 4th naturalized species. We thank F.R. Ganders, University of British Columbia, for providing the determination and description of the species.

Bidens gardneri Baker

Erect annual herbs (0.5–)0.6–1.6 m tall. Leaves simple or trifoliolate below, pinnatifid or bipinnatifid above, usually 3–8 cm long including petiole. Heads 3–12 in compound cymes terminating main stem as well as lateral branches, 2–3 cm in diameter including ray florets, peduncles (5–)10–25 cm long; outer involucral bracts linear or spatulate-tipped, (2.0–)3.0–4.5 mm long; ray florets 6–8 per head, sterile, rays orange, 12–16 mm long; disk florets 20–30 per head, perfect, corollas yellow or brownish; pappus of (3)4 awns 1–2 mm long, with pectinate retrorse barbs. Achenes grayish black, straight, wingless, 7–12 mm long, 1.0–1.5 mm wide, subglabrous. Native from Paraguay to central Brazil; in Hawai'i apparently recently naturalized on Moloka'i. First collected in 1983 on dry, open ridge, Honouli Wai (*Hobdy 1833*; BISH).

Blumea

Previously only *Blumea laciniata* was reported as naturalized in Hawai'i (Degener 1934; St. John 1973). Here we report 1 additional naturalized species.

Blumea sessiliflora Decne.

Similar to *B. laciniata* except its stems are up to 1 m tall, unbranched or branched, erect, leaves 4–16 cm long, 1.4–6.0 cm wide, sessile, heads in clusters of 3–5 in an interrupted spike, sessile, involucral bracts spreading, 1.5–6.5 mm long, receptacle glabrous. A native of Indonesia, Indochina, southern China, Burma, and Peninsular India; in Hawai'i it is known from 1 specimen collected in 1920 (*Forbes s.n.*; BISH) on the island of Maui without further locality data. It is not presently known if this species has persisted. *Blumea laciniata* is known in Hawai'i generally in low-elevation, disturbed sites on O'ahu and Hawai'i. It was first collected on O'ahu in 1923 (*Degener 5286*; BISH).

Calyptocarpus

In Hawai'i *Calyptocarpus vialis* has been confused with *Synedrellopsis grisebachii* Hieron. & Kuntze, which was reported by St. John (1973). We thank F.R. Fosberg, Smithsonian Institution, for information on the earliest collection of this species.

Calyptocarpus vialis Less.

Synedrella vialis (Less.) A. Gray.

Perennial herbs; stems sprawling to prostrate, (1–)2–6 dm long, often rooting at the nodes. Leaves simple, opposite, deltoid, 1–3(–6) cm long, 1–2(–4) cm wide, margins serrate, petioles 0.5–1.5 cm long. Heads radiate, solitary, rarely 2 or more, in the leaf axils; involucral bracts 3–5, herbaceous, partially overlapping, 5–10 mm long, the inner bracts shorter and narrower; receptacle chaffy; ray florets pistillate and fertile, rays yellow, 1.5–3.0 mm long; disk florets perfect and fertile, 4-merous, corollas ca. 2.5 mm long; pappus consisting of a pair of stout, spreading marginal awns 1–2(–4) mm long. Achenes of 2 slightly different types, the inner ones somewhat flattened, the margins rounded, the peripheral ones sometimes with lacerate thickenings on the margins toward the apex, tuberculate. A native of Texas south to Guatemala, Costa Rica, and Cuba; in Hawai'i it is now a common weed of disturbed habitats, especially lawns; it is probably on all of the main islands, but we have seen collections only from Kaua'i, O'ahu, Lāna'i, and Maui. First collected on O'ahu in 1963 (Kalihi, *Fosberg 44449*; US).

Representative specimens examined. HAWAIIAN IS: KAUA'I: Līhu'e, *Herbst 5247* (BISH); LĀNA'I: Lāna'i City, *Herbst & Spence 5797* (BISH); MAUI: Kahului, *Hobdy 1873* (BISH).

Conyza

Plants of this genus in Hawai'i usually have been included in the genus *Erigeron*; however, *Conyza* is generally accepted by botanists worldwide. In Hawai'i there are 2 widely naturalized species.

Key to the Species of *Conyza* in Hawai'i

1. Involucre 4–6 mm high, densely pubescent; pistillate florets 50–200 or more per head; plants usually canescent . . . . **C. bonariensis**
   Involucre 3–4 mm high, glabrous or nearly so; pistillate florets 25–40 per head; plants glabrous to hirsute, green . . . . **C. canadensis**

Conyza bonariensis (L.) Cronq.

Erigeron bonariense L.; *Conyza albida* Willd. ex Spreng.; *C. floribunda* H.B.K.; *Erigeron albidus* (Willd. ex Spreng.) A. Gray.

Perhaps native to South America but nearly cosmopolitan; it is a common weed in both urban and nonurban areas, generally in relatively dry habitats, on all of the main Hawaiian Is and Kure Atoll, Midway Atoll, Laysan, and French Frigate Shoals of the Northwest Hawaiian Is. Naturalized in Hawai'i prior to 1871 (Hillebrand 1888).

This species commonly has been confused with the next one but can be separated by the characters in the key.

Conyza canadensis (L.) Cronq.

Erigeron canadense L.; *Conyza parva* Cronq.; *Erigeron pusillus* Nutt.

A native of southern Canada south to tropical America, widely naturalized; in Hawai'i it is naturalized in relatively dry, disturbed areas on Ni'ihau, Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i.

There are 2 varieties of *Conyza canadensis* in Hawai'i resulting from independent introductions. *Conyza canadensis* var. *pusilla* (Nutt.) Cronq. (incl. *Conyza parva* and *Erigeron pusillus*) is a small, subglabrous plant generally less than 5 dm tall with some or all of the involucral bracts purple-tipped. Its distribution in Hawai'i is the same as that listed above for the species. Naturalized in Hawai'i prior to 1871 (Hillebrand 1888).

Representative specimens examined. HAWAIIAN IS: NI'IHAU: Ka'aliwai, *St. John 23568* (BISH); KAUA'I: Kaholuamanu, *Heller 2820* (BISH); O'AHU: Mānoa Val, *Caum s.n.* (BISH); MOLOKA'I: below Pu'ukolekole, *Nagata 2709* (BISH); LĀNA'I: Kamoku, *Munro 235* (BISH); MAUI: Pu'u'ōuli, *Forbes 2144.M* (BISH); HAWAI'I: Volcano, *Herbst 5539* (BISH).

Conyza canadensis var. *canadensis* has not been previously recorded in Hawai'i; it is taller than var. *pusilla* (generally over 1 m), the lower stem is coarsely hirsute, and the involucral bracts usually lack purple tips. Until 1984 it was known only from the lower slopes of Mauna Kea and the Pōhakuloa Training Area in the saddle between Mauna Loa and Mauna

Kea, Hawai'i; it was collected in 1984 on Maui. The earliest collection in Hawai'i is from Waiki'i, Hawai'i, in 1911 (Mauna Kea, *Forbes 467.H*; BISH).

Representative specimens examined. HAWAIIAN IS: MAUI: Kahului industrial area, *Hobdy 2085* (BISH).

Crassocephalum

Locally the following species has been confused with *Erechtites hieracifolia* (L.) Raf. ex DC.

Crassocephalum crepidioides (Benth.) S. Moore

Gynura crepidioides Benth.

Annual herbs 3–5(–15) dm tall, unbranched or branched above, upper stem and inflorescence strigillose, often densely so. Leaves simple, alternate, elliptic to oblanceolate or ovate, lyrate-pinnatifid to toothed, 5–18 cm long, 1–6 cm wide, margins coarsely and irregularly dentate. Heads in terminal corymbs, nodding during anthesis, becoming erect, discoid, homogamous; involucre in a single series, the bracts coherent, 8–10 mm long, subtended by a series of smaller, distinct, often purple bracts; receptacle naked; florets numerous, red to reddish orange; pappus consisting of numerous white capillary bristles ca. 12 mm long. Achenes reddish brown, cylindrical, ca. 2 mm long, with 8–10 weakly developed ribs, sparsely puberulent between the ribs.

According to Belcher (1955) this species is a native of tropical Africa, widely naturalized throughout the Old World; in Hawai'i it is naturalized in habitats ranging from relatively dry areas to wet forest on Kaua'i, O'ahu, Maui, and Hawai'i, and it apparently is spreading rapidly. First collected on O'ahu in 1929 (Hau'ula, *Bryan 702*; BISH).

Representative specimens examined. HAWAIIAN IS: KAUA'I: Limahuli, *Wagner et al. 5155* (BISH); MAUI: Ke'anae Arboretum access rd, *Hobdy 1921* (BISH); HAWAI'I: Hilo, *Herbst 8552* (BISH).

Crepis

The only species of *Crepis* that is naturalized in Hawai'i has been consistently misidentified as *C. pulchra* L. (e.g., Neal 1965; St. John 1973).

Crepis capillaris (L.) Wallr.

Lapsana capillaris L.; *Crepis pulchra* sensu Hawaiian botanists, non L.

Annual or biennial herbs 2–9 dm tall, often branched; stems hirsute, at least near the base. Leaves lanceolate or oblanceolate, 3–30 cm long, 0.5–4.5 cm wide, glabrous or hirsute, quickly reduced upward, denticulate to pinnatifid, lower leaves on short petioles, upper ones sessile and even clasping. Heads with 20–60 florets; involucre 5–8 mm high, often with long black glandular hairs along the midrib of the bracts. Achenes tawny to pale brown, fusiform, ca. 10-ribbed, 1.5–2.5 mm long. A native of central and southern Europe; in Hawai'i it is naturalized on the island of Hawai'i. First collected in 1934 (Parker Ranch, *Ewart 342*; BISH).

Erigeron

Previously the only *Erigeron* naturalized in Hawai'i was *E. karvinskianus* DC. A 2nd species is now naturalized on O'ahu.

Erigeron bellioides DC.

Delicate herbs, spreading by slender stolons; stems 6–15 cm long, the flowering stems erect, ± with very reduced leaves, the stolons 10–15 cm long, ± with reduced leaves. Leaves primarily basal, spatulate, 1.0–3.5 cm long, 0.3–1.0 cm wide, abruptly constricted to winged petioles 1.0–2.5 cm long. Heads 1.5–3.0(–5) mm in diameter; involucral bracts in 2 series, the inner one ca. 2 mm long, the outer similar but shorter; rays white, ca. 0.3 mm long. Achenes pale straw-colored, ca. 1 mm long. Native to the Greater Antilles; in Hawai'i relatively recently naturalized only in Honolulu and Kāne'ohe, O'ahu. First observed on the University of Hawai'i Manoa campus by Herbst in 1977 and collected in 1984 (*Wagner 5392*; BISH).

One collection of *Erigeron annuus* (L.) Pers. (*Hosaka 1563*; BISH) identified by A. Jones, University of Illinois, was made in 1936 at Hāmākua, Hawai'i, but this species has not been collected since that time.

Gnaphalium

There are 2 naturalized and 1 widespread, variable endemic species of *Gnaphalium* in Hawai'i. The genus was studied by Sherff (1948, 1949) and reviewed by Degener & Degener (1960a, 1960b, 1960c, 1960d, 1962) and by Degener et al. (1970). Below we reassess the native taxa, reducing *G. hawaiiense* to a variety of the common *G. sandwicensium*. Among the naturalized species, *G. purpureum* and *G. peregrinum* have long been recognized in the Hawaiian literature, but they actually represent a single species.

Key to the Species of *Gnaphalium* in Hawai'i

1. Heads in dense, globose clusters, these subtended by linear, leaflike bracts ... **G. japonicum**
Heads in spikelike, corymbose, or rarely nearly globose clusters, these never subtended by linear, leaflike bracts 2
2(1). Pappus bristles connate at base, falling away in a ring; heads in spikelike arrangements; annual or biennial herbs .... **G. purpureum**
Pappus bristles distinct or sometimes slightly connate at base; heads in corymbose or sometimes in nearly globose arrangements; perennial herbs .... **G. sandwicensium**

Gnaphalium japonicum Thunb.

Erect annual herbs usually 2–4 dm tall, often densely white tomentose. Leaves oblong-spatulate to linear, usually 1–7 cm long, 0.1–0.7 cm wide, the margins usually rolled under, glabrate above and densely white tomentose below. Heads small, in dense terminal, globose clusters, these subtended by linear, leaflike bracts; involucral bracts brown or straw-colored, woolly at the base; pappus bristles distinct, scarcely coherent at the base. Native of Australia; in Hawai'i relatively common in dry to wet, disturbed habitats, along roadsides or in pastures, 600–2,800 m, on Moloka'i, Lāna'i, Maui, and Hawai'i. First collected on Maui in 1909 (Haleakalā, *Faurie 928*; BISH).

Representative specimens examined. HAWAIIAN IS: MOLOKA'I: cliffs above Kalaupapa, *Swezey s.n.* (BISH); LĀNA'I: Mahana Ridge, *Rock 8079* (BISH); MAUI: Haleakalā, Ko'olau Gap, *Degener 18451* (BISH); HAWAI'I: Humu'ula, *Neal & Hartt 663* (BISH).

Gnaphalium purpureum L.

G. peregrinum Fernald.

Erect annual or biennial herbs 1–4(–10) dm tall, sparsely to moderately woolly. Lower leaves spatulate to oblanceolate, 2–5(–9) cm long, 0.3–2.0 cm wide, gradually becoming reduced up the stem, the uppermost leaves oblanceolate to oblong or even linear, densely white tomentose below, more sparsely so or glabrate above. Heads in terminal, spikelike, sometimes interrupted clusters, sometimes with a few small, leafy bracts; involucral bracts light brown or purple, woolly below; pappus bristles connate, forming a ring at the base, deciduous as a unit. Native to North America; in Hawai'i naturalized and relatively common from dry to wet, disturbed habitats, especially roadsides, pastures, and open lava, from near sea level to 2,100 m, on all of the main islands except Ni'ihau. Naturalized in Hawai'i prior to 1871 (Hillebrand 1888).

Representative specimens examined. HAWAIIAN IS: KAUA'I: Limahuli Garden, *Wagner et al. 5157* (BISH); O'AHU: Honolulu, *Herbst & Ishikawa 5269* (BISH); MOLOKA'I: peninsula E of Wailau Val, *Fosberg 9647* (BISH); LĀNA'I: Lāna'i City, *Degener & Degener 28408* (BISH); MAUI: 'Ulupalakua, *Hosaka 1797* (BISH); KAHO'OLAWE: Luakeālia Lalo, *Cuddihy & Char 355* (BISH); HAWAI'I: upper Waiākea Forest Res, *Wagner et al. 4842* (BISH).

Gnaphalium sandwicensium Gaud.

Gnaphalium hawaiiense Degener & Sherff; *G. luteo-album* sensu Hillebr., non L.; *G. sandwicensium* var. *flagellare* Sherff; **G. s.** var. **hawaiiense** (Degener & Sherff) W.L. Wagner, Herbst & Sohmer, comb. et stat. nov.; **G. s.** var. **kilaueanum** Degener & Sherff; *G. s.* var. *lineatum* Sherff; **G. s.** var. **molokaiense** Degener & Sherff; *G. s.* var. *typicum* Sherff; *G. s.* var. *t.* f. *canum* Sherff; *G. s.* var. *t.* f. *olivaceum* Degener & Sherff.

Perennial herbs 1.0–6.5 dm tall, moderately to densely woolly; stems olive green to white or gray, erect to prostrate, unbranched to many-branched. Leaves linear-spatulate to spatulate, 1.0–6.5 cm long, 0.1–2.0 cm wide, the uppermost ones usually reduced, both surfaces densely woolly, upper surface sometimes less dense or the hairs deciduous in age, sessile and sometimes somewhat clasping. Heads 1.5–7.0 mm in diameter, arranged in terminal, corymbose or sometimes nearly globose, leafless or nearly leafless clusters; involucral bracts whitish to pale yellow, ± shiny, sometimes obscured by dense woolly hairs; pappus bristles free or cohering at the base, individually deciduous or in clusters. Scattered to common in relatively dry sites from near sea level on clay or consolidated dunes, and at higher elevations on dry sites, especially lava or cinders, 0–3,000 m, on all of the main islands except Kaua'i and Kaho'olawe and apparently also native to Kure and Midway atolls.

All of the native populations of *Gnaphalium* have been treated here as constituting 1 highly variable species. There are, however, 4 modally distinctive entities that can be recognized.

a) var. **hawaiiense** (Degener & Sherff) W.L. Wagner, Herbst & Sohmer, **comb. et stat. nov.** [Based on *Gnaphalium hawaiiense* Degener & Sherff, Am. J. Bot. 36: 507. 1949. TYPE: HAWAIIAN IS: HAWAI'I: Kīlauea, 9.IV.1930, *O. Degener 18462b* (NY, holotype, photo F). Part of this collection also serves as the type of *G. sandwicensium* var. *kilaueanum*]. Differs principally in that it is very fragrant, has leaves 1–2(–3) mm wide and the heads loosely disposed within the clusters, each one easily distinguishable individually. It has a similar distribution as var. *kilaueanum* except it also occurs at Waimea and South Kohala, Hawai'i, and Auwahi, Maui.

Specimens examined. HAWAIIAN IS: MAUI: S slope of Haleakalā, Kamana, *Forbes 2125.M* (BISH); Auwahi, *K. Nagata 1934* (BISH); Maui Zoological and Botanical Gardens (from Auwahi), *Davis & Sylva 12* (BISH); HAWAI'I: Mauna Kea, 0.5 km W of Pōhakuloa Gulch, *Warshauer & McEldowney 3144* (BISH); nr 1907 lava flow, *Degener & Wiebke 2124* (BISH); Kipapala Ranch, *Greenwell s.n. (Degener's no. 20707)* (BISH); Pu'uke'eke'e, *Degener et al. 19818* (BISH); Hawai'i Volcanoes Natl Pk, Halapē Trail, *Herat et al. 833* (BISH); Humu'ula Sheep Sta, *Hosaka 2321* (BISH); Waimea, range paddock, *Hosaka 2057* (BISH); Hualālai, back of Hu'ehu'e, *Rock 3637* (BISH); slopes of Hualālai, *Rock 3636* (BISH); summit of Hualālai, *Forbes 167.H* (BISH); 1853 lava flow nr Pu'uwa'awa'a, *Forbes 63.H* (BISH); Volcano Kīlauea, *Forbes & Brigham s.n.* (BISH).

b) var. **kilaueanum** differs from var. *sandwicensium* in that the stems are up to 6.5 dm long, leaves 1.5–5.0 mm wide, and the exterior involucral bracts are shiny, white to yellowish. It is restricted to the island of Hawai'i on the high plains between Mauna Loa and Mauna Kea, extending down into North and South Kona, and the Ka'u Desert, Kīlauea, 1,200–3,000 m.

Representative specimens examined. HAWAIIAN IS: HAWAI'I: Pu'uhuluhulu, *Wagner et al. 5239B* (BISH).

c) var. **molokaiense** is very densely white woolly over the entire plant, the stems prostrate to sometimes erect, 1–3 dm long, the leaves spatulate to narrowly obovate, the lower ones usually 0.7–2.0 cm wide, and only the tips of the involucral bracts exposed, the remainder densely woolly. It is endemic to the strand and consolidated dunes of western Moloka'i and vulnerable because of potential development of coastal areas.

Representative specimens examined. HAWAIIAN IS: MOLOKA'I I: Mo'omomi, *Herbst & Spence 5103* (BISH).

d) var. **sandwicensium** (vars. *flagellare* and *lineatum*) has stems unbranched to branched, usually erect, usually 2–4 dm long, ± woolly, whitish to distinctly olive green, leaves linear to sometimes spatulate, 1.5–8.0(–15.0) mm wide, densely woolly, the upper surface usually less pubescent, heads 1.5–3.0 mm wide, the involucral bracts tan to whitish, glabrate except at the very base. This variety occurs on Kure Atoll, Midway Atoll, Ni'ihau, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i.

Representative specimens examined. HAWAIIAN IS: KURE ATOLL: Green I, *Lamoureux 2776* (BISH); MIDWAY ATOLL: Eastern I, *Herbst & Takeuchi 6426* (BISH); Sand I, *Herbst & Takeuchi 6361* (BISH); NI'IHAU: 'Ō'iamoi, sand dunes, *St. John 23651* (BISH); O'AHU: Kolekole Pass, *Forbes 2032.O* (BISH); MOLOKA'I: Makakupa'ia Ridge, *Char et al. 82.019* (BISH); LĀNA'I: N of Lāna'i City, *Degener 21993* (BISH); MAUI: 'Ili o kukuipuka, *Degener & Clay 19367b* (BISH); Hawai'i, Mauna Kea, Kaluamakani, *Rock 3261* (BISH).

Intermediates between var. *molokaiense* and var. *sandwicensium* are known from dry, bare, or coastal habitats from Waimānalo and Diamond Head on O'ahu, Hālawa Val on Moloka'i, Lāna'i, and between Waiehu and Wailuku on Maui.

Representative specimens examined. HAWAIIAN IS: O'AHU: Waimānalo, *Lyon s.n.* (BISH); MOLOKA'I: Hālawa Val, *St. John et al. 12787* (BISH); LĀNA'I, Munro Trail near Pu'ukilea, *Degener et al. 26852* (BISH); MAUI: Waiehu Sandhills, *Hobdy s.n.* (BISH).

Variety *sandwicensium* intergrades with var. *hawaiiense* in the vicinity of Mauna Kea and intergrades with var. *kilaueanum* in various parts of its range. This complex is in need of careful study, especially since 3 of the 4 distinctive entities have overlapping distributions yet apparently maintain themselves without any visible ecological differences.

Lipochaeta

When *Lipochaeta venosa* was listed as an endangered species (Herbst & Fay 1979), populations from 2 areas in the Pōhakuloa Training Area [Kīpuka Kalawamauna, 1,550 m, *Stemmermann 1463* (BISH), *Davis 299* (BISH), and the 1859 lava flow, 2,290 m, *Degener et al. 19810* (BISH)] were included in *L. venosa*. Recent reevaluation of the relationship between *L. venosa* and the closely related *L. subcordata* for the *Manual* has shown that these higher-elevation populations from Pōhakuloa represent rather small-leaved plants of *L. subcordata*. These collections represent one end point in the variation of *L. subcordata*. When all of the material is considered, the high elevation populations intergrade smoothly into the low elevation populations and therefore are recognized here as one variable species.

With these rearrangements *L. venosa* is a very narrow endemic species restricted to the low-elevation cinder cones mentioned below. The ranges of these 2 closely related species do not overlap. *Lipochaeta venosa* has leaves 2.1–2.8(–5) cm long, stems low, arcuate-spreading, and heads solitary or sometimes in clusters of 2(3), whereas *L. subcordata* has leaves (2.4–)3.4–10.0(–16.0) cm long, stems erect to ascending, and heads in compound cymes, rarely in clusters of 2–3.

Lipochaeta subcordata A. Gray

Lipochaeta deltoidea St. John; *L. flexuosa* Drake; *L. intermedia* Degener & Sherff; *L. populifolia* (Sherff) Gardner; *L. subcordata* var. *populifolia* Sherff; *L. s.* var. *typica* Sherff.

Suffruticose perennial herbs; stems erect to ascending, 3–30 dm long. Leaves narrowly deltate to deltate, occasionally with 2 basal lobes, (2.4–)3.4–10.0(–16.0) cm long, (2.4–)3–6(–10) cm wide, strigillose, lower surface often densely so, margins irregularly serrate, petioles 1–3 cm long. Heads in compound cymes or sometimes in clusters of 2–3; outer involucral bracts often purple along midrib, lanceolate to ovate, (3–)4–6 mm long, 1.5–2.3 mm wide, sparsely to moderately strigillose, apex attenuate to obtuse; chaffy bracts often purple near apex or tan throughout; ray florets 5–8 per head, rays oblong, (3.0–)4.0–9.3 mm long, 2–4 mm wide; disk florets 5-merous, 11–45 per head, corollas 2.5–3.4 mm long; anthers 1.1–1.5 mm long; pappus of scales forming an uneven corona tipped with short, deciduous awns or solely of short, deciduous awns. Achenes tuberculate, often spotted with purple, with a fringe of scales on upper outer rim, those of ray florets 1.9–2.8 mm long, 1.5–2.5 mm wide, with wings ca. 0.4 mm long, those of disk florets 2.1–2.8 mm long, 1.1–2.2 mm wide, ± winged, the wing ca. 0.2 mm long. Scattered in dryland sclerophyll woodland or grassland, (100–)550–1,800 m, Hikimoe Val, Kaua'i, North Kona Dist, Hawai'i, and formerly Maunalei Val, Lāna'i.

Gardner (1979) presented a narrower concept of *Lipochaeta subcordata* than we have here. *Lipochaeta flexuosa,* and *L. intermedia* also described from the island of Hawai'i clearly fall within the range of variation in *L. subcordata.* Gardner also included the latter 2 names here.

Several collections from other islands also fit well within the range of variation of *Lipochaeta subcordata* and appear to represent relicts of a previously wider distribution. Two collections from Lāna'i and Kaua'i described as *Lipochaeta populifolia* [Maunalei Val, *Munro 670* (F, holotype, not seen; BISH 3 sheets, isotypes)] and *L. deltoidea* [lower Hikimoe Val, *Hobdy 102* (BISH-468055, lectotype; Gardner, Rhodora 81: 323. 1979; BISH, isolectotype)], respectively, are scarcely distinct from *L. subcordata* and therefore are included here. *Lipochaeta subcordata* populations on the island of Hawai'i are variable, especially in leaf size and to some extent shape. In distinguishing features the single collection from Lāna'i described as *L. populifolia* falls well within the range of *L. subcordata* except that the leaves are more broadly deltate than other specimens of *L. subcordata.* The report by Gardner (1979) that the type of *L. populifolia* had rays 9.3 mm long seems to be an error. Measurements made on the 3 isotype sheets at BISH range from 6.3 to 7.0 mm long, which is in agreement with the measurements given by Sherff (1935), and thus are very similar to the length range found in plants of *L. subcordata* on Hawai'i. Likewise, a collection from Kaua'i described as *L. deltoidea* by St. John (1972) is within the range of *L. subcordata* exept that the heads are solitary or in clusters of 2–3. Therefore, these entities seem to be best treated as 1 variable species. *Lipochaeta subcordata* A. Gray var. *membranacea* Sherff (Sherff 1933) was described from 1 collection (*Bishop 14*; B, presumably destroyed) from behind Lahaina; there is no way of determining what species it represents.

Lipochaeta venosa Sherff

Lipochaeta pinnatifida St. John; *L. setosa* St. John.

Suffruticose perennial herbs; stems arcuate-spreading. Leaves deltate, usually dimorphic, pinnately dissected throughout or very coarsely serrate, 2.1–2.8(–5) cm long, 0.8–2.2 cm wide, often with 2 basal lobes, upper surface sparsely strigillose, lower surface more densely so, petioles 0.8–1.5 cm long. Heads solitary or in clusters of 2(3); outer involucral bracts ovate, 5.0–5.5 mm long, 2.5–3.5 mm wide, strigillose, obtuse; chaffy bracts often purple near apex; ray florets 4–6(–8) per head, rays ovate-elliptic, 3–6(–12) mm long, 2.0–2.8 mm wide; disk florets 5-merous, 20–30 per head, corollas 3.0–3.3 mm long; anthers 1.4–1.5 mm long; pappus of short, deciduous awns. Achenes tuberculate, often spotted with purple, those of ray florets 2.0–2.4 mm long, 1.5–1.8 mm wide, with wings ca. 0.2 mm long, those of disk florets 2.0–2.4 mm long, 1.4–1.5 mm wide, wingless. Scattered in dryland sclerophyll woodland, ca. 730–915 m, known only from South Kohala Dist, Nohonaohae, Holoholokū, Pu'upāpapa, and Heihei cinder cones, Hawai'i.

Specimens examined. HAWAIIAN IS: HAWAI'I: South Kohala Dist, Nohonaohae cinder cone, *J.F. Rock 8349* (F, holotype; BISH 2 sheets, GH, UC, isotypes), *S. Anderson 499* (BISH), *Nagata et al. 2026* (BISH), *Nagata et al. 2028* (BISH), *Davis 243* (BISH); Heihei cinder cone, *S. Anderson 500* (BISH); Holoholokū cinder cone, *S. Anderson 502* (BISH), *Hosaka 2114* (BISH); cinder cone NE of Nohonaohae, *S. Anderson 503* (BISH), *Davis 713* (BISH), *S. Anderson 505* (BISH); Pu'upa'a, nr tank rd, *Warshauer 3160* (BISH, holotypes of *L. pinnatifida* and *L. setosa*).

Lipochaeta venosa is closely related to the polymorphic *L. subcordata* and differs principally in the combination of characters presented in the key. It is a rare species and is listed as endangered under the Endangered Species Act of 1973. The principal threats to populations of *L. venosa* include invasion of fountain grass and other alien species, fire, and browsing by cattle and feral goats and sheep (Herbst & Fay 1979; Wagner et al. 1985).

St. John (1984) described both *Lipochaeta pinnatifida* and *L. setosa* from a single population sample, *Warshauer 3160,* dividing the specimens based on leaf lobing and assigning the relatively unlobed sheet, *Warshauer 3160A,* as the holotype of *L. setosa,* and the pinnately dissected sheet, *Warshauer 3160,* as the holotype of *L. pinnatifida.* Both sheets fit well within the morphological range of *L. venosa.* On the label Warshauer stated that the specimens represented the range of variability within the population.

Hybridization in *Lipochaeta*

Natural intersectional hybrids between species of *Lipochaeta* have been reported (Sherff 1935), and the crossing relationships among *Lipochaeta* species and between *Lipochaeta* and closely allied genera have been explored (Rabakonandrianina & Carr 1981). Here we report on a series of plants that appear to represent hybrids between *L. integrifolia* and *L. succulenta.*

A few plants of a *Lipochaeta* similar to *L. integrifolia* (Nutt.) A. Gray growing at Kilauea Point, Kaua'i, were recently brought to our attention by Dan Moriarty. These plants can be characterized by the following description [based on examination of *Flynn 809* (BISH) and *Bottomley s.n.* in 1983 (BISH)]:

Decumbent, mat-forming perennial herbs; stems branched. Leaves oblanceolate to oblong-elliptic, 1.3–3.5 cm long, 0.4–0.7 cm wide, sparsely strigillose to glabrate. Heads solitary in the leaf axils; involucral bracts ovate, 3.0–3.5 mm long, 2.5–3.0 mm wide, glabrate, apex acute; ray florets 9–13 per head, rays 2–3 mm long; disk florets both 4- and 5-merous. Achenes not developing.

These plants appear to represent sporadic hybrids in this locality on Kaua'i between *Lipochaeta integrifolia* and *L. succulenta* (Hook. & Arnott) DC. The evidence for this is basically that although the habit and leaf shape of the putative hybrids are similar to *L. integrifolia,* the very sparse pubescence is that of *L. succulenta.* Also, the involucral bracts are within the shape and size range of *L. succulenta.* Moreover, the heads contain mixtures of 4- and 5-merous disk corollas, of which ca. 80% are 4-merous. This further suggests hybridization, since *L. integrifolia,* which these plants most closely resemble, has 5-merous disk corollas, whereas those of *L. succulenta* are 4-merous. Most importantly, however, the 1 plant tested had sterile pollen based on a test with Alexander's Stain (Alexander 1965), and no mature achenes could be found in any heads of the several plants examined.

We appreciate the assistance of Tim Flynn and Dan Moriarty in obtaining material of the plants studied.

Palafoxia

Palafoxia callosa, a native of the western and central United States, is here reported to be naturalized in Hawai'i.

Palafoxia callosa (Nutt.) Torr. & A. Gray

Polypteris callosa Nutt.

Slender, branching annual herbs 1–6 dm tall, coarsely strigose, the inflorescence pubescent with dark, tack-shaped, stipitate glands. Leaves narrowly lanceolate to linear, 3–6 cm long, 0.2–0.6 cm wide. Heads discoid, peduncles 5–30 mm long; involucre turbinate or campanulate, ca. 4–6 mm high, the bracts equal, herbaceous, tinged pinkish purple; disk florets ca. 5–15 per head, corollas pink, ca. 3 mm long; pappus scales with conspicuous membranous margins ca. 1 mm long. Achenes 4–7 mm long. Native from new Mexico to Arkansas, Oklahoma, and Missouri; in Hawai'i naturalized in dry, disturbed areas in the southwestern part of Moloka'i. First collected in 1971 (Kamāka'ipō, *Pekelo s.n.*; BISH).

Remya

Two species of this endemic genus of obscure affinity have long been known (Hillebrand 1888); however, *Remya kauaiensis* was until recently thought to be extinct. The following key summarizes the principal differences between the species.

Key to the Species of *Remya*

1. Leaves lanceolate to elliptic-lanceolate or broadly ovate, blades usually ca. 2.5 × longer than wide, 4.5–13.0 cm long, 2.2–7.0 cm wide, base cuneate, petioles 1.2–2.2 cm long .... **R. kauaiensis**

   Leaves narrowly elliptic, blades 5–12 × longer than wide, 9–18 cm long, 0.8–2.6 cm wide, base long-attenuate, petioles 0–1 cm long .... **R. mauiensis**

Remya kauaiensis Hillebr.

Remya kauaiensis var. *magnifolia* Sherff.

Erect, canescent shrubs ca. 1 m tall; stems densely leafy near the ends. Leaves lanceolate to elliptic-lanceolate or broadly ovate, blades 4.5–13.0 cm long, 2.2–7.0 cm wide, lower surface densely tomentose, margins sharply serrate-dentate, base cuneate, petioles 1.2–2.2 cm long. Heads in open panicles; involucre globose, ca. 3 mm high, 2.5–3.0 mm wide; ray florets ca. 20 per head, rays ca. 0.5 mm long; disk florets 30–40 per head, corollas ca. 2 mm long; pappus of 4–8 bristles, 2 of them as long as the achene, the others much shorter. Achenes ca. 1.5 mm long, puberulent. Known from a few collections in mixed mesophytic forest in the Kōke'e area of Kaua'i, ca. 1,050 m.

This species was thought to be extinct, but 4 populations recently (1982 and 1985) were rediscovered by T. Flynn (Pacific Tropical Botanical Garden), each consisting of about 3 or 4 plants. *Remya kauaiensis* var. *magnifolia* described by Sherff (1954) represents a plant with somewhat larger leaves than previously observed for this rare species and does not warrant formal recognition.

Representative specimens examined. HAWAIIAN IS: KAUA'I: Ka'ula'ula Val, Lapa Loop Rd, below Lapa tree planting site, *Flynn & Kawakami 448* (BISH); Kauhao Ridge, on a steep slope below the Boy Scout Camp, *Hobdy 1825* (BISH); 2.4 km down Makaha Ridge Rd from Jct. Hwy 550, NW facing slope, *Wagner et al. 5620* (BISH).

Senecio

Senecio sandvicensis Less.

Erect perennial herbs 3.4 dm tall; stems unbranched, glabrous. Leaves mostly basal, oblong-oblanceolate to elliptic, blades 7.5–10.0 cm long, 1.9–3.2 cm wide, becoming reduced above, margins entire, petioles 4.0–5.4 cm long. Heads in terminal cymes, discoid; involucral bracts 7 mm long; disk corollas yellow, ca. 6 mm long. Achenes unknown.

This species is based on 1 specimen collected by J.F. von Eschscholtz on the voyage of the Russian ship *Rurick*. The label of the specimen in Leningrad Herbarium (LE) states the locality as "Sandwich Islands, O Wahu" (St. John 1979); however, this specimen differs in no essential way from *S. hydrophilus* Nutt. from the western United States. It seems likely that there was an error in the original label data and that the collection actually was made at a stop on the California coast during the voyage. *Senecio hydrophilus* grows in the San Francisco Bay area of California where Eschscholtz did in fact collect, and this specimen probably came from there. Alternatively, it may represent an early introduction of *S. hydrophilus* in Hawai'i that persisted for only a short period.

St. John (1979) contends that *Senecio sandvicensis* is indeed from Hawai'i and represents a species distinct from *S. hydrophilus*; however, we see no essential differences when the full range of variation in *S. hydrophilus* is considered.

Wedelia

Wedelia trilobata (L.) Hitchc.

Silphium trilobatum L.

Creeping and mat-forming perennial herbs; stems rounded, rooting at the nodes, 1–3 (–4) dm long, the flowering portions ascending, coarsely strigose to spreading hirsute, sometimes subglabrous. Leaves fleshy, usually 4–9 cm long, (1.5–)2–5 cm wide, irregularly toothed or serrate, usually with a pair of lateral lobes. Heads on peduncles 3–10 cm long; involucre campanulate-hemispherical, ca. 1 cm high; ray florets often 8–13 per head, rays 6–15 mm long; disk corollas 4–5 mm long; pappus a crown of short fimbriate scales. Achenes tuberculate, 4–5 mm long, few achenes maturing in the cultivated plants in Hawai'i. Native to New World tropical regions; in Hawai'i cultivated as a ground cover. Owing to its vigorous vegetative reproduction, it has commonly escaped, probably on all of the main islands.

Plants cultivated in Hawai'i generally have heads that develop few mature achenes. Seedlings occasionally have been observed. If a fertile strain develops, this species could become a serious weed. It has been experimentally hybridized with *Lipochaeta* species (Rabakonandrianina & Carr 1981).

Zinnia

In Hawai'i *Zinnia peruviana* (L.) L., previously known as *Z. pauciflora* L., is naturalized and common in low-elevation, dry areas on Lāna'i, Maui, and Kaho'olawe. Here we report a species naturalized only on Koko Crater, O'ahu. We thank J.L. Strother, University of California, Berkeley, for his assistance. The delimitation of this species follows Strother (1979).

Zinnia palmeri A. Gray

Zinnia maritima sensu Torres, pro parte.

Annual herbs 2–4 dm tall. Leaves narrowly deltate to linear-triangular, 2–5 cm long, 0.4–1.2(–2) cm wide, margins often obscurely serrate, base truncate to subcordate-clasping, subsessile. Rays yellow to sometimes orange, suborbicular to oblong, 5–11 mm long; disk corollas purple to blackish at the apex, 3–4 mm long; pappus of 2 awns. Achenes 1.8–2.8 mm long. Native to central Mexico; in Hawai'i naturalized only on Koko Crater, O'ahu. First collected in 1980 (*St. John 26944*; BISH).

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BISHOP MUSEUM OCCASIONAL PAPERS 26: 123–127 MAY 1986

The Fauna of Thai Caves
I. Three Phalangids from Thailand (Arachnida)

Seisho Suzuki[1] and Fred D. Stone[2]

ABSTRACT

A new species of Phalangodidae, *Paratakaoia minima,* is described from Thailand. Further records for 1 assamiid and 1 gagrellid are cited. These phalangids were collected from Thai caves and adjacent forest litter, and environmental notes are included.

INTRODUCTION

A small collection of Thai phalangids deposited in the B.P. Bishop Museum, Honolulu, were sent to one of us (S.S.) for identification. The specimens, in 12 vials, consisted of 3 named species, including 1 new species, and unidentifiable juveniles. The present report describes the new species and records collections of the others.

The holotype and paratypes of the new species are deposited in the B.P. Bishop Museum (BPBM).

These phalangids were all collected by one of us (F.D.S.) from Thai caves and adjacent forest litter as part of a study of Thai cave biology begun in 1965 by F.D. Stone and F.G. Howarth (Stone 1983). The only previous published records of phalangids from Thai caves resulted from the "Skeat Expedition" of 1899–1900 to caves in southern Thailand (Simon 1901).

Forest litter, including partially decomposed surface material and the decomposed organic layer beneath, was collected from native forest about 50 m outside the entrance of Tham (cave) Thap Khwang, Saraburi Province, central Thailand (1, Fig. 10). Hand-sorting of the litter revealed *Paratakaoia minima,* n. sp., *Bandona palpalis* Roewer, and a juvenile Gagrellidae.

Tham Thap Khwang was carefully surveyed for organisms during several trips to the cave in 1972 and 1973. A dry, upper-level tourist passage, 500 m long and with artificial lighting, did not have phalangids, though vegetable debris was present. *Bandona palpalis* adults were found on plant litter recently washed into the dark zone of a 900-m-long, intermittent stream passage. Unidentifiable juveniles of Assamiidae, appearing pale and fragile, were present on the surface of litter near pools in the dark zone of this passage and apparently were restricted to areas of high humidity. Temperature of the stream passage was 22–23 °C. Near the inlet to the stream passage, a 300-m-long passage contained a large colony of the fruit bat *Rousettus leschenaulti* and abundant guano. *Gagrella spinulosa* Roewer was found walking on the surface of the guano in the transitional zone not far from an entrance.

A single specimen of a juvenile Assamiidae was collected in 1981 from Tham Kaew, a cave in Sai Yok Yai National Park, Kanchanaburi Province (2, Fig. 10). This specimen

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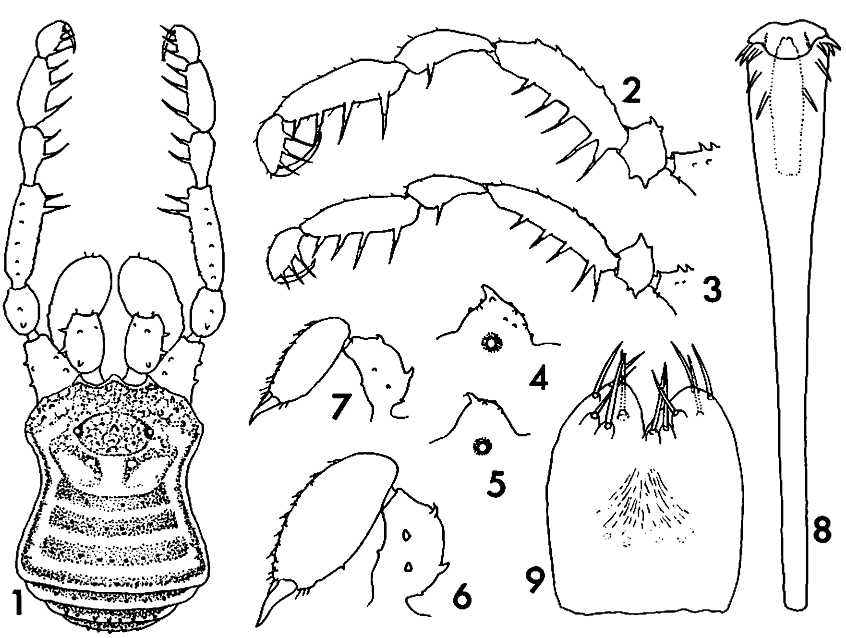

Fig. 1–9. *Paratakaoia minima.* **1**, Dorsal view of body, ♂ (23×). **2–3**, Lateral views of palpi: **2**, ♂; **3**, ♀ (28×). **4–5**, Left side views of eye tubercle: **4**, ♂; **5**, ♀ (55×). **6–7**, Lateral views of chelicerae: **6**, ♂; **7**, ♀ (28×). **8**, Ventral view of penis (130×). **9**, Dorsal view of ovipositor (114×).

occurred in the same habitat as the juvenile Assamiidae from Tham Thap Khwang, in a moist spot above a pool in the dark zone (23 °C). This cave is frequently visited by tourists.

Tham Chiang Dao, in Chiang Mai Province, northern Thailand (3, Fig. 10), had the most abundant population of *B. palpalis.* This cave has a lighted tourist passage, which occasionally floods from a lower-level stream passage; it also has upper-level passages with insectivorous bat colonies (which appear to have declined recently). Tourists also visit the upper-level passages, using hand-held lights. Adults of *B. palpalis* were collected at 4 locations in the cave:

1. On decomposed wood next to a pool 125 m from the entrance, along the lighted tourist route (18.2 °C, RH 100%).
2. On woody debris from incense sticks near a Buddha image at the end of the lighted passage, 325 m from the entrance.
3. On moist bat guano in the first upper-level bat chamber, 100 m from the entrance (23.0 °C, RH 97%).
4. Walking on plant debris near small pools in the upper-level passage beyond the bat chamber (also a tourist route), 200 m from the entrance (23.0 °C, RH 97%). Juvenile assamiids (unidentifiable) were also collected at the same 4 locations as the adult *B. palpalis.*

In summary, it seems most likely that *B. palpalis* is a widespread troglophilic species in Thailand that lives in forest litter but is able to complete its life cycle in the dark zone of caves. It is almost always found in areas with abundant plant litter, the one exception being on bat guano.

SYSTEMATICS

Family PHALANGODIDAE Simon, 1879

Paratakaoia minima Suzuki, **new species** Fig. 1–9

Measurements (in mm) ♂ (♀): body 1.51(1.43) long, 1.13(1.10) wide; length of femora 0.75:0.98:0.80:0.94(0.65:0.89:0.72:0.84); total length of legs 2.66:4.04:2.98:3.70(2.52:3.82:2.66:3.55); tarsal segments 5:13:6:7(5:11:6:7); penis 0.58 long.

♂. Body very small, as shown in Fig. 1. Carapace with 2 small tubercles on each side at anterior lateral region. Eye tubercle enlarged, with a low median spine and some scattered tubercles (Fig. 1, 4). All scutal areas and free tergites each with a row of small tubercles, tubercles slightly larger on free tergites; anal plate with coarse tubercles. Free sternites each with a row of fine tubercles. Coxae of all legs with scattered tubercles, tubercles larger on coxae I. Coxae III with a row of small tubercles anteriorly and posteriorly. *Chelicerae* (Fig. 1, 6) well developed, strong. Segment 1 with a large distodorsal elevation, 2 dorsal and 2 ventrolateral spines on elevation; segment 2 prominently swollen, frontally with hair-tipped tubercles, some tubercles larger than others. *Palpi* as shown in Fig. 1–2. Trochanter with 2 low dorsal and 2 low ventral spines. Femur dorsally with 2 rows of low tubercles, ventrally with 5 long spines, and distomedially with 2 spines. Patella with 2 medial and 1 lateral spine. Tibia with 3 medial and 4 lateral spines. Tarsus with 3 spines on either side of ventral surface. *Legs* unarmed; distitarsi I and II with 2 and 3 segments, respectively; tarsi III and IV with double simple claws. *Penis* (Fig. 8). Distal part somewhat widened; dorsal side of distal end with a shallow median indentation. Ventral side of shaft with 5 pairs of setae. Disposition of these setae as shown in Fig. 8.

Coloration. Body and all appendages rusty yellow; carapace and eye tubercles reticulated with brown; scutal areas each with a dark brown band, free tergites with a dark brown band, a dark brown stripe along scutal margins. Free sternites with a narrow brown band. Chelicerae and palpi obscurely reticulated, leg segments reticulated with dark brown.

♀. With a slightly larger body; eye tubercle not as distended as that of ♂ (Fig. 5). Chelicerae, especially segment 2, not swollen but normal (Fig. 7). Palpi less strong than those of the ♂ (Fig. 3). Coloration paler. *Ovipositor* as shown in Fig. 9; both lobes with 3 dorsal and 2 or 3 ventral setae.

Type data. Holotype ♂, THAILAND: Changwat Saraburi: Amphoe Kaeng Khoi: nr Tham Thap Khwang, forest litter, 12.VIII.1973 (F. Stone) (BPBM 13,432). 2♀ paratypes, same data as holotype.

Distribution. Thailand.

Remarks. This species differs from *P. parva* Suzuki, the only other known species of this genus from Thailand, by the penis [compare Fig. 8 with Suzuki's (1985) fig. 6G, J, K].

Family ASSAMIIDAE Soerensen, 1884

Bandona palpalis Roewer, 1927: 389; 1935: 15, fig. 8.—Suzuki 1985: 92, fig. 12.

Material examined. THAILAND: Changwat Saraburi: Amphoe Kaeng Khoi: Tham Thap Khwang, in cave, 27.V.1973, 2♀; same data except forest litter nr cave, 12.VIII.1973, 1♀. Changwat Chiang Mai: Amphoe Chiang Dao: Tham Chiang Dao, in cave, 14.VIII.1981, 7♀; same data except 16.VIII.1981, 1♀.

Distribution. Thailand

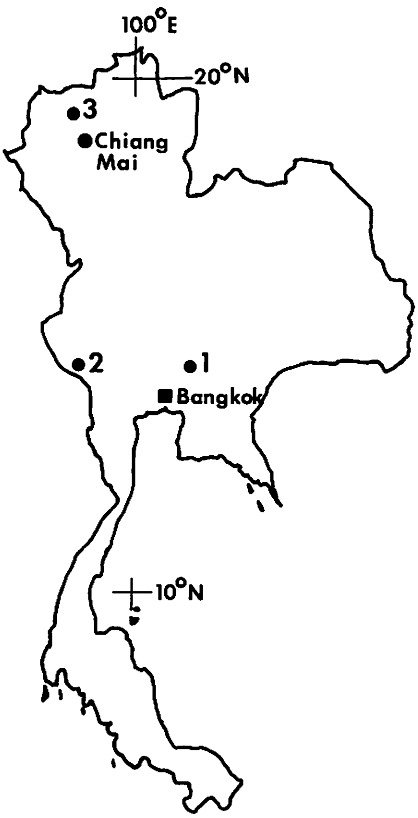

Fig. 10. Map of central and northern Thailand showing location of caves from which phalangids were collected: 1—Tham (=cave) Thap Khwang, Saraburi Prov; 2—Tham Kaew, Sai Yok Yai National Park, Kanchanaburi Prov; 3—Tham Chiang Dao, Chiang Mai Prov.

Undetermined genus and species

Material examined. THAILAND. Changwat Saraburi: Amphoe Kaeng Khoi: Tham Thap Khwang, in cave, 27.V.1973, 1 juv.; same data except 22.XII.1973, 3 juv., Changwat Chiang Mai: Amphoe Chiang Dao: Tham Chiang Dao, in cave, 14.VIII.1981, 4 juv.; same data except 16.VII.1981, 1 juv., Changwat Kanchanaburi: Amphoe Sai Yok: Tham Kaew, in cave, 22.VII.1981, 1 juv.

Family GAGRELLIDAE Thorell, 1876

Gagrella spinulosa Thorell, 1889.—Roewer 1923: 961, fig. 1091; 1954: 205.—Suzuki 1969: 99, fig. 14–15.

Material examined. THAILAND: Changwat Saraburi: Amphoe Kaeng Khoi: Tham Thap Khwang, in cave (accidental?), 30.XII.1973, 2♂.

Distribution. Burma, Thailand.

Undetermined genus and species

Material examined. THAILAND: Changwat Saraburi: Amphoe Kaeng Khoi: Tham Thap Khwang, forest litter nr cave, 12.VIII.1973, 1 juv.

ACKNOWLEDGMENTS

Thanks are extended to Dr. F.G. Howarth for the opportunity to investigate the material, and to Dr. Thomas Briggs of the California Academy of Sciences for making the preliminary identifications.

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Manuscripts printed on dot-matrix printers may be submitted provided that (1) lowercase letters have true descenders (i.e., the "tails" on letters such as *g, y,* and *p* extend below the baseline); (2) the inked impression from all characters is clean and without fill-in; and (3) the original and all copies are sufficiently dark to be easily readable.

Where American and British orthography differ, the former is followed, e.g., "color" not "colour," "while" not "whilst."

Editorial style

General. Research papers must include an ABSTRACT (1 paragraph) immediately preceding the text. Text is often organized as INTRODUCTION, MATERIALS AND METHODS, RESULTS, and DISCUSSION, but deviation from this format may be necessary depending on the subject treated. ACKNOWLEDGMENTS come after the text, preceding LITERATURE CITED.

Headings. For examples of heading styles, refer to headings used in this guide.

Numbers and measurements. As a general rule, cardinal numbers (1, 2, etc.) are not written out unless they begin a sentence. Ordinal numbers are treated as for cardinal numbers (e.g., 4th, 31st). Use commas with numbers of 4 or more digits (e.g., 1,000, 35,000). For quantities less than 1, a zero should be set before the decimal point (e.g., 0.1, $P = 0.05$).

Use of the 24-h time system (e.g., 0830 not 8:30 a.m.; 2030 not 8:30 p.m.) is preferred. Use of the SI metric system is required; where it is advantageous, authors may give metric measures with English equivalents, e.g., "at intervals of 7.6 m (25 ft)."

Express dates as in the following examples: on 15 June 1985 (no punctuation); during the 1960s (*not* 1960's), but EC_{50}'s; from 1920 *to* 1921, but in the winter of 1920–21; 20th century (*not* twentieth century); A.D. 870, but 500 B.C.

Use of italics. Italicize foreign words and give proper diacritical marks. Appropriate diacritical marks must be used for all Hawaiian words. For Hawaiian, the following may be used as authorities: *Hawaiian Dictionary* (Pukui & Elbert, 1981, Univ. of Hawaii Press, Honolulu); *Place Names of Hawaii* (Pukui, Elbert & Mookini, 1974, Univ. of Hawaii Press); and *Reference Maps of the Islands of Hawai'i* (Univ. of Hawaii Press). Do not italicize commonly used or anglicized non-Hawaiian foreign words or abbreviations such as ad hoc, a priori, et al., and ibid.

Mathematical copy. Whenever possible, formulae should be set on 1 line using the solidus (/) or ÷ rather than set on 2 or more lines using the horizontal rule, e.g., $(a + b)/(ac + d)$. Underline (to be italicized) all letters that represent mathematical variables.

Footnotes. Footnotes to title, author(s), and items in text should be indicated by consecutive numerals (not symbols) set as superscripts. Avoid footnotes to text items if possible; parenthetical insertions are preferable. Footnotes to tables are indicated by superscript symbols in the following sequence: *, **, ***, †, ††, †††, §, etc.

Quotations. Quotations of fewer than ca. 50 words should be run in with the text, with author, year, and page numbers following the quote in parentheses. Example: He concluded that ". . . words speak for themselves . . ." (Bernstein 1971: 11). Longer quotations should be set off from the text as a paragraph, indented, without quotation marks, double-spaced, with literature citations as indicated:

> Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary parts. This requires not that the writer make all his sentences short . . . but that every word tell. (Strunk & White 1979: xiv)

Abbreviations and symbols. Define all nonstandard symbols and abbreviations when they first appear in text. Use the same abbreviations for singular and plural, without periods, except as noted. Leave a space between the numeral and unit of measure (e.g., 23 °C, 12 m). The standard abbreviations and units shown in Appendix 1 may be used without explanation. Other standard abbreviations may be found in the 2 style manuals cited under "Editorial policy."

Literature citations in the text. Designate literature citations in the text by name of author(s) and year of publication and arrange chronologically: (Benjamini et al. 1960, 1963; Audy 1961; Sako & Yamane 1962a,b). Note the absence of comma between author and date. For personal communication and "in litt." citations, give initials and date if possible, e.g. (R. Smith, pers. comm. 1982).

LITERATURE CITED SECTION

This section includes published references, papers in press, and unpublished theses. It should not list papers in preparation or personal communications, which should be cited in the text only. Cite as "in press" only manuscripts that have been accepted for publication. Style for literature cited generally follows Style B of *The Chicago Manual of Style* (Section 16.5 and following). Arrangement is strictly alphabetical. Note the following points in the examples below: use initials for first and middle names, with initials closed up; capitalize only the 1st letter of the main title, the subtitles, and any proper nouns for titles of books and articles; abbreviate titles of journals, series, and proceedings; do not underline titles; use an ampersand between authors' names; delete repeated page numbers (e.g., 214–22); and do not repeat authors' names. Periodical title abbreviations follow the *Serial Sources for* *the BIOSIS Data Base* and the *International Standard ISO 833.* If references not cited in the text or unpublished materials (e.g., diaries, letters) are included, the section should be titled REFERENCES.

Journal Article

Baldwin, P.H. 1945a. The Hawaiian Goose: Its distribution and reduction in numbers. Condor 47: 27–37.

———. 1945b. The Laysan Rail. Audubon Mag. 47: 343–48.

Book

Weaver, W.R. 1963. The theory of probability. 2nd ed. Doubleday, Garden City, N.Y. 329 p.

Portion of Book

Kaiser, E.E., L.M. Jones & C.P. Ready. 1964. The literature of Harlem. p. 210–50. In: J.H. Clarke, ed., Harlem: A community in transition. Citadel Press, New York.

Series

Bartram, E.B. 1933. Manual of Hawaiian mosses. Bernice P. Bishop Mus. Bull. 101. 275 p.

Proceedings

Vogl, R.J. & S. Bear. 1969. The role of fire in the evolution of the Hawaiian flora. p. 5–60. In: R.J. Smith, ed., Proc. Annu. Tall Timbers Fire Ecol. Conf. Vol. 2. Tallahassee, Fla., 10 Apr. 1969. Viking Press, New York.

Unpublished Thesis or Dissertation

Davidson, K.T. 1983. Contributions to the biology of the lousewort. M.S. thesis, Cornell Univ. xi + 387 p.

Newspaper Article

Daily Pacific Commercial Advertiser. 1885. 2 May.

Krauss, B. 1978. Our island style. Honolulu Advertiser, 12 Oct.

Government Agency

U.S. Department of Commerce. Market Research and Service Division. 1973. Shellfish: Market review and outlook. GPO, Washington, D.C. 302 p.

TABLES

The cost of publishing tables compared to text is very high. Do not construct a table for data that can be more concisely expressed in the text; similarly, a table should not repeat data already given in the text or figures. Type tables double-spaced, each on a separate sheet, and each with a caption above the table body. Designate tables with arabic, not roman, numerals. Guidelines for preparation are as follows:

General

- Place horizontal lines above and below the boxhead and at the bottom of the table. Use no vertical lines.
- For easier comparison of data and economy of space, tables should be organized so that like data read down, not across.
- Very complicated tables with mathematical formulae, diagrams, sub- and superscripts, etc. should be prepared as camera-ready copy after approval by editor.

Column Headings

- Do not repeat column headings in the table title.
- Capitalize only the 1st word (and proper nouns) in headings.

- If all entries are in the same unit (e.g., m, days, °C), the unit should be shown in column heading and not repeated in column.
- Use abbreviations whenever possible to reduce length of headings.

Body of Table

- For "no data" use "—"; for "not applicable" leave blank; and for quantities equal to zero, type "0."
- Avoid tables with only 2 columns.

Footnotes to Tables

- Place footnotes on the same page as the table.
- Indent explanations of footnotes at the bottom of the page.
- See section on "Footnotes" for symbols to be used in tables.

Statistics

- Standard symbols are sample size, n; arithmetic mean, $\bar{x}$; standard deviation, SD; standard error, SE; probability, P; nonsignificant, NS. These need not be defined.
- For quantitites less than 1, a zero should be set before the decimal point (e.g., 0.1).
- Letters following numbers to denote significance should not be sub- or superscripts, should be lower case, and should be separated from the number by a space (e.g., 12.5 ab).

ILLUSTRATIONS

General

- Design figures to fit size and layout of page. *Line drawings* are best planned for ⅓ reduction; generally they should not have to be reduced to less than ½ of original size. Ideally, photographs, washes, and other art to be *halftoned* should be submitted exact size, to be neither reduced nor enlarged.
- Submit original line illustrations when possible, but high-quality glossy prints and PMTs are also acceptable.
- Identify each illustration on back with figure number, author's name, ms. title, and top of figure. Use a gummed label or felt tip; do not use pencil, ballpoint, or any tool that might indent or mar the art.
- Type figure captions together on a page separate from text. Do not type captions on plates.

Mounting and Labeling

- Number consecutively as figures all photographs, graphs, drawings, and maps.
- In the case of composite figures, parts should be identified by letters only; do not repeat figure number. For example, if Fig. 1 has several parts, letter the parts as a, b, c (not 1a, 1b, 1c). Do not number a single figure on its face.
- Do not combine line drawings and halftones on the same plate.
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- Labeling must be neat and attractive.
  - Typed labeling is unacceptable.
  - Lettering should be large enough to withstand reduction but not so large as to overwhelm figure.
  - Labels must be designed so that letters on different figures will be approximately the same size after reduction.
  - Avoid excessively bold characters and very thin lines.
  - Scale lines on figures should be either vertical or horizontal.
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- Special symbols used in an illustration should be explained in a legend included as part of the

illustration itself. If you must define symbols in the caption, use only standard symbols, such as open and closed circles, triangles, and squares.

SYSTEMATICS ARTICLES

All systematics papers must follow international rules of nomenclature. The following are intended as general guidelines applicable to taxonomic papers in both botany and zoology.

Names

Authors of scientific names should be included at first mention in the text. Omit authors of scientific names from the title and abstract. Authorities following species names should be written with a comma between author and date, e.g., *Alauda arvensis* L., 1758.

Common names of invertebrates and plants are not capitalized. For all vertebrate groups, vernacular names referring to species or subspecies, with the exception of common domesticated species, are capitalized and follow recent authoritative sources.

Headings

Headings for order, family, and genus should be centered. Species headings should be flush left, with figure numbers on the same line. Author's name is included in species heading, even for new species. Designations of "n. sp." and "n. gen.," or comparable terminology, must be used with names of new taxa preceding their description; they may be omitted thereafter.

Synonymies

References should be arranged chronologically, and identical combinations should not be repeated. Some flexibility is allowed to accommodate various styles for synonymies used in different disciplines; it is important to be consistent witih the pattern selected. The following are examples of full and abbreviated synonymies:

Abbreviated Synonymy

Geomydoecus geomydis (Osborn) Fig. 32
Trichodectes geomydis Osborn, 1891: 54; 1892: 23.—Smith 1897: 131.
Trichodectes signis: Baker 1902: 23 (misident.).
Geomydoecus geomydis (Osborn): Ewing 1929: 38.

Full Synonymy

Cyrtandra fauriei H. Lév. Fig. 2a–3d
Cyrtandra fauriei H. Lév., Repert. Spec. Nov. Regni Veg. 10: 123. 1911. TYPE: USA, Hawai'i, Moloka'i, Puko'o, V.1910, *U. Faurie 632* (P, holotype; BISH, BM, isotypes).
Cyrtandra lysiosepala (A. Gray) C.B. Clarke var. *fauriei* (H. Lév.) Rock, Am. J. Bot. 6: 50. 1919.
Cyrtandra rotata St. John, Pac. Sci. 25: 56. TYPE: USA, Hawai'i, Maui, 1.XII.1919, *C.N. Forbes 1740.M* (BISH, holotype).

Descriptions

Diagnoses and descriptions must be in telegraphic style. If measurements are included separately, they may be listed in a paragraph following the descriptive text and headed by "Measurements."

Material examined

The description is followed by a section presenting type data (if new species) and/or a "Specimens examined" section. Listing of data should approximate the house style. Note in the examples below: (1) order of data presented; (2) that geographic entries run from largest to smallest; (3) correct form for dates; (4) that collectors and depositories are in parentheses; and (5) that only surnames of collectors are repeated.

Example for New Species

Type data. Holotype ♀, MALAYSIA: SARAWAK: Gunong Matang, 120 m, 15.IX.1958, on tree trunk (J.L. Gressitt) (BPBM 10,552). Allotype ♂, same data as holotype, except 20.IX.1958. 3♀,1♂ paratypes, LAOS: Vientiane Prov: Phou Khao Khouei, 800 m, 16.IV.1965, secondary forest (Gressitt). Holotype, allotype, and 1 paratype in BPBM; 2 paratypes in USNM; 1 paratype in author's collection.

Example for Species Not New

Specimens examined. PHILIPPINE IS: 23♀, Mindanao I: Masawan, 28.XII.1962, ex *Tupaia palawanensis,* BBM-PI 1462 (M. Thompson) (BPBM); 1♂, Balabac I: Palawan Bay, 22.IV.1962, ex *Cacatua* sp. (Thompson). HAWAIIAN IS: 1♀, O'ahu I: Mānoa Val, ex *Rattus rattus* (J. Tenorio); Hawai'i I, Kamuela, 488 m, ex nest of *Mus* (J. Jacobi) (USNM).

Remarks

This section should contain a statement differentiating the species from its nearest relatives. It may also contain discussion of systematic changes and problems, morphological variation, etc. Patronyms should be acknowledged here.

Keys

Keys should have a title (centered), with scope clearly denoted. They should be telegraphic, with phrases separated by semicolons. The dichotomous bracket key is preferred, with backrun numbers for long keys. Distribution and hosts, if included, should be enclosed in parentheses and separated from character portion of key by points of ellipsis. Omit genus-group names before species-group names if key is to 1 genus-group only. New species, new combinations, new names, etc. should be designated as such in the key.

Key to Species of *Rattus* in New Guinea

1. Large urban rats (HB > 200 mm); ears small; tail shorter than HB ... (introduced) .... **R. norvegicus**
Not as above 2
2(1). Large lowland rats; fur spiny; feet white and tails white-tipped... (New Guinea, Queensland) .... **R. leucopus**
Not as above 3

Place names

Major geographic headings in material examined sections should follow most recent usage, e.g., Irian Jaya (not Netherlands New Guinea) and Zimbabwe (not Rhodesia). It is the author's responsibility to use full and correct diacritical marks in Hawaiian place names. Appendix 2 lists geographical/political abbreviations that should be used in place names; no periods are used unless needed to avoid ambiguity.

Acronyms

When several collections are treated, acronyms should be used to make reference to them. A separate collections section should include a list of acronyms if there is not a standard list commonly in use in the discipline. *Index herbariorum I* (1981) should be used for designation of botanical repositories.

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APPENDIX 1

SELECTED STANDARD ABBREVIATIONS AND UNITS

alternating current	AC	micrometer (=micron)	µm
average	avg. (tables)	mile	mi
centimeter	cm	miles per hour	mph
circa (about)	ca.	milligram	mg
confer (compare)	cf.	milliliter	ml
correlation coefficient	*r*	millimeter	mm
counts per minute	cpm	minute	min
day	spell out	molar	*M*
degrees Celsius	°C	month	mo (tables)
degrees of freedom	df	normal	*N*
department	dept.	number	no. (tables)
diameter	diam	numbers	nos. (tables)
dram	dr	number (sample size)	*n*
elevation	elev.	page(s)	p.
et alia (and others)	et al.	parts per million	ppm
et cetera (and so forth)	etc.	personal communication	pers. comm.
exempli gratia (for example)	e.g.	pint	pt
figure(s)	fig.	pound	lb
foot	ft	probability	*P*
gallon	gal	relative humidity	RH
gram	g	revolutions per minute	rpm
gravity	*g*	second	s
hectare	ha	sensu lato (in the broad sense)	s. lat.
hertz	Hz	sensu stricto (in the strict sense)	s. str.
hour	h	species	sp., spp.
id est (that is)	i.e.	standard deviation	SD
in correspondence	in litt.	standard error	SE
inch	in.	subspecies	ssp., sspp.
kilogram	kg	unpublished	unpubl.
kilometer	km	versus	vs.
kilometers per hour	km/h	*videlicit* (namely)	viz.
liter	spell out	volt	V
lux	lx	volume	vol
magnification	×	watt	W
male, female	♂, ♀ (tables, lists, collection data)	week	wk
		weight	wt (tables)
mean, arithmetic	$\bar{x}$	year	yr (tables)
meter	m		

APPENDIX 2

GEOGRAPHICAL AND POLITICAL ABBREVIATIONS FOR USE IN PLACE NAMES

Archipelago	Arch	Islands	Is	Province	Prov
County	Co	Lake	Lk	Range	write out
Creek	Crk	Mountain	Mt	Road	Rd
Department	Dept	Mountains	Mts	River	Riv
District	Dist	Peninsula	Pen	Station	Sta
Fort	write out	Plateau	Plat	Stream	write out
Harbor	Hbr	Point	Pt	Valley	Val
Island	I	Port	write out	Village	Vill

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In general, papers should conform to the latest editions of *The Chicago Manual of Style* and the *CBE Style Manual.* Diacritical marks are required in all Hawaiian words and place names. Authors using Hawaiian words should consult the *Hawaiian Dictionary* (Pukui & Elbert 1981), *Place Names of Hawaii* (Pukui, Elbert & Mookini 1974), and *Reference Maps of the Islands of Hawai'i* (Univ. of Hawaii Press).

All measurements should be expressed using the SI metric system; English equivalents may be included parenthetically. Cardinal and ordinal numbers should be expressed as numerals, e.g., 2, 3, 2nd, 3rd. Dates should be written as day, month, year, e.g., 20 June 1985. Use of the 24-hour time system is preferred (e.g., 2030 h, not 8:30 p.m.).

References or Literature Cited should be listed alphabetically at the end of the paper following style B, § 16.5, of *The Chicago Manual of Style,* 13th edition (1982). Literature citations in the text should consist of author and year of publication, with citations arranged chronologically; when enclosed in parentheses, author and date should have no comma intervening (e.g., Smith 1980).

Accompanying line art, maps, and photographs should be numbered consecutively as figures, and each should be clearly identified on its reverse side. Photos to be mounted together must be abutted squarely so that no space shows between; the parts should be identified, preferably with lower case letters (e.g., a, b). The author should indicate in the margin of the manuscript the approximate placement of figures as they should appear in the published paper.

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