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July 7, 1986

Dr. George H. Balazs
Marine and Mammals Endangered Species Program
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

Dear George:

Thank you for your recent informative letter. I certainly enjoyed the enclosed items concerning Johnston Atoll and marine turtles.

I am sorry to learn that you are having problems with *Ornithodoros capensis* bites and their subsequent infection. We had the same problems back in the 1960s. The problem is that, instead of building up resistant to the bites, one becomes more susceptible the more one is bitten. This susceptibility varies from one individual to another. Fortunately, I was not too susceptible, but some POBSP field workers had problems. We used "Off" and "Cutter's" insect repellant, but still got bitten. I do not know of any successful efforts to become desensitized against these tick bites.

One person who did not heed my warning concerning tick bites was Gene Kridler. (I am sure that you remember him as Refuge Manager for the Fish and Wildlife Service back in the 1960s and 1970s.) I well remember that he liked to sleep unprotected (i.e., with just a light sleeping bag or ground cloth) on the beaches at French Frigate Shoals and the other atolls. He refused to sleep inside our zipped up tents unless it rained. On one of the trips to FFS in the late 1960s, he had a severe reaction to tick bites. One of his legs suddenly swelled up twice the normal size and turned all colors—red, yellow, and blue, among others. We got him back to Tern Island and the Coast Guard medic saw immediately that he needed help. A message went out to Honolulu, and a CG plane made an emergency flight to French Frigate Shoals with a doctor aboard. I am not sure of all the details, but the doctor gave him a shot and he got ok. I have forgotten whether or not he was airlifted back to Honolulu, but Gene sure was careful with tick bites after that experience. If you want to write him about it, his address is: Eugene Kridler, 103 Huckleberry Crest, Sequim, Washington 98382; his telephone number is 206/683-8635. He has been retired for a number of years. I talked to him a couple of years ago, and learned that he had had mild stroke.

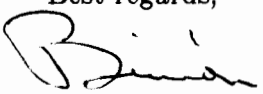
Yes, more work needs to be done on the soft ticks and their relationship to seabirds, turtles, and monk seals on the Northwestern Hawaiian Islands and on the other islands in the Central Pacific. We collected live ticks from many of the islands during the 1960s and shipped them to the U.S. Public Health Service, Rocky Mountain Laboratories in Hamilton, Montana. They ran various tests on them and subsequently published several papers on their findings. I remember that they isolated a virus similar to Hughes Virus from a tick from Sand Island, Johnston Atoll. I will try to dig up the references and send them to you. Blood tests were also taken from all of the seabird species. I think that we also got a few blood samples from green turtles. I do not know all the results from these samples as they were sent elsewhere.

As to my observation of a tick sucking blood from a sea turtle at FFS, I well recall the incident. I had captured a fairly small turtle (about 1 and 1/2 foot caripace) on the beach late one afternoon at Whale-Skate Island. Because of its manageable size, I kept it in a small enclosure for several hours prior to releasing it. While in captivity (after dark), I noticed a tick drawing blood from the soft portions of the turtle's neck.

Your paper on the incidence of fibropapillomas on green turtles at French Frigate Shoals is most interesting. I remember seeing a number of these growths on adult turtles at FFS and the other Northwestern Hawaiian Islands during the 1960s. Unfortunately, we made no effort to record incidence. I doubt there is a connection between these growths and a tick-born virus, but there is always that possibility. I never saw growths on seabirds. As you gathered from reading my 1968 paper, *Ornithodoros capensis* is a common seabird tick found around the world. Of course, sea turtles are also associated with many of these seabird colonies.

I best stop and get back to work. I am printing this letter on our new Imagen laser printer. We are using it to print camera ready copy for our computer documentation. We think it is almost as good as typeset quality; it sure is a lot cheaper.

Best regards,



A. Binion Amerson, Jr.

Tick bite forces medical leave

A U.S. Fish and Wildlife Service researcher was flown to Honolulu yesterday after suffering lingering effects from a probable tick bite on Laysan Island in the French Frigate Shoals.

Cindy Newton, 26, was taken from Laysan to Tern Island aboard the Coast Guard tender Mallow, and then flown to Honolulu in a chartered airplane.

Ken McDermond of the Fish and Wildlife Service said Newton was to see a doctor upon her arrival, but probably would not require hospitalization.

He said Newton was evacuated because her symptoms of itching, sore joints and fatigue persisted three weeks after she was bitten, but she was not in a life-threatening situation.

7-14-92 A5 Honolulu Advertiser

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J. Med. Ent. Vol. 1, no. 2: 165–168 1 July 1964

IXODES LAYSANENSIS, A NEW SPECIES OF TICK FROM BIRDS ON LAYSAN ISLAND (METASTIGMATA : IXODIDAE)[1]

By Nixon Wilson[2]

Abstract: *Ixodes laysanensis* n. sp. is described from sea and shore birds from Laysan Island. It is the first species of ixodid tick endemic to the Hawaiian Islands.

The following new species of *Ixodes* was collected from sea and shore birds during the first week of December 1963 on Laysan Island. It is the first species of ixodid tick endemic to the Hawaiian Islands.

In the following descriptions total length is taken from the tips of the palpi to the posterior body margin and width at the widest part of the body. Length of the capitulum is measured from the tips of the palpi to the posterior margin of the basis and width at the widest point. Dentition of the hypostome does not include the fine denticles at the apex. The measurements of the holotype are given in parentheses. Identical views of the ♀ and nymph are drawn to the same scale.

Acknowledgment is extended to Mr. Ronald L. Walker of the Hawaii Division of Fish and Game for the opportunity to accompany him on the trip to Laysan Island and to the U. S. Coast Guard for furnishing transportation. Mrs. Sharon Burmeister made the drawings.

Ixodes laysanensis Wilson, n. sp.

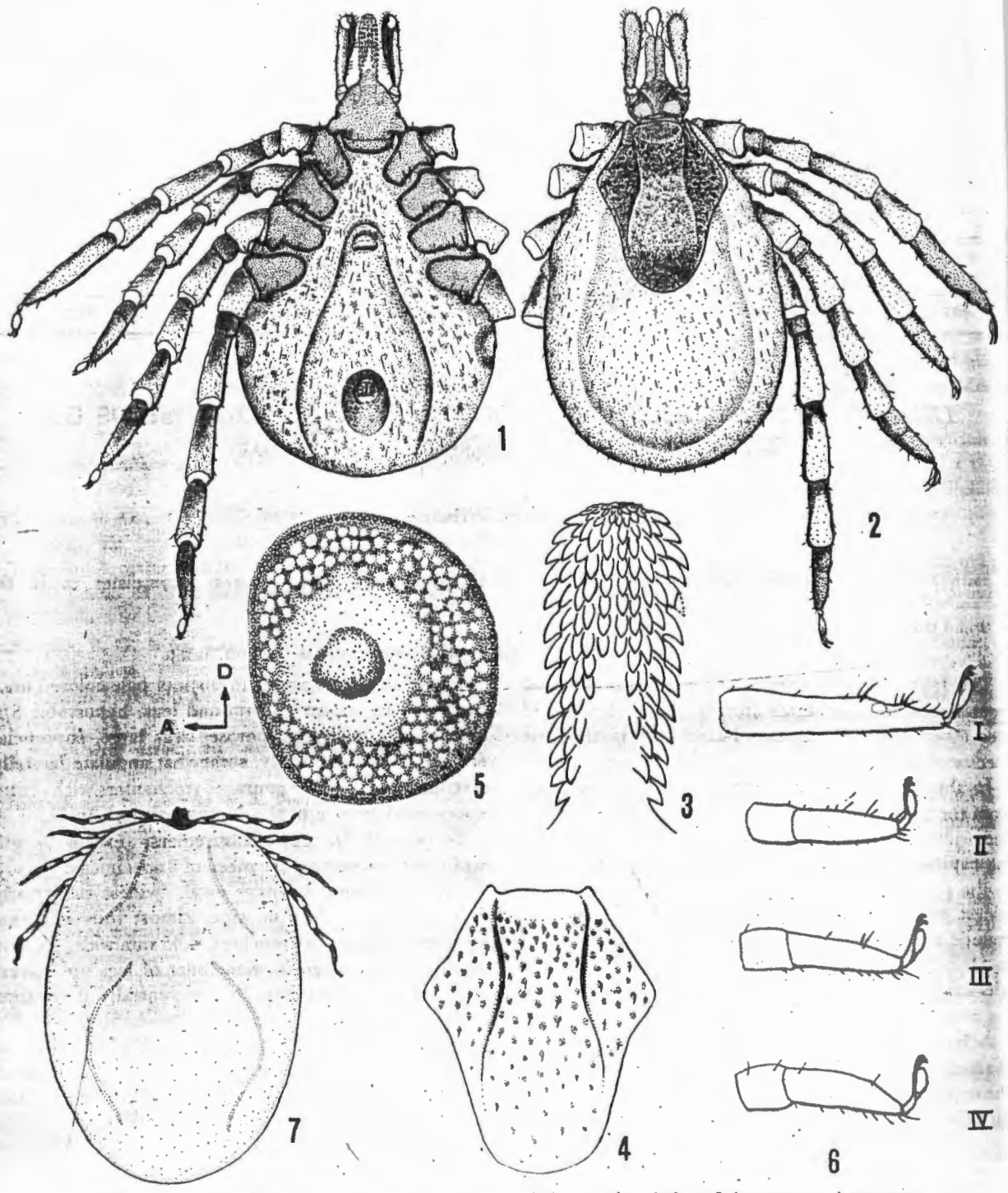
A medium sized tick with distinct pale colored areas on otherwise brown scutum and legs, hypostome 5/5, auriculae spur shaped, porose areas large, superficial, scutum widest anteriorly, somewhat angulate laterally, all coxae with external spurs, all trochanters with ventral spurs, anal groove oval. Nymph similar to ♀.

♀ (figs. 1–7). All measurements except length, width and hypostome the mean of 8 specimens. Body: slightly engorged holotype oval, widest posteriorly, 2.76 mm long, 1.51 mm wide, almost fully engorged paratype oblong, 6.54 mm long, 4.45 mm wide. Capitulum and coxae brown, remainder of legs tan colored with areas of brown dorsally and ventrally at proximal ends of each segment except trochanter. Scutum brown with paler central area bounded on sides by cervical grooves. Non-sclerotized areas with moderate number of long, fine setae. Marginal groove and body fold distinct in slightly engorged specimens. *Capitulum:* length .70 mm, width .43 mm (.72–.44), dorsum of basis broad, sides divergent and angled at about midlength of basis, posterior margin sinuous, porose areas oval, large, superficial, separated by less than

1. Partial results from National Institutes of Health grant AI-01723 to Bishop Museum.

2. Bernice P. Bishop Museum, Honolulu, Hawaii 96819.

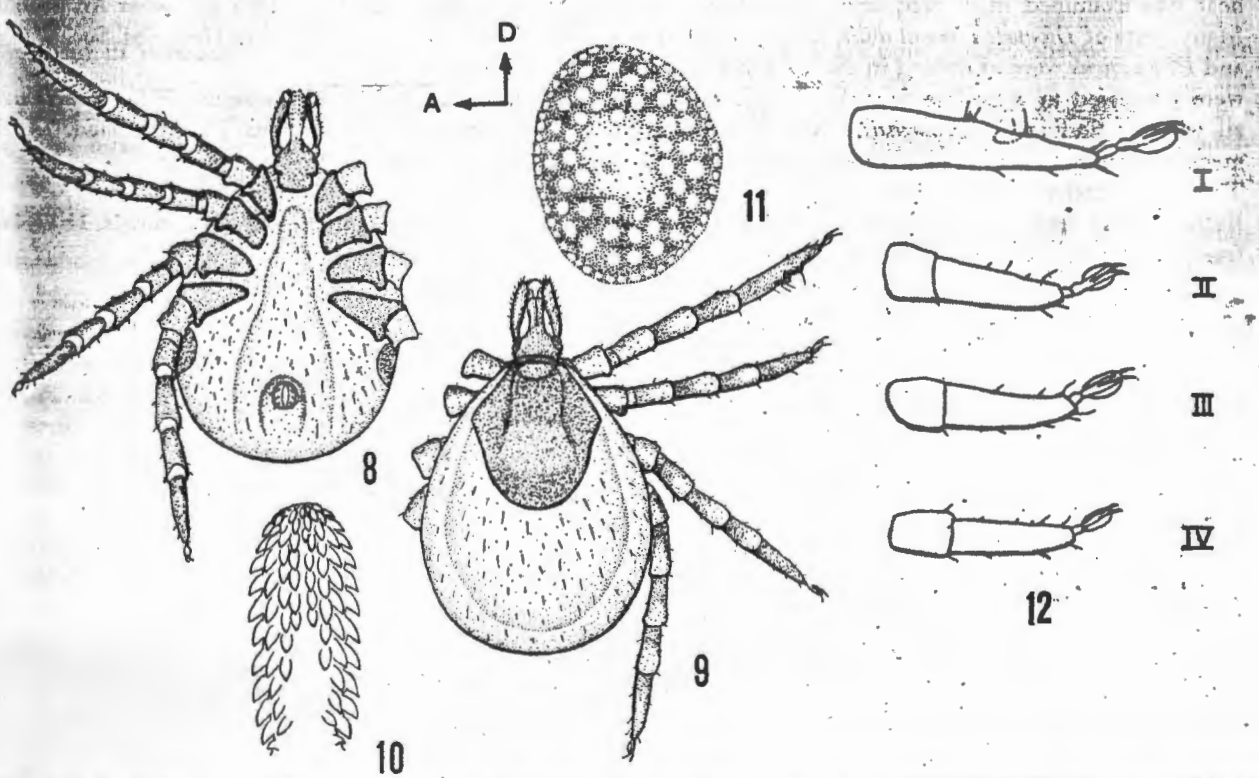
their width, cornua slightly shorter (.03 mm) than basal width (.05 mm), rounded apically. Palps long, narrow, outer margin slightly concave, inner margin convex, length of segments 2–3, .48 mm, greatest width .12 mm (.49–.12), suture line between them indistinct; setae few and short, more numerous on ape of segment 3. In ventral view basis broadest acros auriculae, slightly constricted behind auriculae; posterc lateral margins angular, posterior margin straigh salient, auriculae distinct retrograde spurs, transvers



Figs. 1–7. *Ixodes laysanensis* n. sp., ♀. 1, ventral view; 2, dorsal view; 3, hypostome; 4, scutum; 5, spiracular plate; 6, tarsi I-IV; 7, engorged ♀.

sutural line faintly indicated, inner surface of palps concave. *Hypostome:* .40 mm long (7 specimens) (.39), apex rounded, dentition 5/5, file 1 extends to base with 12 teeth, files 2–5 subequal to preceeding file, with 11, 10, 9 and 7 teeth respectively, file 5 about 1/2 length of hypostome, 2 apical rows of fine denticles, lateral denticles slightly larger than inner denticles. *Scutum:* longer than broad, length 1.09 mm, width .92 mm (1.09–.86), widest just in front of middle, lateral margins angulate, converging posteriorly, rounded behind, scapulae short, broadly rounded, cervical grooves deep, first convergent then divergent, terminating short of postero-lateral margins. Punctations numerous, large, deep and scattered over anterior 3/4 of scutum, few and shallow in posterior 1/4, moderate number of short setae, more numerous anteriorly and antero-laterally, lateral carinae absent. *Legs:* moderate in length and width, coxae I-IV with large, blunt, external spurs, coxa I with internal salience suggestive of very small spur, posterior margin salient, trochanters I-IV with rounded ventral spurs, large on I-III, small on IV, tarsi tapering gradually, with slight subapical humps, length of tarsus I, .65 mm (.65), II, .46 mm (.48), III, .47 mm (.46) and IV, .52 mm (.52), puvilli 3/4 as long as claws. *Spiracular plate:* elliptical, broader than long, length .27 mm, width .31 mm (.27–.30), goblets large, numerous, macula antero-median to center. *Genital aperture:* opposite coxae III. *Genital groove:* rounded in front of genital aperture, converging opposite coxae IV, then diverging opposite spiracular plates and converging posteriorly. *Anal groove:* oval, open posteriorly. Anal aperture located in anterior region of area outlined by anal groove, with 3 pairs of anal setae.

Nymph (figs. 8–12). All measurements, except length, width and hypostome the mean of 11 specimens. Body: slightly engorged paratype oval, widest posteriorly, 1.20 mm long, .69 mm wide, almost fully engorged paratype oblong, 2.90 mm long, 2.06 mm wide. Capitulum, legs and scutum pale brown, pattern as in ♀ except less distinct on legs. Marginal groove and body fold distinct in slightly engorged specimens. *Capitulum:* length .33 mm, width .20 mm, dorsum of basis triangular, posterior margin and cornua as in ♀ only latter shorter. Palps as in ♀, length of segments 2–3, .24 mm, greatest width .06 mm. In ventral view basis as in ♀ except auriculae smaller and less pronounced. *Hypostome:* as in ♀, .20 mm long (10 specimens), dentition 4/4, file 1 extends to base with 12 teeth, files 2–4 subequal to preceeding file with 11, 8 and 6 teeth respectively, file 4 extends 1/2 length of hypostome, sometimes file 5 represented by 1–2 irregularly placed teeth, 2 apical rows of fine denticles. *Scutum:* shape as in ♀, about as wide as long,



Figs. 8–12. *Ixodes laysanensis* n. sp., Nymph. 8, ventral view; 9, dorsal view; 10, hypostome; 11, spiracular plate; 12, tarsi I-IV.

length .49 mm, width .46 mm, cervical grooves not as deep, punctations fewer, smaller and not as deep, a few short, scattered setae. *Legs:* as in ♀, length of tarsus I, .35 mm, II, .25 mm, III, .26 mm and IV, .28 mm, spurs on coxae and trochanters as in ♀ but somewhat smaller. *Spiracular plate:* shape as in ♀, length .11 mm, width .14 mm, goblets large, few, separated, macula centered. *Anal groove:* as in ♀, anal aperture as in ♀.

Holotype ♀ (Bishop 3611), Laysan Island, *Puffinus pacificus*, 7. XII. 1963, N. Wilson.

Paratypes: 1 ♀, 5 NN, Laysan Island, *Arenaria interpres*, 4.XII. 1963, N. Wilson; 3 NN, Laysan Island, *Diomedea immutabilis*, 4.XII. 1963, N. Wilson; 2 ♀♀, 2 NN, Laysan Island, *Puffinus pacificus*, 5. XII.1963, N. Wilson; 1 ♀, Laysan Island, *Puffinus pacificus*, 6.XII.1963, N. Wilson; 2 ♀♀, 1 N, same data as holotype.

Other specimens: 1 ♀, Laysan Island, *Puffinus pacificus*, 6.XII.1963, N. Wilson; 1 ♀, same data as holotype.

The holotype and 15 paratypes deposited in the acarology collection of Bishop Museum; 2 paratypes in Rocky Mountain Lab., Hamilton, Mont.

I. laysanensis has been collected from 3 species of sea and shore birds and appears to have little avian host preference on Laysan Island. Nine of the 11 collections were from *Puffinus pacificus*. However, this host was examined more frequently than any other. Many nests of *Diomedea immutabilis*, *Diomedea nigripes* and *P. pacificus* were examined in the field and several were processed in a Berlese funnel in the laboratory, all without finding *I. laysanensis*. Numerous specimens of *Ornithodoros* were recovered by these methods. The 3 specimens of an immature *Ixodes* reported by Butler (1961) and again by Butler & Usinger (1963) from the ear of *Anas wyvilliana* on Laysan Island are probably this species. Distribution and location of *laysanensis* on the 11 infested hosts were as follow 1 ♀, 6 NN (1 N lost) attached to the throat and ventr side of the neck of *Arenaria interpres;* 3 NN crawlir on underside of wing near base, of recently dead *I immutabilis;* 1♀, 2 NN attached to throat of *P. pac ficus;* 1 ♀ attached to throat of *P. pacificus;* 1 attached to side of head of *P. pacificus;* 1 ♀ attache to ventral side of neck of *P. pacificus;* 1 N attached t throat of dead *P. pacificus;* 1 N (lost) attached t underside of wing near base of *P. pacificus;* 2 ♀ attached to throat of *P. pacificus;* 1 ♀ attached t ventral side of neck of *P. pacificus;* 1 ♀ attached t throat of *P. pacificus.*

I. laysanensis falls within the group of ticks from se birds which lack the meso-dorsal spur and mesal ex tension on palpal article I. The following species ar in this group: *I. eudyptidis* Maskell, *I. kohlsi* Arthu *I. murreleti* Cooley & Kohls, *I. rothschildi* Nuttall & Warburton, *I. signatus* Birula, *I. unicavatus* Neuman and *I. uriae* White. *I. laysanensis* appears to be mos closely related to *I. kohlsi*, *I. rothschildi* and *I. murreleti* In Zumpt's (1952) key to the ixodid ticks of sea bird *I. laysanensis* keys to *I. murreleti.* It may be distinguished from this species by the shape of the hypostome which is pointed in *murreleti* and rounded in *laysanensis*

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NOTICE TO AUTHORS

The editors will be happy to receive short notes and articles up to one page or so in length. These will not be subject to the page charge. Also, reviews or book notices of pertinent subject matter will be considered. Ed.

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CLOACARIDAE, A NEW FAMILY OF CHEYLETOID MITES FROM THE CLOACA OF AQUATIC TURTLES

(ACARI: ACARIFORMES: ELEUTHERENGONA)[1]

By Joseph H. Camin, W. Wayne Moss[2], James H. Oliver, Jr.[3] and George Singer[4]

Abstract: A new family (Cloacaridae), a new genus (*Cloacarus*) and two new species (*C. faini* and *C. beeri*) of parasitic cheyletoid mites are described from the cloaca of two species of North American aquatic turtles. *Chelydra serpentina* and *Chrysemys picta*. Because of the extreme morphological modification of these mites, especially of their legs, it is postulated that they are probably venereally transmitted from host to host and are highly host-specific. Several alternative hypotheses are offered concerning the probable life histories of the mites and the possible correlation of these with the mating cycles of their hosts.

The Cheyletoidea comprise a diverse group of eight mite families, most of which are parasitic. The group is highly plastic, ecologically and morphologically, and parasitism probably has arisen independently within it many times. The predaceous members of the central family, the Cheyletidae, are commonly found associated with vertebrates where they prey upon parasitic acarines, frequently attacking mites much larger than themselves. It seems a comparatively small step for them to begin feeding on the vertebrates themselves and, indeed, many Cheyletidae have become obligate vertebrate parasites. All of the remaining cheyletoid families are parasites of vertebrates, except for the Heterocheylidae, which parasitize passalid beetles. Clark (1964) and Dubinin (1957) have suggested, however, that the Syringophilidae may be only facultative parasites and that they may also prey upon other mites in their microhabitat, the feather shafts of birds. The Myobiidae, Psorergatidae and Demodicidae on mammals, the Harpyrhynchidae on birds, and the Ophioptidae on snakes are the most highly modified of the cheyletoid mites; all are obligate parasites. This paper is concerned with a ninth family of Cheyletoidea, another extremely modified mite and also an obligate parasite of vertebrates, in this case turtles.

In July 1958 some acariform mites were discovered in the cloaca of a mature painted turtle, *Chrysemys picta* (Schneider), near Douglas Lake, Michigan, and donated to Oliver. Many mites were observed but, unfortunately, only three were recovered. These mites, in their well-developed coxal apodemes, bear superficial resemblance to certain members of the Acaridei, but because of the morphological reduction exhibited by the then available specimens we were unable to determine with certainty their developmental stage. Accordingly, we were hesitant to assign them to a suborder of the Acariformes and decided to delay publication of a description until additional material could be obtained.

Five years later, in May 1963, Singer collected a series of similar mites from the cloaca of a large, female snapping turtle, *Chelydra serpentina* Linn., near Lawrence, Kansas. This series consisted of a single adult male, 34 females and 86 nymphs. In November 1965 another collection of 36 mites, all females, was made from the cloaca of a female snapping turtle maintained in the laboratory since its capture the previous May near Emporia, Kansas.

The lone male specimen of the cloaca mite has a conspicuous, eversible aedeagus (FIG. 1) located dorsally in the podosomal region, a characteristic shared by cheyletoid mites of the families Myobiidae, Harpyrhynchidae, Ophioptidae, Psorergatidae, and Demodicidae, but found in no other described group of acarines. With this as a clue to the proper taxonomic placement of the turtle parasite, additional characters were subsequently found which confirmed its placement in the superfamily Cheyletoidea of the suborder Eleutherengona and refuted its placement in the suborder Acaridei.

Freshly-collected, living specimens of the cloaca mite possess a pair of bright carmine, subintegumental pigment spots in the podosomal region. In the female and nymph the spots flank the dorsal shield,

[1]Contribution No. 1323 from the Department of Entomology, University of Kansas, Lawrence. This research was supported in part by Research Grant AI-02487 from the National Institute of Allergy and Infectious Diseases, U.S. Public Health Service.

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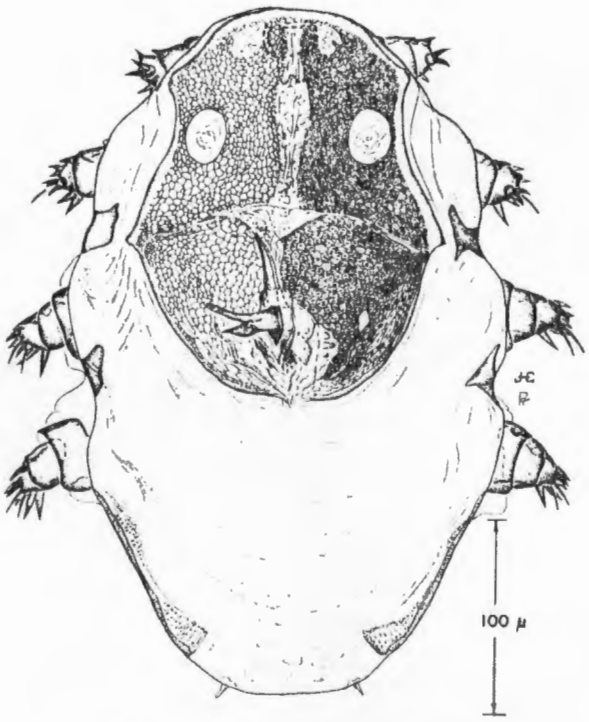

FIG. 1. *Cloacarus faini*, male, dorsal view.

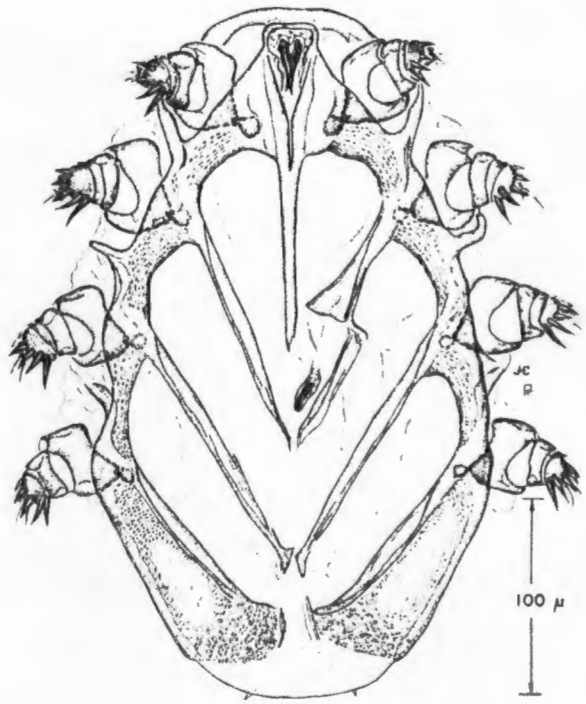

FIG. 2. *Cloacarus faini*, male, ventral view.

but they fade in preservative and no remnants remain in cleared and mounted specimens. The dorsal shield of the male is more extensive, however, and in these the spots occur in a pair of large, circular, membranous areas within the dorsal shield. In the mounted specimen the membranous areas persist after the pigment spots have faded (FIG. 1). The subintegumental pigment spots are probably photoreceptors, but their role in the behavior of the mite is unknown. In a host-dwelling endoparasite, such as the cloaca mite, the behavior patterns are probably reduced, simplified and stereotyped (Camin 1963, 1964). Photoreceptors might serve only to prevent the mites from accidentally leaving the host. Bright red eyes are common in the podosomal region of many Eleutherengona, including some members of the Cheyletoidea. Such structures do not occur in the Acaridei.

In many Eleutherengona there is no connection between the mesenteron and the proctodeum (Hughes 1959). The anus, therefore, actually functions as an excretory pore. The anus has been lost in the cheyletoid families Harpyrhynchidae, Ophioptidae, Psorergatidae, and Demodicidae, and in some of these the genital aperture is terminal or subterminal in position. The cloaca mite also appears to be lacking an anus, and its genital opening is terminal in the female (FIG. 3, 4). This terminal aperture possibly represents contiguous genital and anal openings such as are thought to occur in the Cheyletidae, but the obvious lack of an anal opening in the male (FIG. 1, 2) suggests that this is not the case. Although genital apertures have not been reported in the nymphs of other cheyletoid mites, they are known in other Eleutherengona. The terminal aperture in cloacarid nymphs (FIG. 11, 12, 13) is so similar to that of the female, that it seems unreasonable to conclude that this aperture is the anus in the nymph. Clarification of the nature of the external openings in the Cheyletoidea must await further investigations of their internal anatomy. Acaridei always possess an anus and a complete digestive tract; the genital opening of both sexes is distinctly ventral in position, usually in the podosomal region.

Many Acaridei lack pretarsal claws, but all species that possess claws are monodactylous. Most Eleutherengona are bidactylous and usually have an empodium, which is sometimes claw-like, between the two claws. Pretarsi, each bearing a pair of claws, are present on the anterior two pairs of legs of the cloaca mite, but are totally lacking on the metapodal legs (FIG. 1, 3, 5, 9, 10, 11, 12).

The gnathosoma of the turtle cloaca mite bears a pair of strong, fang-like structures (FIG. 2, 8, 9, 10, 13) which might be interpreted as chelicerae. No other gnathosomal appendages are discernible.

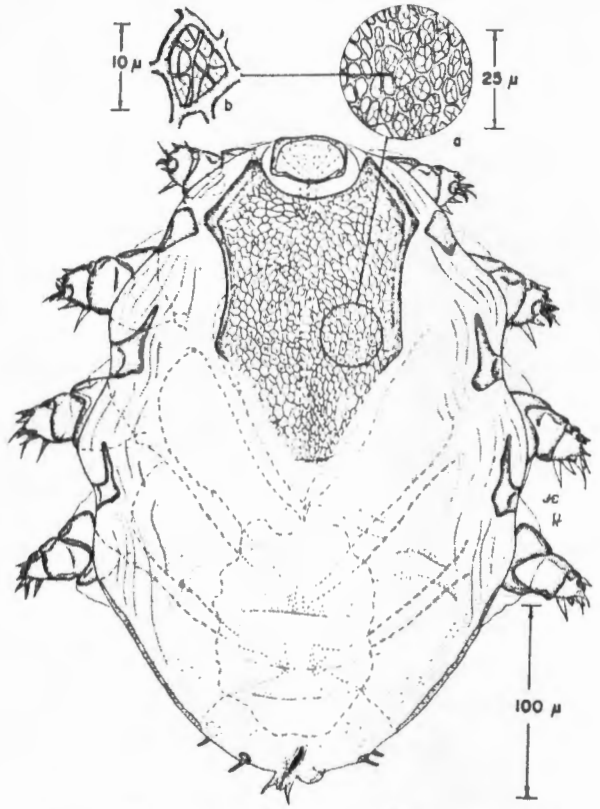

FIG. 3. *Cloacarus faini*, female, dorsal view; *a* and *b* are successive enlargements of a portion of the dorsal shield to show the complexity of the reticular pattern.

In the Acaridei the pedipalps are always greatly reduced, but the chelicerae are usually well-developed, strong and chelate, except among the members of the Cytoditoidea in which the chelicerae are also much reduced. The cheyletoid Eleutherengona all possess reduced stylet-like chelicerae, but the pedipalps are variously modified and are frequently greatly hypertrophied as grasping structures. There is a striking similarity between the fang-like appendages of the cloaca mite and the palpal projections of some Myobiidae. Comparison of the recurved apical projections on the palps of *Blarinobia simplex* (Ewing) (FIG. 6) with the foreshortened palps and enlarged projections in *Neomyobia inaequalis* (Ewing) (FIG. 7) demonstrates an apparent tendency in the Myobiidae toward reduction of the pedipalps and hypertrophy of the apical projections of their terminal segments. The fang-like structures of the cloaca mite gnathosoma probably are extremely hypertrophied homologues of the palpal projections of the Myobiidae. If this is the case, these structures are then remnants of the pedipalps rather than chelicerae, again suggesting relationship of the cloaca mite to the cheyletoid Eleutherengona rather than to the cytoditoid or other Acaridei. The palpal nature of these fang-like organs is further attested to by the fact that they appear to be articulated with the distal margin of the gnathosoma and are not retractable into it.

Thus, only the well-developed coxal apodemes of the turtle parasite suggest a relationship of this mite to the Acaridei. However, such structures, although not as pronounced, are also present in some Cheyletoidea, such as the Demodicidae.

For these reasons, we conclude that the turtle cloaca mite is a member of the superfamily Cheyletoidea.

CLOACARIDAE, New Family

Diagnosis: Minute, soft-bodied, oval mites with greatly reduced legs and gnathosoma. Gnathosoma tubular, oriented vertically, perpendicular to axis of idiosoma; with ventral apodemes fused and continuous with apodemes of legs I; pedipalps 1-segmented, freely articulated and fang-like; no discernible chelicerae. Legs strong, but greatly foreshortened, being less than $1^1/_2\times$ as long as wide and less than 1/5 length of idiosoma; with strong, claw-like setae restricted to distal 2 segments. Legs I and II each bear a pretarsus arising from dorsal surface of tarsus and bearing a pair of well developed claws, but no empodium; legs III and IV without pretarsi. All legs arise laterally, rather than ventro-laterally, inserting above a sclerotized ventro-marginal frame that joins together a series of conspicuous coxal apodemes. Idiosoma with an ornate, reticulated podonotal shield; with subintegumental red pigment spots (photoreceptors?) which fade in preservative, becoming indiscernible. A pair of round, membranous areas in scutum of male marks position of pigment spots, but no such remnants are present in preserved females or nymphs. Body devoid of setae except for 1 or 2 pairs of setae or seta-like projections on opisthosoma. Anus lacking; male genital aperture and aedeagus dorsal, arising from

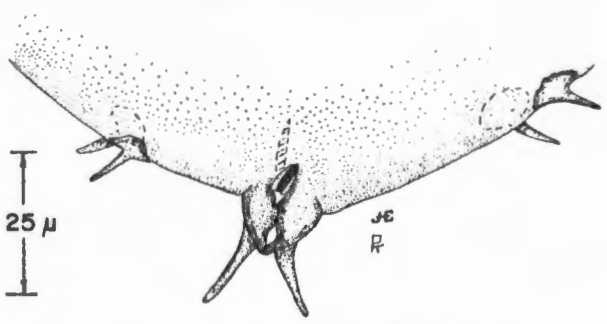

FIG. 4. *Cloacarus faini*, female, ventral view of posterior end of opisthosoma.

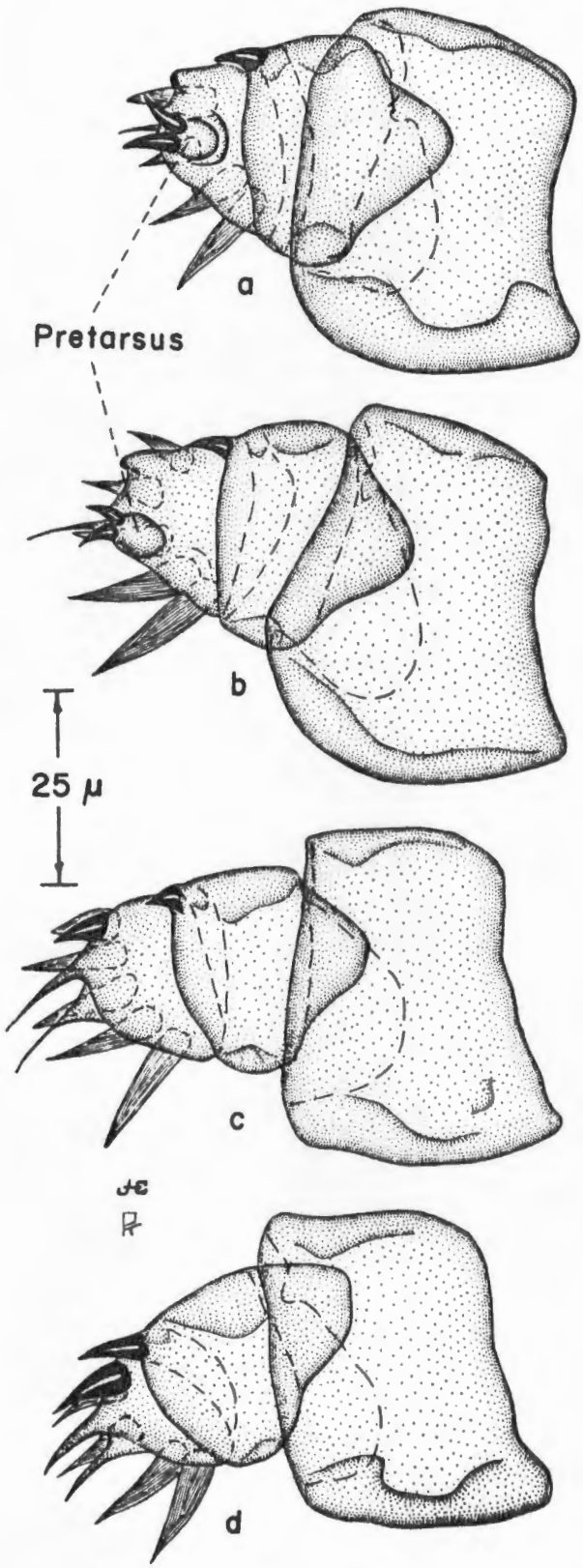

FIG. 5. *Cloacarus faini*, male, dorsal view of legs: a. Leg I, b. Leg II, c. Leg III, d. Leg IV.

podonotal shield; female and nymphal genital apertures terminal or dorsal, posterior to podonotal shield.

Type genus: *Cloacarus*, new genus.

CLOACARUS, new genus

Diagnosis: Gnathosoma tubular, with ventral apodemes fused with apodemes of legs I, but free dorsally from podonotal shield; sclerotization smooth, not reticulate like that of dorsal shield. Fang-like palpal segment approximately 1/2–3/4 as long as greatest width of first movable segment of leg I; directed downward and slightly outward in life (FIG. 2, 8, 9, 10, 13). Coxal apodemes of legs I fused medially and extending to posterior margins of legs III; apodemes of legs II often contiguous medially, but usually not fused except in some immatures; apodemes III and IV separated medially. Legs I and II with paired claws on a pretarsus which arises dorsally from "tarsus".

Aside from these pretarsi on legs I and II, all legs are 3-segmented dorsally and 4-segmented ventrally, the middle segment (genu-tibia?) being divided ventrally but fused dorsally. All legs with one strong, thorn-like seta on distal edge of antero-dorsal margin of middle segment; all other setae on distal segment ("tarsus"). "Tarsi" I and II each with a single, finely-pointed, seta-like projection distally and a thick, blunt projection on distal edge of antero-dorsal margin. "Tarsi" III and IV each with 2 finely-pointed, seta-like, distal projections and a strong, thorn-like seta at distal edge of antero-dorsal margin. "Tarsi" I and IV with 4, and II and III with 5, greatly hypertrophied, claw-like ventral setae, which are progressively larger from anterior to posterior aspect of each leg.

In life, the legs are tilted in such manner that the posterior 2 claw-like, ventral setae of each leg are directed downward and backward (FIG. 5, 9, 10), while the true claws of legs I and II are directed upward and backward. Podonotal shield ornate, with complex reticulations (FIG. 3); shape relatively constant within developmental stages, but differing markedly between stages. Male with genital aperture and eversible aedeagus within dorsal shield. Female and nymphs with genital aperture terminal or, if dorsal, subterminal and reaching posterior margin of body. Distance between anterior margin of female or nymphal genital aperture and posterior margin of dorsal shield at least 2× length of genital aperture, a longitudinal slit.

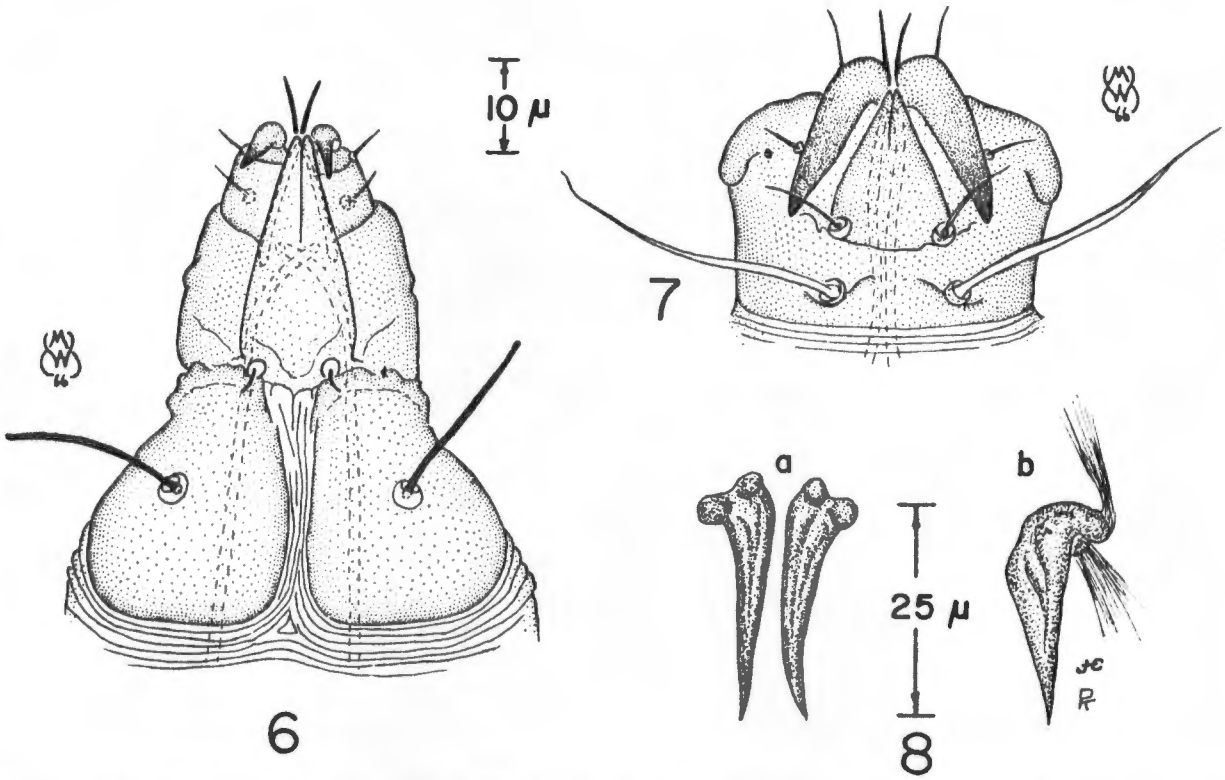

FIG. 6, 7, 8. (6) *Blarinobia simplex* (Ewing 1938), female, ex *Blarina brevicauda* (Say), ventral view of gnathosoma. (7) *Neomyobia inaequalis* (*Ewing* 1938), male, ex *Tadarida mexicana* (Saussure), ventral view of gnathosoma. (8) *Cloacarus faini*, female, fang-like pedipalps; a. dorsal view, b. lateral view.

The generic name, *Cloacarus*, is an anagram combining the words *cloaca* and *acarus*, referring to the mite's habitat in the cloaca of aquatic turtles.

Type species: *Cloacarus faini*, new species.

Cloacarus faini Camin & Singer, **n.sp.** FIG. 1-5, 8-11.

MALE. Body 355.3 μ long, 209.5 μ wide. Dorsal shield (FIG. 1) slightly more than 1/2 length of body, extending from anterior margin of idiosoma to a line between legs III and IV; broadly rounded posteriorly; projecting laterally just behind legs I and again, to its greatest width, between legs II and III. Dorsal shield highly reticulate in a complex network of reticulations within reticulations (in FIG. 1 shown coarsely in left half and in somewhat greater detail in right half, but complexity of reticulations is shown best in FIG. 3); with smoother, sclerotized margins; with irregular clear areas flanking gnathosoma and in posterior part of shield, representing muscle insertions; with shallow trough running longitudinally down mid-line of shield from anterior margin to aedeagus. (The holotype specimen, the only male, has a horizontal line across the middle of the dorsal shield, but this appears to be a fold, an artifact caused by the pressure of the coverglass on the dorsum of the mite.) Two circular membranous areas, respresenting the "eyes", located within dorsal shield, just anterior to legs II.

An eversible, bifid aedeagus arises from longitudinal aperture in posterior part of dorsal shield between legs III. Anterior arm of aedeagus narrow, elongate, bluntly rounded and approximately 2× length of posterior arm, which is laterally flattened, approximately 2× as broad as anterior arm, and tapered to a sharp point. Opisthosoma unsclerotized dorsally; short, approximately 1/3 length of podosoma; with single pair of terminal, seta-like projections.

Ventral surface (FIG. 2) with sclerotized marginal framework, joining apodemes of gnathosoma and legs; with lateral extensions projecting between legs I–II, II–III and III–IV to dorsal surface (FIG. 1, 9, 10); with minute punctations, tending to form reticulate pattern, between and bordering coxal apodemes; reticulations show greatest development on postero-lateral expansions behind fourth coxal apodemes, which form ventro-marginal "plates", covering most of the opisthosoma and extending over lateral surfaces to margins of the dorsum. These marginal "plates" also with reti-

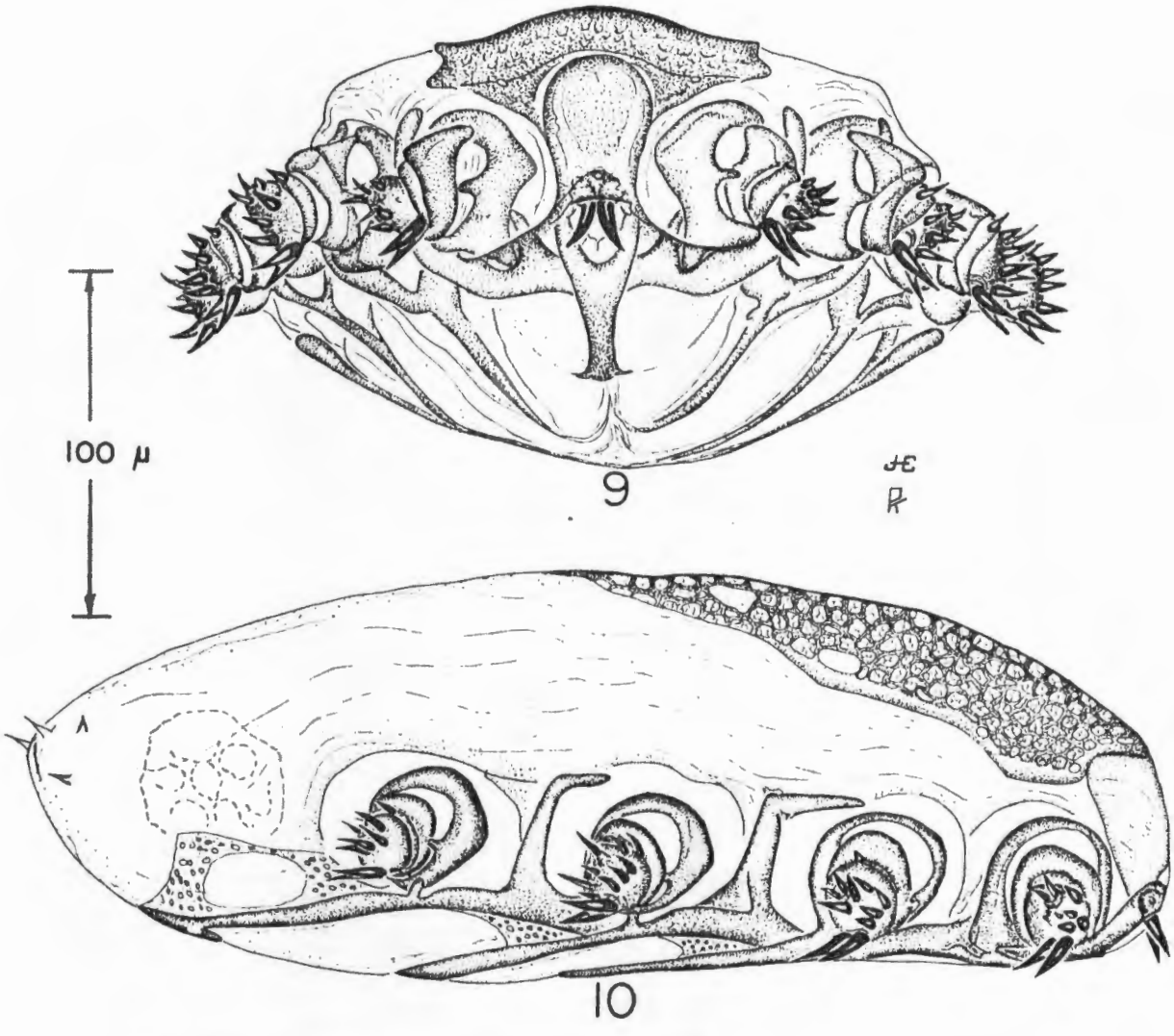

FIG. 9, 10. (9) *Cloacarus faini*, female, anterior view. (10) *Cloacarus faini*, female, lateral view.

culate pattern similar to that of dorsal shield, but with unsclerotized central area.

Gnathosomal apodemes join those of legs I, which fuse medially behind legs I and extend posteriorly to posterior margins of legs III. Coxal apodemes II remain separate, but approach each other medially between legs IV (the right member of this pair is broken in FIG. 2 and laid on its side, showing the depth to which the apodemes project into the body); apodemes III approach each other at a point halfway between posterior margins of legs IV and tip of opisthosoma; apodemes IV separated medially by a distance 2–3× that between posterior extension of apodemes III and tip of opisthosoma, forming anterior border of ventro-marginal expansions of ventro-marginal framework. Legs arise laterally (FIG. 2, 9, 10), dorsal to ventro-marginal sclerotized framework, articulating with this framework.

Legs (FIG. 2, 5) as described for the genus; first movable segment of all legs approximately 1½× width, but approximately equal in length to next segment. This large basal segment probably represents the fusion of trochanter and femur, but this will not be known until more thorough studies of the development and the musculature have been undertaken. Second segment single dorsally, but divided into 2 quite short, broad segments ventrally and probably represents the genu and tibia. Dorsally this segment bears 1 thorn-like seta. The 3rd segment, probably tarsus, bears all remaining setae of leg, as described for the genus. Arising dorsally from "tarsal" segment of legs I and II is a pretarsus bearing a pair of strong claws; legs III and IV lack pretarsus and have no true claws. Gnathosoma tubular, perpendicular to body, fused with ventro-marginal sclerotized frame ventrally,

TABLE. Measurements (in microns) of body* and dorsal shield** of *Cloacarus faini* and *Cloacarus beeri*.

	NUMBER	RANGE (min.–max.)	MEAN	STANDARD DEVIATION
Cloacarus faini				
MALE				
Body:				
Length	1	— —	355.3	—
Width	1	— —	209.5	—
Dorsal Shield:				
Length	1	— —	199.4	—
Width I	1	— —	118.5	—
Width II	1	— —	160.8	—
FEMALE				
Body:				
Length	23	321.9— 374.8	335.7	13.38
Width	23	180.5— 211.7	194.1	8.20
Dorsal Shield:				
Length	21	139.6— 180.8	171.7	8.66
Width I	23	104.2— 127.3	112.3	5.15
Width II	22	91.2— 115.7	98.8	5.25
"PROTONYMPH"				
Body:				
Length	25	211.0— 241.4	221.6	8.58
Width	25	110.9— 137.8	124.3	8.02
Dorsal Shield:				
Length	25	129.5— 152.3	143.4	5.41
Width I	25	67.6— 80.3	74.6	2.95
Cloacarus beeri				
"DEUTONYMPH"				
Body:				
Length	3	278.4— 298.7	285.8	11.24
Width	3	161.7— 175.5	169.2	6.98
Dorsal Shield:				
Length	3	183.3— 185.8	184.7	1.58
Width I	3	99.6— 109.9	104.3	5.15
Width II	3	127.7— 135.7	131.0	4.36

* Measurements of body length and width made with a Cooke A.E.I. Image Splitting Eyepiece on a Zeiss GF phase contrast microscope.
Length of body = Total length; Width of body = Width immediately behind legs IV.

** Measurements of dorsal shield made with a Bausch and Lomb Filar Micrometer Eyepiece on a Zeiss GF phase contrast microscope.
Length of dorsal shield = Maximum length; Width I = Maximum width between legs I and II; Width II = Maximum width between legs II and III.

but free dorsally; only appendages a pair of 1-segmented, fang-like pedipalps; no discernible chelicerae.

FEMALE. Similar to male. Body dimensions of allotype specimen are $328.4 \times 204.5\ \mu$ (additional measurements in TABLE). Dorsal shield (FIG. 3) with convex anterior margin; lateral margins sloping laterad to greatest width between legs I and II, then becoming slightly convex to almost parallel-sided to a line between legs II and III, and finally tapering to a blunt point at level of posterior margins of legs III; with complex pattern of reticulations (shown at progressively greater magnifications in FIG. 3). Genital aperture (FIG. 3, 4) a longitudinal slit, terminal in position, approximately 2/3 dorsal and 1/3 ventral, flanked by 2 pairs fleshy projections which form a terminal papilla; dorsal projections long, slender and approximately 2× length of ventral projections, which are bulbous at bases, but become narrow and nipple-like apically. Flanking genital aperture and its papillae at posterior margin of opisthosoma are 2 pairs seta-like projections, the more dorsal pair being closer together than the ventral pair. Ventral apodemes (shown by dashed lines in FIG. 3) similar to those of male; first apodemes fused medial-

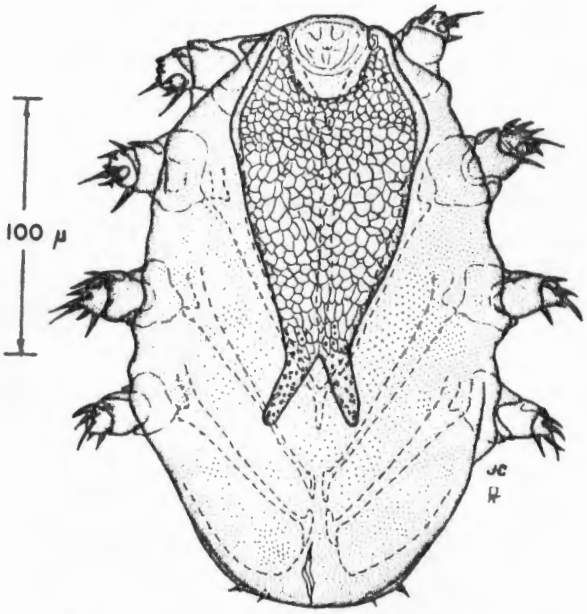

FIG. 11. *Cloacarus faini*, nymph, dorsal view.

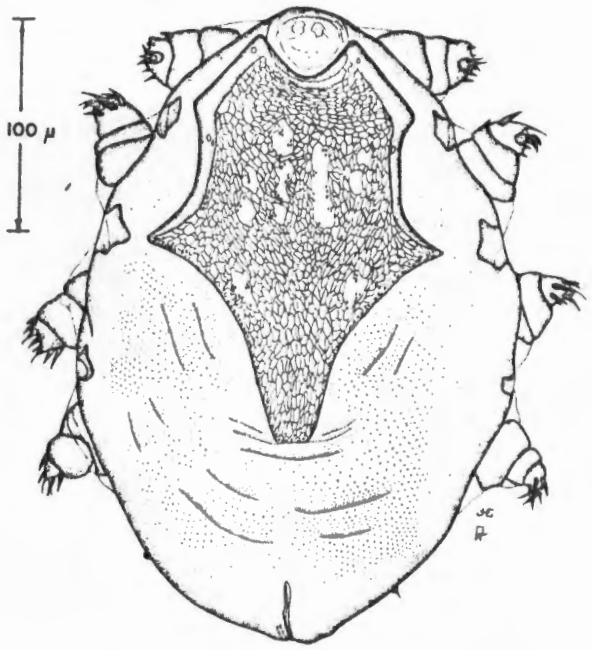

FIG. 12. *Cloacarus beeri*, nymph, dorsal view.

ly and extend posteriorly to level of posterior margins of legs III; apodemes II contiguous medially, but not fused, and extend to level of anterior margins of legs IV; apodemes III approach each other, but remain separate medially and extend slightly posterior to legs IV; apodemes IV separated by approximately 2 × the distance between apodemes III and reach a point halfway between ends of apodemes III and tip of body. The single-segmented, fang-like pedipalps (FIG. 8), like those of male, approximately 2/3 as long as width of basal segment of leg I, tapering to a sharp point distally and with 2 ball-like expansions basally, on which the muscles insert; lateral view shows that palp is operated by 2 muscles. A single, relatively large ovum (shown by dashed lines in FIG. 3, 10) usually visible within opisthosomal region of female.

NYMPH. Similar to female, but considerably smaller (measurements in TABLE). Dorsal shield (FIG. 11) with convex anterior margin; laterally expanding to its greatest width between legs I and II and then tapering posteriorly to level of anterior margins of legs IV, where it bifurcates and then extends to level of posterior margins of legs IV. Genital aperture a longitudinal slit, completely dorsal in position, but reaching tip of opisthosoma; flanked by 2 pairs seta-like projections, similar in structure and placement to those of female. Coxal apodemes I fused medially behind legs I and extending to level of posterior margin of legs III; apodemes II often fused medially at their tips, extending almost to posterior margins of legs IV; apodemes III separated medially, extending to a point halfway between anterior margins of legs IV and tip of opisthosoma; apodemes IV separated and extending to a point halfway between posterior margins of legs IV and tip of opisthosoma. Judging from the difference in size between this nymphal stage and the adult, it is likely that this is the protonymph.

Type Data: (Series 1) Ex cloaca of mature female snapping turtle, *Chelydra serpentina* Linn., 46 cm long and containing 20 ova; collected 15.V.1963 in permanent stream near U.S. Route 59 at county line between Douglas Co. and Franklin Co., Kansas, by George Singer. Turtle dissected and mites recovered by Singer on same date turtle collected. Mites (1♂, 34♀♀, 86 "protonymphs") all slide-mounted in Hoyer's medium, ringed with Zut's lacquer.

(Series 2) Ex cloaca of mature female snapping turtle, *Chelydra serpentina* Linn., collected V.1965 on U.S. Route 50, 18.4 km west of Emporia, Kansas, by William Vensel. Turtle sacrificed and mites collected 20.XI.1965 by J.H. Camin. Mites (30 ♀♀) all preserved in 70% ethyl alcohol.

Type Specimens: Holotype ♂ and Allotype ♀, with data of Series 1, to be deposited in the acarological collection of the Snow Entomological Museum, University of Kansas, Lawrence.

Paratype "protonymphs" and ♀♀, with data of Series 1 or 2 to be deposited in the following collections: Snow Entomological Museum, Lawrence,

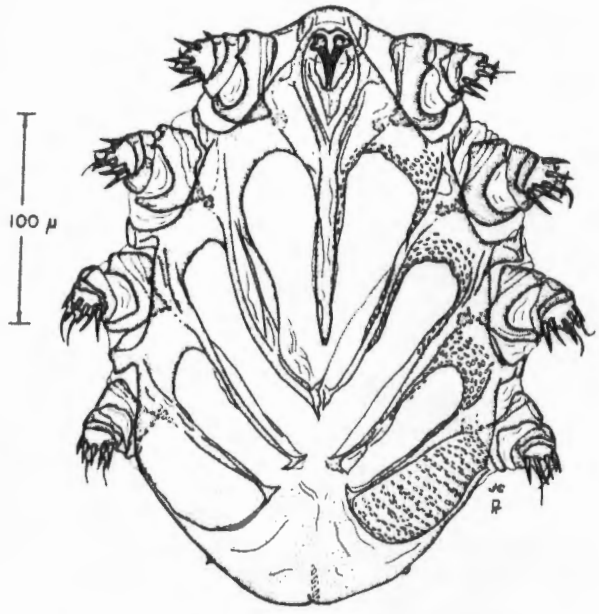

FIG. 13. *Cloacarus beeri*, nymph, ventral view.

Kansas; U.S. National Museum, Washington, D.C.; Institute of Acarology, Columbus, Ohio; Field Museum of Natural History, Chicago, Illinois; Bernice P. Bishop Museum, Honolulu, Hawaii; Canadian National Collection, Ottawa; British Museum (Natural History), London, England; Institut Royal des Sciences naturelles de Belgique, Bruxelles, Belgium; Institut de Médecine Tropicale, Antwerp, Belgium; Muséum National d'Histoire naturelle, Paris, France; Zoological Institute of the Academy of Sciences of the USSR, Leningrad, USSR; South Australian Museum, Adelaide; Natal Museum, Pietermaritzburg, Union of South Africa.

Type Host: Snapping turtle, *Chelydra serpentina* Linn. (Reptilia: Chelydridae).

Type Locality: Stream near U.S. Route 59 at county line between Douglas Co. and Franklin Co., Kansas.

Remarks: The specific epithet is in honor of Dr Alex Fain, the well-known Belgian acarologist and parasitologist, whose excellent and prolific research has demonstrated the fact that no habitat, no matter how strange, should be overlooked in the search for parasitic acarines.

Cloacarus beeri Camin & Oliver, **n.sp.** FIG. 12, 13.

NYMPH. Similar to females and nymphs of *Cloacarus faini*, except in the following characters. Body dimensions intermediate between those of female and "protonymph" of *C. faini* (measurements in TABLE). Dorsal shield (FIG. 12) similar to that of female of *C. faini*; anterior margin convex; lateral margins sloping laterad to level of posterior margins of legs I, then becoming convex and projecting laterad to dorsal shield's greatest width between legs II and III, and then tapering posteriorly to a blunt point between legs IV; surface reticulate (shown coarsely in FIG. 12; clear areas represent muscle insertions); with smoother margins, similar to *C. faini* (FIG. 3). Genital aperture longitudinal and terminal, approximately 1/5 ventral and 4/5 dorsal, separated from posterior margin of dorsal shield by more than 2× length of genital aperture. Posterior margin of opisthosoma with 2 seta-like projections flanking genital aperture at a distance of approximately 2× length of the latter. Ventrally, fang-like pedipalps approximately 1/2 as long as greatest width of first movable segment of leg I. Coxal apodemes I fuse just behind legs I and project to level of posterior margins of legs III, as in *C. faini;* apodemes II contiguous medially and project almost to middle of legs IV; apodemes III clearly separated medially and project only slightly beyond posterior margins of legs IV; apodemes IV separated medially by 4× the distance between ends of apodemes III, projecting to point approximately halfway from anterior margins of legs IV to tip of opisthosoma; punctations, reticulations (shown only on right half, FIG. 13) and form of sclerotized ventro-marginal frame similar to that of *C. faini*. Leg form and chaetotaxy and form of gnathosoma almost identical to that of *C. faini*.

The body size of the 3 specimens of *C. beeri* is intermediate between that of the adult females and the nymphs of *C. faini*. Also, the females of *C. faini* usually shown signs of an ovum in the opisthosoma, whereas the specimens of *C. beeri* do not. Consequently, it seems probable that the 3 specimens of *C. beeri* are deutonymphs and the nymphal specimens of *C. faini* are protonymphs. It is possible that the specimens of *C. beeri* are females of a smaller species or protonymphs of a larger species than *C. faini*. All that can be said with certainty at this time is that they are not larvae or adult males. It is also possible, inasmuch as specimens of identical stages have not yet been compared, that the specimens of *C. beeri* are deutonymphs of the same species as *C. faini*. This, however, seems unlikely in that mites as highly modified as the cloacarids are probably highly host-specific. The answers to these questions must await the collection and study of further specimens.

Type Data: Ex cloaca of mature painted turtle, *Chrysemys picta* (Schneider), collected 14.VII.1958 by M. D. Little from a small pond between the

Maple River and Dam Site Inn, Emmet Co., near University of Michigan Biological Station, Douglas Lake, Michigan. Mites were collected by Little and slide-mounted in PVA by J.H. Oliver. The holotype specimen was subsequently remounted in Hoyer's medium and ringed with Zut's lacquer. Because painted turtles from Minnesota were also being searched for parasites on the same day, there is a remote possibility that the host of the 3 specimens of *C. beeri* was one of these. Therefore, the source of the host and the type locality are not known with certainty.

Type Specimens: Holotype nymph, with above data, to be deposited in the acarological collection of the Snow Entomological Museum, University of Kansas, Lawrence.

The 2 paratype nymphs, with same data as holotype, to be deposited in the U.S. National Museum, Washington, D.C., and in the British Museum (Natural History), London, England.

Type Host: Painted turtle, *Chrysemys picta* (Schneider) (Reptilia: Testudinidae).

Remarks: The specific epithet is in honor of Dr Robert E. Beer, chairman, Department of Entomology, University of Kansas, in recognition of his own acarological research and of the enthusiastic aid and stimulation he has given his colleagues and students in acarology over the years.

DISCUSSION

Adults of *Cloacarus faini* were all found in the cloaca of the host, individually embedded under a thin layer of the mucosa; the surrounding tissues showed no discernible pathological changes. The "protonymphs" were aggregated in minute pustules in the mucosal lining and there appeared to be true lesions associated with them. The lesions gave a hardened, patchy appearance to the surface of the surrounding tissues. In addition to the two mature female snapping turtles from which *C. faini* was recovered, one juvenile female, one juvenile male, one mature female, and two mature male snapping turtles were dissected. No mites were found in these, but all had numerous helminth eggs in the cloaca.

The extreme reduction of their legs suggests that cloacarid mites would not be able to move about efficiently outside the body of the host, while the hypertrophy and claw-like modification of the leg setae and the fang-like development of the pedipalps suggest that these probably are effective burrowing and holdfast structures. With such highly modified appendages these mites may require direct contact between turtles to permit dispersal from host to host. It is probable, therefore, that cloacarids occur only in mature turtles and are venereally transmitted. If this is the case, the life history of the mite is probably correlated to some extent with the mating cycle of the host.

Existing literature on the mating habits of turtles is not entirely clear. Most of the data have been collected on captive turtles and the reports of these data rarely distinguish between laboratory and field observations. Burger (1937) demonstrated a photoperiodic effect on the reproductive cycle of the "slider", *Pseudemys scripta elegans* (Wied), and Carr (1952) has suggested that the role of photoperiodism in the mating cycles of turtles may be as important as it is in birds. If such is the case, then laboratory observations of turtles copulating at all times of the year, under uncontrolled artificial light regimes, may be very misleading. In any case, both in the laboratory and in the field, the majority of turtles mate in the spring, shortly after emergence from hibernation. Therefore, even if the hosts do mate occasionally at other times of the year, the greatest opportunity for venereal transmission of the mites would occur in the spring.

In Kansas the snapping turtle hibernates from October or November until March (Smith 1956). This species, like others, has been observed copulating in captivity in all months when the turtles were not in hibernation. However, the fact that oviposition by *Chelydra serpentina* in Kansas usually occurs in June and hatching always takes place in August, suggests that this species may have a regular mating season which occurs soon after emergence from hibernation in March or April.

The painted turtle, *Chrysemys picta*, in Michigan (Pope 1946), and probably in Minnesota, hibernates from late October to late March or early April. Mating is most common in the spring shortly after emergence, but has also been observed in the summer and early fall. In the late season matings no sperm were found in the females after copulation (Carr 1952) and the matings were probably ineffectual. However, even without sperm transfer, such pairing, if it occurs in nature, would provide some additional limited opportunity for mite transfer. Eggs of the painted turtle are laid from May to July (usually in June) and hatch in September. Accordingly, the mating cycle of the painted turtle in Michigan is similar to that of the snapping turtle in Kansas. Therefore, if the life cycles of cloacarids are correlated with the mating cycles of their hosts, it is probable that the life cycles of *C. beeri* and *C. faini* are also similar.

Correlation of the cloacarid life cycles with

the mating cycles of their hosts may account for the fact that only 1 male of *C. faini* was found among 34 females and 86 "protonymphs" in the turtle dissected in mid-May and only females were present in the turtle that was dissected in November. It is also interesting to note that the three specimens of *C. beeri*, recovered from the painted turtle in Michigan in July, all appear to be deutonymphs. However, in this latter case it should be kept in mind that there were many more mites in the cloaca of the host than were recovered and many of these may have represented other instars. With only the meager data of three collections it is impossible at this time to make more than an educated guess about the probable life histories of the cloaca mites. Nevertheless, some reasonable hypotheses are possible and such speculation may stimulate further elucidation of the relationships between the cloacarids and their reptilian hosts. The following hypotheses are based on the initial hypothesis that cloacarid transmission from host to host is venereal and that, therefore, the life cycles of the mites are probably correlated with the mating cycles of their hosts.

Females of most mites (and of other animals) usually live longer than the males, and female mites are frequently the predominant or the only overwintering form (e.g., some species of Tetranychidae, Eriophyidae, Anoetidae, Dermanyssidae). This may account for the fact that only females of *C. faini* were recovered from the snapping turtle dissected in November. If the cloacarids have only one generation per year, correlated with the mating cycle of the host, they may overwinter as fecundated females in the hibernating turtle. If this is the case, mating of the mites may occur in the fall with most of the males dying off soon after they fecundate the females. The gravid females would then survive the winter, perhaps along with a few males, in the cloaca of the hibernating turtle and transfer to new hosts could occur the following spring when the hosts are copulating. The gravid females may then produce eggs or young in April or May and, at that time, one might expect to find adult female mites, larvae, if they occur, and protonymphs, along with a few male stragglers which may have survived from the previous fall. As the season progresses, the protonymphs would metamorphose into deutonymphs, while any remaining males and most of the females would die. In late summer and early fall the deutonymphs would transform into adult males and females, mating would take place and the cycle would continue. This pattern could explain the three collections of cloacarids described in this paper.

There is strong evidence (Oliver & Nelson unpublished) of arrhenotokous sex determination in several species of mites in a closely related family, the Harpyrhynchidae, and it is quite probable that such a haplo-diploid mechanism also operates in the Cloacaridae. This would permit the overwintering of unmated females which, after transferring to new hosts in the spring, could produce male offspring parthenogenetically. These males would then inseminate their mothers and other available females. After mating in the spring, the males would gradually die off while the females continued to survive and produce offspring, all of which would be female. A similar pattern has been reported (Oliver 1962) for *Histiostoma murchiei* Hughes & Jackson, an anoetid parasite of earthworms.

Such a pattern is even more compatible with the data of the three collections of cloacarids herein described. If there is only one generation of *Cloacarus* each year and this is synchronized with the mating and hibernation cycle of the host, one would expect to find male and female mites in the early spring. Males would gradually decrease in number as the season progressed and larvae, if they occur, and protonymphs would appear along with females in the late spring and early summer. By mid-summer deutonymphs would probably appear. These would transform into adult females in the fall and these unmated females would then overwinter in their hibernating hosts.

On the basis of the currently available data, it is entirely possible that the cloacarids complete several generations during the warmer months of the year and that all instars are capable of being venereally transmitted whenever the hosts copulate. It is also possible, of course, that the mites are not venereally transmitted, but other means of dispersal are difficult to imagine. The resolution of these problems must await further investigation.

Acknowledgments: The authors take pleasure in acknowledging the original discovery of the cloaca mites in the painted turtle by Dr Maurice Dale Little of Tulane University, New Orleans, Louisiana; the donation of the snapping turtle which yielded the second series of *C. faini* by William Vensel, Department of Zoology, University of Kansas; the determinations by Dr E.W. Jameson, Jr., University of California, Davis, of the two species of Myobiidae cited in this paper; and the meticulous and artistic skill of Mrs Parto Kamrani in her inking of the illustrations.

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Insects and Other Terrestrial Arthropods from the Leeward Hawaiian Islands[1]

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Introduction

The Leeward Hawaiian Islands comprise a chain of small rocky islets and coral atolls which extend west-northwest of Kauai. Nihoa, the nearest, is about 150 miles from Kauai, while Kure, the furthermost, is some 1,150 miles away (see map, p. 158). All Leeward Islands except Midway and Kure are now a part of the Hawaiian Islands National Wildlife Refuge administered by the U.S. Fish and Wildlife Service.

This paper summarizes results of recent entomological field work in these islands, and attempts to update the existing lists of insects and other terrestrial arthropods known.

The terrestrial arthropod fauna of these islands is a mixture of endemic or indigenous elements and recently, adventive forms. The numbers of endemic species are greatest on the two relatively undisturbed southeastern volcanic islands of Nihoa and Necker, and apparently have disappeared largely from the more northwesterly atolls where, in most cases, the original vegetation has changed drastically in the past 100 years or so. Extinction of native plants and endemic insects has been documented fairly well for Laysan (Christophersen & Caum, 1931, Butler & Usinger, 1963a). Unfortunately, less is known about the original biota of the other atolls.

Most recent immigrant insects now known from the Leeward Islands occur also on the larger inhabited islands of Hawaii; however, two species could become serious crop pests should they spread into agricultural areas of the state. The Egyptian cotton moth, *Spodoptera litura* (Fabricius), is established on Pearl and Hermes Atolls and may be present also on Kure Atoll and Midway. In addition to cotton, this insect is also a pest of many garden and truck crops throughout the tropical and subtropical areas of the Old World and on many south and western Pacific islands. A species of scarab beetle, *Anomala sulcatula* Burmeister, known as a pest of sugar cane in the Philippine and Mariana Islands is present on Midway Island.

New immigrant arthropods are continuing to invade and spread within the Leeward Islands. Such immigrants may have profound effects upon the delicate ecosystems of these small islands. Therefore, it seems worthwhile to record the recently discovered additions to the known terrestrial faunas for the benefit of ornithologists, ecologists, and others concerned with the biota of these islands.

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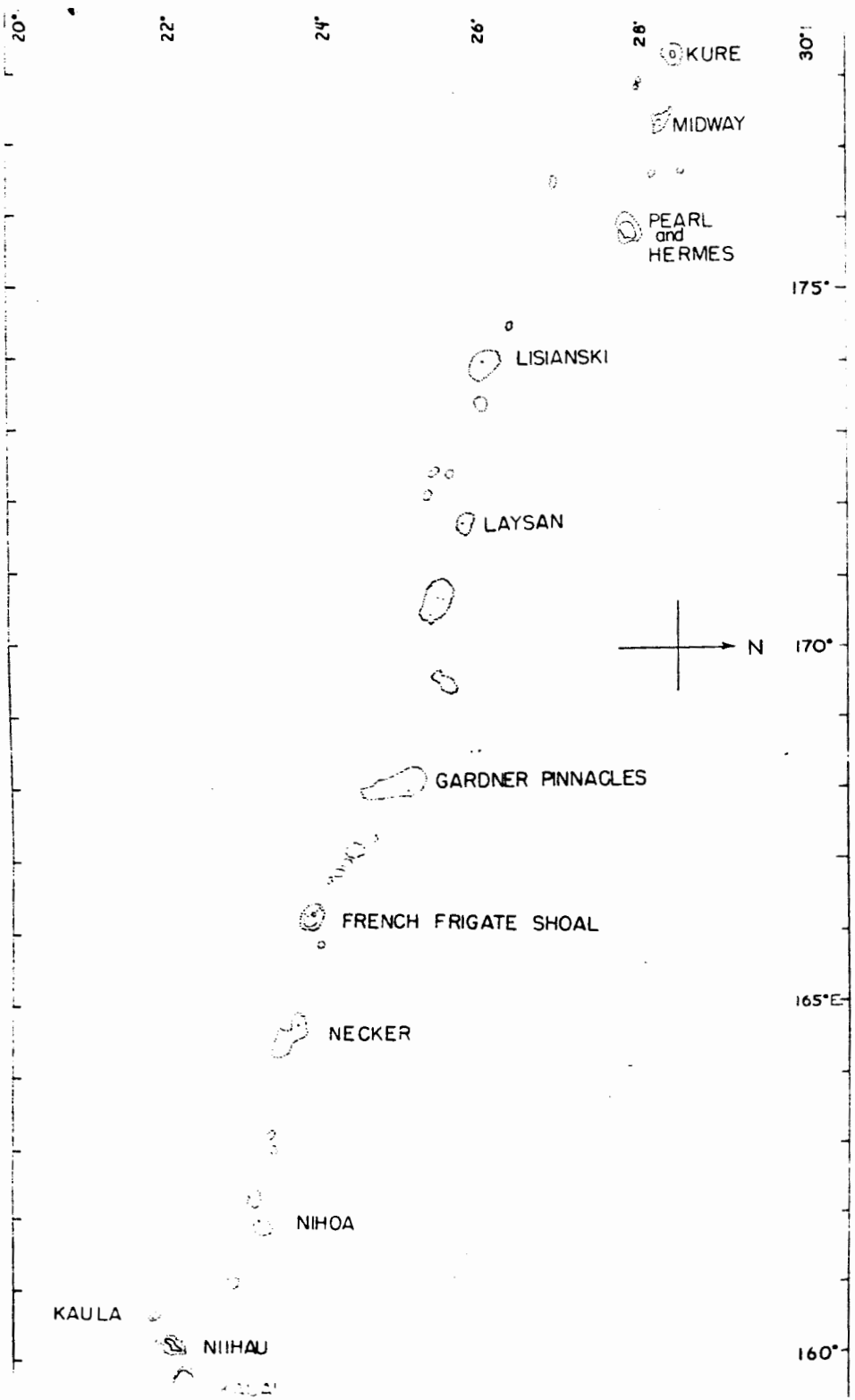
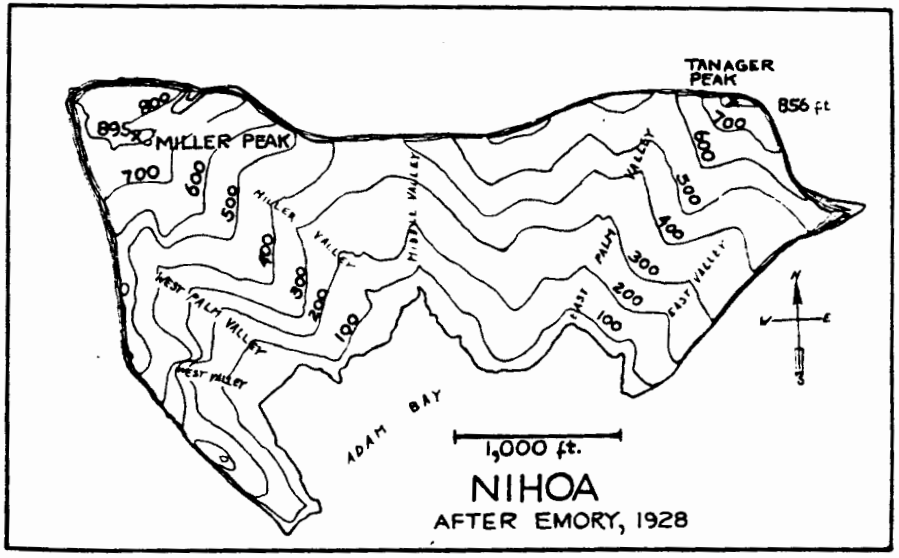


The principal work on terrestrial arthropods of the Leeward Islands (Bryan et al. 1926) deals with material collected by the 1923 Tanager Expedition and other earlier collectors. This paper contains a nearly complete listing of the species then known from each of the islands. Several recent papers list arthropods known to be from the following islands: Laysan (Butler 1961, Butler & Usinger 1963 a), Midway (Suehiro 1960), and Kure (Butler & Usinger 1963b). No attempt is made here to duplicate lists for these islands, although a few new records from my own recent collecting are given. A relatively complete list is provided for each remaining island I visited. I have indicated also the collection dates (year), pertinent host and other ecological data, abundance, etc.

One group of insects, the Mallophaga, is not included since they are being worked on by others. Published records of Mallophaga from the Leeward Islands are principally from Laysan Island (Thompson 1948; Zimmerman 1948, Vol. 2; Butler & Usinger 1963a), although the species concerned probably will be found wherever their avian hosts occur.

I am indebted to the following persons for assistance in identifying specimens: P. D. Ashlock, F. A. Bianchi, E. A. Chapin, Mrs. D. Fellows, D. E. Hardy, D. F. Hardwick, Louise M. Russell, C. W. Sabrosky, T. W. Suman, E. L. Todd, N. Wilson, W. W. Wirth, C. M. Yoshimoto, and E. C. Zimmerman. Other identifications are from Bryan (1926) or were made by this writer. Most Tanager Expedition material is at the Bernice P. Bishop Museum in Honolulu, and where misidentifications in Bryan's list are indicated, I have examined the specimens. Specimens collected by me in 1962 and 1964 will be placed in the Bishop Museum with duplicates in the collection of the Entomology Department,



University of Hawaii.

New island records in the species lists which follow are indicated by an asterisk.

Thanks are due the U.S. Fish and Wildlife Service (particularly to E. Kridler of the Honolulu office), the State of Hawaii Division of Fish and Game, personnel of the U. S. Navy and U. S. Coast Guard for making possible my field work in the Leeward Islands during 1962 and 1964 and to E. H. Bryan, Jr. of the B. P. Bishop Museum who kindly supplied maps and other information used to prepare the figures.

NIHOA ISLAND

Nihoa Island, the nearest and highest of the Leeward Islands, is a steep rocky remnant of a former extensive volcanic dome. The island's area is about 156 acres; the highest point about 895 feet (Emory, 1928). Although Nihoa was the site of a prehistoric Hawaiian settlement, it remains in a relatively undisturbed condition. The island is covered sparsely with a scrubby growth of native plants, predominantly *Chenopodium oahuense*, *Sida cordifolia*, *Solanum nelsoni*, *Sesbania tomentosa* and *Portulaca lutea*, with native bunch grass *Eragrostis variabilis* along some of the higher ridges, *Euphorbia celastroides* as a prostrate shrub above 800 feet on Miller Peak (the highest point on the island), and an endemic fan palm *Pritchardia remota* in scattered groves in two of the larger gulches. Other less prominent plants include *Amaranthus brownii*, *Panicum torridum*, *Rumex giganteus*, *Sicyos microcarpus*, and *Tribulus cistoides*. A few others are recorded which I did not see Christophersen & Caum, 1931). All the plants are considered to be native, and, apparently, there are no recently established exotic weeds present.

I spent about 7 hours on Nihoa on 10, June 1962 and one night and most of two days in September, 1964. The vegetation was relatively green, indicating recent abundant rainfall in June, 1962, but was much drier in September, 1964. A total of 102 species of terrestrial arthropods was collected or observed during these two visits: 51 are new records. Of the 72 species listed by Bryan, 21 were not collected in 1962 or 1964. Of the 123 species listed below, at least 35 are restricted either to the island or are species endemic to the Hawaiian Archipelago.

In addition to the arthropods listed, a small gecko, *Lepidodactylus lugubris* Dumeril & Bibron determined by Karl Frogner, University of Hawaii Department of Zoology, was taken in *Eragrostis* clumps in 1964, and appears to be a recently established immigrant.

CRUSTACEA (Det. by Mrs. D. Fellows)

ISOPODA

Armadilliidae

**Armadillidium* or *Spherillo* sp., 1964, in *Eragrostis* clumps.

Porcellionidae

**Porcellio* (?) sp., immature specimen; 1964, in *Eragrostis* clumps.

ARACHNIDA

PSEUDOSCORPIONIDA

*undetermined genus and species, 1964.

ARANEIDA (Det. by T. W. Suman)

Argiopidae

*unidentified genus and species (mature ♀); 1964.

Clubionidae

**Chiracanthium diversum* L. Koch; 1964.

Oonopidae

**Gamasomorpha* sp. (1 ♀); 1964.

Salticidae

*unidentified genus and species; 1964.

Thomisidae

*unidentified genus and species (immature ♂); 1964.

INSECTA

THYSANURA

Lepismatidae

Acrotelsella hawaiiensis (Silvestri); 1923. Listed by Bryan as an undetermined species (see Zimmerman 1948, 2 : 36).

COLLEMBOLA

*undetermined genus and species; 1964.

ORTHOPTERA

Blattidae

Cutilia soror (Brunner); 1923; 1964.
Periplaneta americana (L.); 1923.
Periplaneta australasiae (Fabricius); 1923; 1964.
Pycnoscelus surinamensis (L.); 1923; 1964.

Tettigoniidae

Banza nihoa Hebard; 1923; 1964, in *Eragrostis* clumps.

DERMAPTERA

Labiduridae

Euborellia annulipes (Lucas); 1923; 1964.

PSOCOPTERA

undertermined genus and species; 1923: 1964.

THYSANOPTERA (Det. by F. A. Bianchi)

Thripidae

**Frankliniella sulphurea* (Schmutz); 1962; 1964, in flowers of *Sesbania*, *Tribulus* & *Solanum*.

Phlaeothripidae

**Haplothrips gowdeyi* (Franklin); 1962; 1964, in flowers of above.

EMBIOPTERA

Oligotomidae

Oligotoma oceania Ross; 1923; 1962, in *Eragrostis* clumps, 1964 under *Chenopodium*; listed by Bryan as *O. insularis* McLachlan? (see Ross, 1951).

HEMIPTERA

Cydnidae

**Geotomus pygmaeus* (Dallas); 1964, at light.

Lygaeidae (Det. by P. D. Ashlock)

**Geocoris punctipes* (Say); 1964.

Nysius longicollis Blackburn; 1923.

Nysius nihoae Usinger; 1923; 1962; 1964, on *Chenopodium*.

Nysius suffusus Usinger; 1923; 1962; 1964, on *Chenopodium*, *Sida*.

The above *Nysius* species were listed by Bryan as "*Nysius* spp.".

Reclada moesta (White); 1923; 1964, in *Eragrostis* clumps.

Corizidae

**Liorhyssus hyalinus* (Stål); 1962, on *Chenopodium* and *Sida*.

Nabidae

Nabis capsiformis Germar; 1923; 1964.

Nabis sp. near *kahavalu* Kirkaldy; 1923; 1962, on *Chenopodium oahuense*. Listed as *Reduviolus kahavalu* by Bryan, but apparently distinct (see Zimmerman 1948, 3:152).

Anthocoridae

Orius persequens (White); 1923; 1962; 1964.

Miridae

**Hyalopeplus pelucidus* (Stål); 1962, on *Sida* and *Chenopodium*.

**Oronomiris hawaiiensis* Kirkaldy; 1962, on *Eragrostis*.

**Rhinachloa forticornis* Reuter; 1964, on *Chenopodium*.

"unidentified species"; 1923, specimens not located.

HOMOPTERA

Cicadellidae

**Circulifer tenellus* (Baker); 1962; 1964, on *Chenopodium oahuense*.

**Empoasca solana* De Long; 1962; 1964, on *Chenopodium*.

**Deltocephalus sonorus* Ball; 1962, on *Eragrostis*.

"*Nesosteles* spp."; 1923, specimens not located.

**Scaphytopius loricatus* (Van Duzee); 1962; 1964, on *Chenopodium* and *Sida*.

Delphacidae

**Sogatella kolophron* (Kirkaldy); 1962, on *Eragrostis*.

Aphididae

**Aphis craccivora* Koch; 1962; 1964, on *Solanum nelsoni* and *Tribulus*.

Pseudococcidae

**Rhizoecus hawaiiensis* (Hambleton); 1964, on roots of *Chenopodium*.

Phoenicococcidae

**Platycoccus tylocephalus* Stickney; 1962; 1964, on leaves of *Pritchardia remota*.

Diaspididae

**Odonaspsis ruthae* Kotinsky; 1962; 1964, on *Eragrostis* stems.

LEPIDOPTERA

Lycaenidae

**Lampides boeticus* (L.); 1962, one larva in *Sesbania* flower.

Noctuidae

Agrotis bryani (Swezey); 1923, 1964, adults at light.

Helicoverpa pallida Hardwick (Det. by D. F. Hardwick); 1923; 1962; 1964; larvae on *Chenopodium*, adults at light. Listed by Bryan as *Chloridea obsoleta* (Fabricius) (see Hardwick, 1965:89).

Pyralidae

Hymenia recurvalis (Fabricius); 1923; 1962; 1964, larvae and adults on *Chenopodium*.

**Lineodes ochrea* Walsingham (?); 1964, adults at light.

Tamsica sp. (Det. by E. C. Zimmerman); 1923; 1962; 1964, adults at light. Listed by Bryan as *Talis hyacinthina* Meyrick.

Pterophoridae

Megalorhipida defectalis (Walker); 1923. Listed by Bryan as *Trichoptilus oxydactylus* (Walker) (see Zimmerman 1958, 8:397).

Tortricidae

**Crocidosema plebiana* Zeller (?); 1962; 1964, larva in *Sida* flower, adults at light.

Hyponomeutidae

Hyposmocoma spp. (Det. by E. C. Zimmerman); 1964, three species taken at light. Bryan lists *H. arenella* Walsingham, *H. quinquemaculata* Walsingham and *H.* sp. from Nihoa, collected in 1923, but the specific identifications may not be correct.

Tineidae

**Monopis meliorella* (Walker); 1962, one adult.

Gracillaridae

Parectopa marginestrigata Walsingham; 1923; 1962; 1964, larvae and adults on *Sida*, larvae mining in leaves.

Cygnodidae (Det. by E. C. Zimmerman)

Petrochroa dimorpha Busck; 1923; 1964, adults at light.

Xylorictidae (Det. by E. C. Zimmerman)

**Thyrocopa* sp.; 1964, adults at light and reared from larva taken in litter under bushes.

COLEOPTERA

Staphylinidae

Atheta coriaria Kraatz; 1923.

Coccinellidae

Coelophora inaequalis (Fabricius); 1923, fragments (elytra) only.

**Scymnus debilis* Leconte; 1964, on *Eragrostis*.

Scymnus loewii Mulsant: 1923; 1962, feeding on *Platycoccus* on *Pritchardia*; 1964, on *Chenopodium* and *Euphorbia*. Listed by Bryan as *Pullus kinbergi* (Boheman).

"*Scymnus* sp., near *bipunctatus*"; 1923, specimens not located.

Nitidulidae

**Carpophilus dimidiatus* (Fabricius); 1964.

Cucujidae

Cryptomorpha desjardinsi Guenée; 1923.

Lathridiidae

**Lathridius* (?) sp.; 1962, ex *Eragrostis*, one.

Dermestidae

Dermestes ater De Geer; 1923; 1964, under dead birds. Listed by Bryan as *D. cadaverinus* Fabricius.

Dermestes frischii Kugelam; 1923; 1964, under dead birds. Misidentified in Bryan's list as *D. vulpinus* Fabricius.

Labrocerus sp.; 1923; 1964, on *Euphorbia celastroides*.

Tenebrionidae

Sciophagus pandanicola (Boisduval); 1923; 1964. Listed by Bryan as an undetermined species.

Histeridae

**Saprinus lugens* Erichson; 1964, under dead birds.

Anobiidae

**Xyletobius gossypii* Ford (?); 1964, at light.

Cioidae

Cis vagans Perkins; 1923; 1964, on *Euphorbia*.

Cleridae

Necrobia rufipes De Geer; 1923.

Cerambycidae

Plagithmysus nihoae Perkins; 1923, ex *Euphorbia* stems.

Chrysomelidae

Epitrix hirtipennis Melsheimer; 1923; 1962; 1964, feeding on *Solanum nelsoni*. Misidentified in Bryan's list as *E. parvula* (Fabricius).

Anthribidae

Araecerus fasciculatus (De Geer); 1923; 1962; 1964, adults at light, on *Chenopodium* and on *Euphorbia*.

Curculionidae

Oodemus breviscapum Perkins; 1923; 1962; 1964, ex *Eragrostis*.

Oodemus erro Perkins; 1923; 1964.

Oodemus laysanensis Fullaway; 1923; 1962; 1964, reared from larvae in *Chenopodium* stems.

Penthorthrum pritchardiae Perkins; 1923, on *Pritchardia*.

Rhyncogonus exsul Perkins; 1923; 1962, adults abundant on *Chenopodium*; 1964, a few adults in *Eragrostis* clumps.

Proterhinidae

Proterhinus abundans Perkins; 1923; 1964, on *Euphorbia*.

Proterhinus bryani Perkins; 1923, on *Euphorbia*.

DIPTERA

Chironomidae (Det. by D. E. Hardy)

**Chironomus esakii* Tokunaga, 1962.

**Telmatogeton pacificus* Tokunaga; 1964.

Dolichopodidae

Paraphrosylus acrosticalis (Parent); 1923. Listed by Bryan as *P.* sp. (see Hardy, 1964:249).

Syrphidae

**Ischiodon grandicornis* Macquart (?); 1962, seen flying but not captured.

Ephydridae

Neoscatella sexnotata (Cresson); 1923; 1962, 1964.

**Atissia antennalis* Aldrich (Det. by W. W. Wirth); 1962, one specimen.

Canaceidae

Canaceoides nudata (Cresson); 1923. Reported by Bryan in 1932.

Sphaeroceridae

**Leptocera hirtula* (Rondani) (?) 1962; 1964.

Asteiidae

Bryania bipunctata Aldrich; 1923; 1962; 1964. Listed by Bryan as an undetermined Asteinae.

*New genus and species (Det. by C. W. Sabrosky); 1962.

Drosophilidae (Det. by D. E. Hardy)

**Scaptomyza* (*Bunostoma*) sp.; possibly *hamata* Hardy; 1962 one ♂.

**Scaptomyza* (*Parascaptomyza*) *pallida* Zetterstedt; 1962, one specimen.

Agromyzidae

Liriomyza sp.; 1923. Listed by Bryan as *Agromyza pusilla* Meigen.

**Pseudonapomyza spicata* (Malloch) (Det. by D. E. Hardy); 1962, one specimen.

Milichiidae

Milichiella orientalis Malloch; 1923. Listed by Bryan 1925 as an undetermined Milichiinae, and subsequently determined by Aldrich (Bryan, 1931).

**Leptometopa* n. sp. (Det. by C. W. Sabrosky); 1962; 1964, plentiful.

Chloropidae

Siphunculina signata (Wollaston); 1925; 1962; 1964, abundant.

Tachinidae

Achaetoneura archippivora (Williston); 1923.

Sarcophagidae

Goniphyto bryani Souza-Lopez; 1923; 1962; 1964. Listed by Bryan as an undetermined species.

Calliphoridae

Lucilia sericata Meigen (?); 1923; 1962; 1964.

Hippoboscidae

Olfersia spinifera Leach; 1923; 1962; 1964, adults at light.

HYMENOPTERA

Braconidae

**Apanteles marginiventris* Cresson; 1962, reared from *Hilicoverpa* larva; 1964.

**Chelonus blackburni* Cameron; 1962; 1964.

Doryctes pallidiceps (Perkins); 1923.

Ichneumonidae

Horogenes blackburni Cameron 1923; 1962; 1964.

Mymaridae (Det. by C. M. Yoshimoto)

**Lymaenon mexicanus* Perkins; 1964.

Eulophidae

Euderus metallicus Ashmead; 1923.

Hemiptarsenus semialbiclavus (Girault); 1923; 1964. Listed by Bryan as *Pseudopheliminus vagans* Timberlake, a synonym.

Eupelmidae

Eupelmus nihoaensis Timberlake; 1923.

Lepideupelmus bryani Timberlake; 1923.

Lepideupelmus robustus Timberlake; 1923; 1962; 1964.

Pteromalidae

**Spalangia drosophilae* Ashmead (Det. by C. M. Yoshimoto); 1962; 1964.

Diapriidae

*genus and species unidentified; 1964.

Bethylidae

Sclerodermus nihoaensis Timberlake; 1923.

Formicidae

Monomorium floricola (Jerdon); 1923; 1964.

Phrenolepis longicornis Fabricius; 1923; 1964.

Tapinoma melanocephalum (Fabricius); 1923; 1962; 1964.

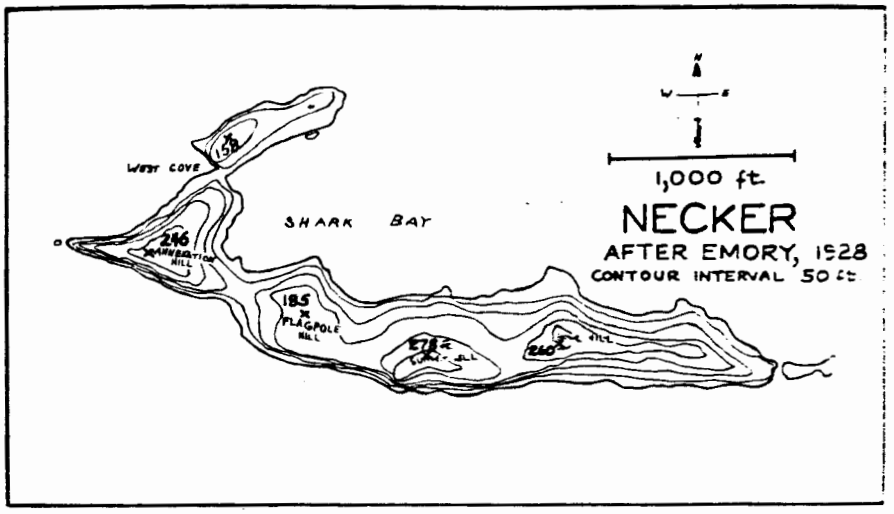
Tetramorium guineense (Fabricius); 1923; 1962; 1964.

Hylaeidae

Nesoprosopis perkinsiana Timberlake; 1923; 1964.

NECKER ISLAND

Necker Island, 300 miles northwest of Kauai, is both smaller and lower than Nihoa and consists of a long, roughly hook-shaped ridge with steep sides and a fairly broad, easily traversable summit at 150–200 ft elevation. The highest elevation is 278 feet, and the land area is about 41 acres



(Emory, 1928). The surface is rocky and is partly clothed with sparse, scrubby vegetation. During June, 1962, I spent approximately three hours on the island, and during September, 1964, one night and most of two days.

The flora of Necker includes only five species of vascular plants: *Chenopodium oahuense*, *Panicum torridum*, *Portulaca lutea*, *Sesbania tomentosa*, and *Sesuvium portulacastrum* (Christophrensen and Caum, 1931). Despite the simplicity of the flora, the terrestrial fauna includes a fair number of apparently endemic arthropods. Of the approximately 69 species here recorded, about 20 are known only from Necker, or from Necker and Nihoa. Twenty-eight of the species reported below are new records. Of the 41 species previously recorded, 10 were not re-collected in 1962 or 1964.

CRUSTACEA

ISOPODA (Det. by Mrs. D. Fellows)

Porcellionidae

Porcellio* sp., Prob. *laevis Latrielle; 1964, on rocks, 30 feet above sea level.

ARACHNIDA

ARANEIDA (Det. by T. W. Suman)

Lycosidae

**Lycosa* sp.; 1962; 1964.

Salticidae

*genus and species not identified; 1964.

Scytodidae

**Scytodes striatipes* (L. Koch); 1964.

Thomisidae

*genus and species not identified; 1962; 1964, common on *Chenopodium oahuense*.

ACARINA (Det. by N. Wilson)

Argasidae

**Ornithodoros* sp., *capensis* Neumann group; 1964.

CHILOPODA

Schendylidae

Nyctunguis bryanus Chamberlin; 1923.

Mecistocephalidae

Mecistocephalus spissus Wood; 1923.

INSECTA

ORTHOPTERA

Blattidae

Periplaneta americana (L.); 1923.

EMBIOPTERA

Oligotomidae

Oligotoma saundersii Westwood; 1923; 1964. ♂♂ at light. Listed by Bryan as *O. insularis* McLachlan?

DERMAPTERA

Labiduridae

Euborellia annulipes (Lucas); 1923; 1962; 1964.

PSOCOPTERA

unidentified genus and species; 1923; 1964.

THYSANOPTERA (Det. by F. A. Bianchi)

Phlaeothripidae

**Haplothrips gowdeyi* (Franklin); 1962; 1964.

Thripidae

**Frankliniella sulphurea* Schmutz; 1962; 1964.

HEMIPTERA

Lygaeidae (Det. by P. D. Ashlock)

Nysius chenopodii Usinger; 1923; 1962; 1964, on *Chenopodium*.

Nysius neckerensis Usinger; 1923; 1962; 1964, on *Chenopodium* and *Portulaca*. Apparently misidentified as *N. delectus* White in Bryan's list.

Miridae

**Rhinachloa forticornis* Reuter; 1964, on *Chenopodium*.

HOMOPTERA

Cicadellidae

**Circulifer tenellus* (Baker); 1962; 1964, plentiful on *Chenopodium*.

**Empoasca solana* De Long; 1962; 1964, plentiful on *Chenopodium*. "*Nesosteles* spp."; 1923, specimens not located.

Pseudococcidae

**Ferrisia virgata* (Cockerell); 1964, on *Portulaca*.

**Pseudococcus* n. sp.; 1964, on *Chenopodium oahuense*.

**Rhizoecus hawaiiensis* (Hambleton); 1962; 1964, on roots of *Chenopodium* and *Portulaca*.

Diaspididae

**Hemiberlesia lataniae* (Signoret); 1962; 1964, on twigs and branches of *Chenopodium*.

LEPIDOPTERA

Lycaenidae

Lampides boeticus (L.); 1923; 1962; 1964, adults flying, larvae in *Sesbania* flowers.

Noctuidae

Helicoverpa pallida Hardwick (Det. by D. F. Hardwick); 1923; 1962; 1964, larvae on *Chenopodium*, adults at light. Misidentified in Bryan's list as *Chloridea obsoleta* (Fabricius).

Pyralidae

Hymenia recurvalis Fabricius; 1962; 1964; 1923, larvae and adults on *Chenopodium*.

Tortricidae

Crocidosema plebiana Zeller (?); 1923; 1964.

Hyponomeutidae

Hyposmocoma spp. (Det. by E. C. Zimmerman). Two species taken at light in 1964 appear to be identical to two of the 3 species from Nihoa. Bryan lists *H. mimica* Walsingham, *H. quinquemaculata* Walsingham, and *H.* sp. collected in 1923 but the specific determinations may not be correct.

Tineidae

Monopis meliorella (Walker); 1923.

Cygnodidae

Petrochroa dimorpha Busck (Det. by E. C. Zimmerman); 1923; 1964, at light.

Petrochroa neckerensis Swezey; 1923.

COLEOPTERA

Staphylinidae

*genus and species undetermined (minute); 1964, one.

Coccinellidae

Scymnus loewii Mulsant; 1923; 1962; 1964, on *Chenopodium*. Listed by Bryan as *Pullus kinbergi* (Boheman).

Nitidulidae

**Carpophilus dimidiatus* (Fabricius); 1964.

Dermestidae

Dermestes maculatus De Geer; 1923. Listed by Bryan as *D. vulpinus* Fabricius; specimen not located.

Dermestes ater De Geer; 1923; 1964. Listed by Bryan as *D. cadaverinus* Fabricius.

Labrocerus sp.; 1923.

Histeridae

**Acritus* sp.; 1962, ex ground litter.

Tenebrionidae

Sciophagus pandanicola (Boisduval); 1923; 1964. Listed by Bryan as an unidentified tenebrionid.

Elateridae

Itodactus novicornis Van Zwaluwenburg; 1923; 1964, under rocks under *Chenopodium*.

**Itodactus* sp.; 1964, under rocks under *Chenopodium*.

Anthribidae

Araecerus fasciculatus (De Geer); 1923; 1964.

Curculionidae

Rhyncogonus biformis Perkins; 1923; 1964, plentiful under *Chenopodium* bushes.

Oodemus laysanensis Fullaway; 1923; 1964, ex *Chenopodium* twigs.

Oodemus neckerensis Perkins; 1923; 1964.

DIPTERA

Chironomidae (Det. by D. E. Hardy)

**Telmatogeton pacificus* Tokunaga; 1964, adults at light.

Ceratopogonidae

*genus and species not yet identified; 1964.

Dolichopodidae

Paraphrosylus acrosticalis (Parent); 1923. Listed by Bryan as *P.* sp.

Phoridae

**Diplonevra peregrina* (Wiedemann); 1964.

Ephydridae

Neoscatella sexnotata (Cresson); 1923; 1962; 1964.

Atissia antennalis Aldrich; 1923. Not listed by Bryan (1926), but description based on specimens from Necker collected by Tanager Expedition (Aldrich, 1931).

Sphaeroceridae

**Leptocera hirtula* (Rondani) (?); 1964.

Asteiidae

*New genus and species (Det. by D. E. Hardy); 1964 same as Nihoa species.

Chloropidae

Siphunculina signata Wollaston; 1923; 1962; 1964.

Milichiidae

Milichiella orientalis Malloch; 1923. Not listed by Bryan 1926, but a specimen from Necker was subsequently determined by Aldrich (Bryan, 1931).

**Leptometopa* n. sp. (Det. by C. W. Sabrosky); 1964.

Sarcophagidae

Goniophyto bryani Souza Lopez; 1923; 1962; 1964.

Hippoboscidae

Olfersia spinifera Leach; 1923; 1964, adults at light.

HYMENOPTERA

Encyrtidae

**Anagyrus* n. sp.; 1964, reared from *Pseudococcus* n. sp. on *Chenopodium*.

Eupelmidae

Lepideupelmus robustus Timberlake; 1923; 1964.

Signiphoridae

**Thysanus aspidioti* Ashmead; 1964, reared from *Hemiberlesia lataniae* on *Chenopodium*.

Pteromalidae (Det. by C. M. Yoshimoto)

**Spalangia drosophilae* Ashmead; 1964.

Formicidae

Cardiocondyla nuda minutior Forel; 1923; 1964.

Monomorium minutum Mayr; 1923; 1964.

Ponera kalakauae Forel; 1923.

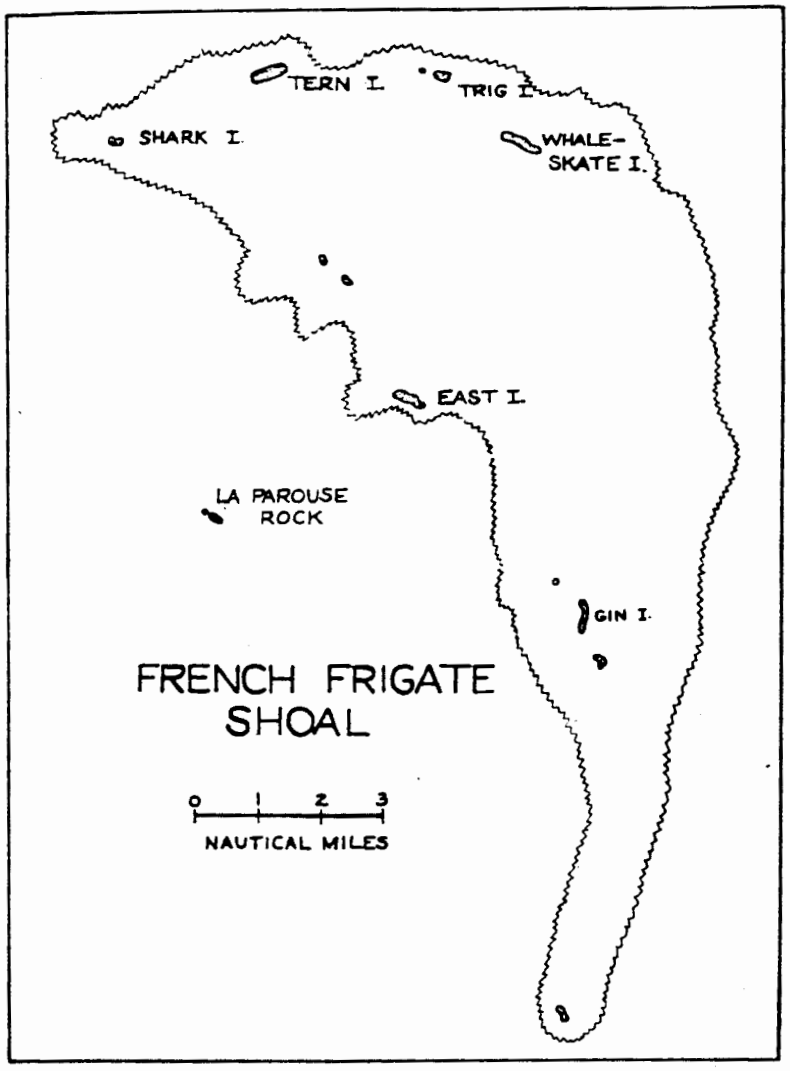
Tetramorium guineense (Fabricius); 1923; 1962; 1964.

FRENCH FRIGATE SHOAL

French Frigate Shoal, situated about 80 miles west of Necker, is a group of about a dozen small coraline islets with a total land area of some 50 acres enlosed within a large reef. The largest islet, Tern Island, is the site of a U.S. Coast Guard Station and is occupied now almost entirely by the airstrip, buildings, and other facilities associated with the station. Vegetation of a limited sort occurs on 6 or 7 of the islets. La Parouse Rock, a small remnant of the original volcanic dome, lies outside the fringing reef and, apparently, is void of higher plant life.

During the Tanager Expedition visit in 1923 only 6 species of vascular plants were found: *Boerhavia diffusa*, *Chenopodium oahuense*, *Ipomoea pes-caprae*, *Portulaca lutea* and *Tribulus cistoides*, (Christophersen & Caum, 1931). In addition to these, there are now several introduced weeds and a few ornamentals on Tern Island.

In June, 1962, I spent a few hours collecting on Tern Island, and in September, 1964, I made brief visits to Trig, Whale-Skate, and East Islets. Fifty-two species of terrestrial arthropods from the atoll are listed below, of which 25 are new records. Of the 27 species listed by Bryan 1926, 11 were not collected in 1962 or 1964.



Two species, *Agrotis kerri* Swezey and *Nysius frigatensis* Usinger are known only from French Frigate Shoal, and two or three others are forms known only from the Leeward group. The remainder are probably all relatively recent immigrants.

ARACHNIDA

Araneida (Det. by T. W. Suman)

Argiopidae

**Neoscona* sp.; 1964, Whale-Skate I.

**Tetragnatha* sp.; 1964, Trig I.

Clubionidae

**Chiracanthium diversum* L. Koch; 1964, Whale-Skate I.

Salticidae

**Hasarius adansoni* (Audouin); 1964, Whale-Skate I.

INSECTA

Odonata

Libellulidae

**Pantala flavescens* (Fabricius); 1962, Tern I., one adult flying.

Orthoptera

Blattidae

Pycnoscelus surinamensis (L.); 1923; 1964, Trig I., Whale-Skate I., East I.

Periplaneta americana (L.); 1923.

Gryllidae

**Gryllodes sigillatus* (Walker); 1962, Tern I., under boards.

Gryllus oceanicus Le Guillon; 1923.

**Metioche vittaticollis* (Stål); 1964, Trig. I.

Dermaptera

Labiduridae

Anisolabis eteronoma Borelli; 1923; 1964, Trig I., Whale-Skate I. Listed by Bryan as *Anisolabis maritima* (Gene) (see Zimmerman 1948, 2:201).

Euborellia annulipes (Lucas); 1923; 1962, Tern I.

Thysanoptera (Det. by F. A. Bianchi)

Thripidae

**Frankliniella sulphurea* Schmutz; 1964, East I., on *Tribulus* flowers.

Hemiptera

Lygaeidae (Det. by P. D. Ashlock)

Nysius frigatensis Usinger 1923; 1962, Tern I.; 1964, Trig I., Whale-Skate I., East I., on *Chenopodium*, *Boerhavia* and *Portulaca*.

Nysius coenosulus Stål; 1923. Listed by Usinger (1942) and Zimmerman (1948, 3;104) as *N. nigriscutellatus* Usinger, a synonym.

The above were listed as *Nysius* spp. by Bryan (1926).

Nabidae

Nabis capsiformis Germar; 1923; 1962, Tern I.

Homoptera

Cicadellidae

**Circulifer tenellus* (Baker); 1964, Trig I., Whale-Skate I., on *Chenopodium oahuense*.

Deltocephalus sonorus Ball; 1962, Tern I.; 1964, Trig I., on grass.

Aphididae

Aphis craccivora Koch; 1923; 1964, Whale-Skate I., East I., on *Chenopodium*, *Tribulus* and *Portulaca*. Listed by Bryan as *A. medicaginis* Koch.

Pseudococcidae

**Ferrisia virgata* (Cockerell); 1964, Trig I., on *Portulaca* and *Boerhavia*.

Coccidae

**Saissetia oleae* (Bernard); 1962, Tern I., on *Coccoloba uvifera* twigs.

Diaspididae

**Hemiberlesia lataniae* (Signoret); 1964, Whale-Skate I., on twigs and branches of *Chenopodium oahuense*.

**Odonaspis ruthae* Kotinsky; 1962, Tern I., 1964 Trig I., on *Lepturus* stems.

LEPIDOPTERA

Noctuidae

Agrotis kerri Swezey; 1923.

**Chrysodeixis chalcites* (Esper); 1962, Tern I., one reared from larva on *Messerschmidia argentea* foliage.

Spodoptera exempta Walker; 1923. Misidentified in Bryan's list as *S. mauritia* (Boisduval).

Pterophoridae

Megalorhipida defectalis (Walker); 1923; 1964, Trig I., Whale-Skate I., East I., on *Boerhavia*. Listed by Bryan as *Trichoptilus oxydactylus* (Walker).

Pyralidae

Hymenia recurvalis (Fabricius); 1923.

Tineidae

Ereunetis kerri Swezey; 1923; 1964, Trig I.

Tineola uterella Walsingham; 1923.

Tortricidae

Crocidosema plebiana Zeller (?); 1923.

COLEOPTERA

Coccinellidae

Scymnus loewii Mulsant 1923; 1964, Trig I., Whale-Skate I. Listed by Bryan as *S. kinbergi* (Boheman).

Dermestidae

Dermestes ater De Geer; 1923; 1964, Trig I. Listed by Bryan as *D. cadaverinus* Fabricius.

Tenebrionidae

**Alphitobius laevigatus* Fabricius; 1964, Whale-Skate I., under boards.

Curculionidae

Dryotribus mimeticus Horn; 1923; 1964, Trig I., under driftwood.

Dryotribus wilderi Perkins; 1923.

DIPTERA

Syrphidae

**Ischiodon grandicornis* (Macquart); 1962, Tern I.; 1964, Trig I., Whale-Skate I., East I., adults flying, larvae preying on aphids.

Dolichopodidae

Paraphrosylus acrosticalis (Parent); 1923. Listed by Bryan as *P.* sp.

Ephydridae

**Hecamede persimilis* Hendel; 1962, Tern I.; 1964, Trig I., Whale-Skate I.

Agromyzidae

**Liriomyza* sp., *hawaiiensis* group; 1964, Tern I., reared from mines in *Tribulus* leaves, Trig I., Whale-Skate I.

Chloropidae

Siphunculina signata Wollaston; 1923; 1962, Tern I.; 1964, Trig I., Whale-Skate I., East I.

Sphaeroceridae

**Leptocera hirtula* (Rondani)?; 1962, Tern I.; 1964, Trig I.

Sarcophagidae

Goniophyto bryani Souza-Lopez; 1923; 1962, Tern I.; 1964, Trig I., Whale-Skate I., East I. Listed by Bryan as an undetermined species.

Hippoboscidae

Olfersia spinifera Leach; 1923.

HYMENOPTERA

Eulophidae

**Hemiptarsenus semialbiclavus* Girault; 1962, Tern I.; 1964, Tern I., reared from *Liriomyza* larvae in *Tribulus* leaves.

Formicidae

Cardiocondyla nuda Mayr; 1923; 1964, Trig I.

**Phrenolepis longicornis* (Latreille); 1962, Tern I.

Ponera kalakauae Forel; 1923.

**Monomorium floricola* (Jerdon); 1962, Tern I.; 1964, Trig I.

Monomorium pharaonis (L.); 1923; 1964, Whale-Skate I.

**Tetramorium guineense* (Fabricius); 1962, Tern I.

**Tetramorium tonganum* Mayr; 1962, Tern I.

LISIANSKI ISLAND

Lisianski Island, about 360 miles WNW of French Frigate Shoal and 100 miles WNW of Laysan, is a single, roughly rectangular low coraline

islet approximately one-half square mile in area. The greatest elevation is about 40 feet.

Lisianski is now covered with low vegetation, although it was almost completely denuded by rabbits prior to the arrival of the Tanager Expedition in 1923. The vascular plants present include *Scaevola frutescens* (mostly along the beach margins), *Eragrostis variabilis*, *Portulaca lutea* (?), *Nama sandwicensis* and *Tribulus cistoides*. A few ironwood trees (*Casuarina sp.* are present, also.

Approximately 7 hours were spent collecting insects on Lisianski on 18. IX. 64. Thirty-five species of terrestrial arthropods are known now from the island, 21 being new records. Bryan (1926) listed only 13 species, 7 of which were not re-collected in 1964. In addition, Hardwick (1964) recently has described an apparently endemic species of *Helicoverpa* from Lisianski, based on specimens apparently taken prior to 1923 by an unknown collector.

ARACHNIDA

Araneida (Det. by T. W. Suman)

Argiopidae

**Neoscona* sp.; 1964.

**Tetragnatha* sp.; 1964.

Clubionidae

**Chiracanthium diversum* L. Koch; 1964, plentiful.

INSECTA

Orthoptera

Blattidae

**Blatella germanica* (L.); 1964.

**Periplaneta americana* (L.); 1964.

Dermaptera

Labiduridae

Anisolabis eteronoma Borelli; 1923.

Thysanoptera (Det. by F. A. Bianchi)

Phlaeothripidae

**Karnyothrips melaleuca* (Bagnall); 1964, on *Eragrostis*.

Hemiptera

Lygaeidae (Det. by P. D. Ashlock)

Nysius fullawayi Usinger; 1923; 1964, on *Portulaca*. Listed by Bryan as *Nysius* spp.

Nabidae

Nabis capsiformis Germar; 1923.

Homoptera

Aphididae

Aphis craccivora Koch; 1923; 1964, on *Tribulus*. Listed by Bryan as *A. medicaginis* Koch.

**Hysteroneura* sp. (Det. by Louise M. Russell); 1964, on *Eragrostis*.

Pseudococcidae

**Trionymus insularis* Ehrhorn; 1964, on *Eragrostis* stems, plentiful.

Coccidae

**Saissetia nigra* (Nietner); 1964, very heavy infestations on *Scaevola*, less abundant on *Eragrostis*.

Diaspididae

**Hemiberlesia lataniae* (Signoret); 1964, heavy infestation on twigs of *Scaevola*, also on *Portulaca*.

Lepidoptera

Noctuidae

Helicoverpa minuta Hardwick; date unknown, presumably prior to 1923.

Pseudaletia unipuncta (Haworth); 1923.

Pterophoridae

**Megalorhipida defectalis* (Walker); 1964, plentiful on *Boerhavia*.

Tineidae (Det. by E. C. Zimmerman)

**Ereunetis kerri* Swezey; 1964, reared from larvae on *Eragrostis*.

Cygnodiidae (Det. by E. C. Zimmerman)

**Petrochroa dimorpha* Busck; 1964.

Coleoptera

Coccinellidae

**Scymnus loewii* Mulsant; 1964, preying on *Trionymus insularis*. Listed by Bryan as *S. kinbergi* (Boheman).

Dermestidae

Dermestes ater De Geer; 1923; 1964. Listed by Bryan as *D. cadaverinus* Fabricius.

Diptera

Dolichopodidae

Paraphrosylus acrosticalis (Parent); 1923; 1964, along rocky beach, preying on small flies. Listed by Bryan as *P.* sp.

Phoridae

Diplonevia peregrina (Wiedemann); 1923; 1964. Misidentified in Bryan's list as *Apiochaeta scalaris* (Loew).

Ephydridae

**Hecamede persimilis* Hendel; 1964, along beach.

Canaceidae

Canaceoides nudata (Cresson); 1923; 1964, along beach.

Sphaeroceridae

Leptocera sp.: 1923.

Milichiidae

**Milichiella lactipennis* Loew); 1964.

**Leptometopa* n. sp. Det. by C. W. Sabrosky); 1964.

Chloropidae

Cadrema pallida Loew: 1923. Listed by Bryan as *Hippelatus nigricornis* var. *flavus* Thomson.

Siphunculina signata Wollaston; 1923; 1964.

Tethinidae Det. by D. E. Hardy)

**Tethina albula* Loew); 1964.

**Tethina insularis* Aldrich; 1964.

Calliphoridae

**Lucilia graphita* Shannon; 1964.

Muscidae

**Musca domestica* L.: 1964, very abundant and annoying.

Hippoboscidae

Olfersia spinifera Leach; 1923.

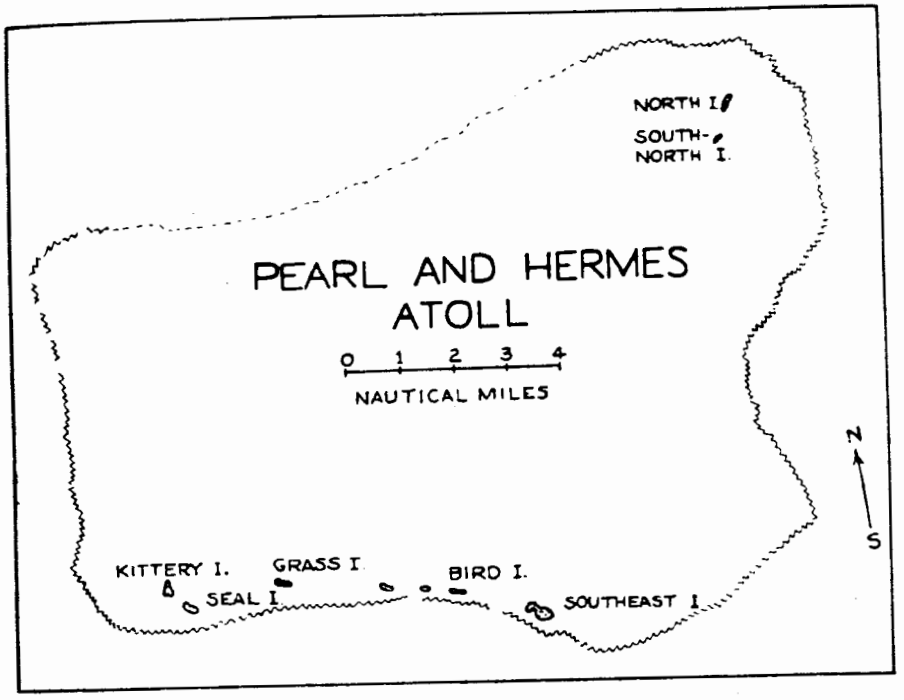
PEARL AND HERMES ATOLL

Pearl and Hermes Atoll is a large, shallow, reef-enclosed lagoon with about seven small islets along its south side and two near the northeast corner. The total land area probably amounts to one-half square mile. Several of the islets are large enough to support permanent vegetation.

Three of the Pearl and Hermes islets were visited in September, 1964. One night and several daylight hours were spent on Southeast Islet (the largest of the group), and about two hours on North Islet at the northeastern corner of the atoll including a few minutes on the nearby small "South-North" Islet. Records from two northeastern islets are cited together under North Islet in the list below.

The vascular plants observed were *Portulaca* sp., (Southeast I. only) *Sesuvium portulacastrum*, *Boerhavia diffusa*, *Tribulus cistoides*, *Ergrostis variabilis*. *Lepturus repens*. *Setaria* sp. Southeast I. only), *Sicyos* sp., *Lepidium owaihuense* (North Islet), *Achyranthes splendens* (North Islet), *Solanum nelsoni*, and the dead stalks of an introduced mustard (on Southeast Islet). A few shrubs of *Scaevola frutescens* and *Messerschmidia argentea* were also seen along the beaches. In general, North Islet seemed to have suffered less disturbance from the activities of man than had Southeast Islet.

Fifty-one species of terrestrial arthropods from Pearl and Hermes Reef are recorded below; of these, 30 are new records. Of the 21 species listed by Bryan, 7 were not re-collected in 1964.



ARACHNIDA

ARANEIDA (Det. by T. W. Suman)

Argiopidae

**Neoscona* sp.: 1964. North I., Southeast I.

**Tetragnatha* sp.; 1964. North I., Southeast I.

Salticidae

**Hasarius adansoni* (Audouin); 1964. Southeast I.

CHILOPODA

Geophilidae

Honuaphilus alohanus Chamberlin: 1923.

INSECTA

ORTHOPTERA

Blattidae

**Periplaneta americana* (L.); 1964. Southeast I.

Pycnoscelus surinamensis (L.); 1923. 1964. Southeast I.

DERMAPTERA

Labiduridae

Anisolabis eteronoma Borelli; 1923; 1964. North I., Southeast I. Listed

by Bryan as *A. maritima* Gene).

Euborellia annulipes Lucas.: 1923; 1964, North I., Southeast I.

PSOCOPTERA

*undetermined: 1964, Southeast I.

HEMIPTERA

Cydnidae

**Geotomus pygmaeus* Dallas.: 1964, Southeast I.

Lygaeidae (Det. by P. D. Ashlock)

Nysius fullawayi Usinger; 1923; 1964, North I., Southeast I., on *Boerhavia* and *Eragrostis*. Listed by Bryan as *Nysius* spp.

**Nysius palor* Ashlock; 1964, Southeast I., on *Portulaca*.

Nabidae

**Nabis capsiformis* Germar; 1964, North I.

Anthocoridae

**Orius persequens* White; 1964, North I., Southeast I.

Miridae

**Cyrtopeltis modesta* (Distant); 1964, North I., Southeast I., on *Boerhavia*.

HOMOPTERA

Delphacidae

Sogatella paludum Kirkaldy.: 1923; 1964, North I., on *Eragrostis*.

Aphididae

**Aphis craccivora* Koch; 1964, Southeast I., on *Tribulus*.

Pseudococcidae

**Antonina graminis* Maskell.; 1964, North I., Southeast I., on *Eragrostis* and *Lepturus* stems.

**Dysmicoccus brevipes* (Cockerell); 1964, Southeast I., on *Eragrostis* stems.

**Trionymus insularis* Ehrhorn; 1964, North I., on *Eragrostis* stems.

Diaspididae

**Odonaspis ruthae* Kotinsky; 1964, Southeast I., on *Eragrostis* stems.

NEUROPTERA

Chrysopidae

Chrysopa carnea Stephens; 1923. Listed by Bryan as *Chrysopa* sp.

LEPIDOPTERA

Noctuidae

**Heliothis zea* Boddie); 1964, North I., adult flying, several small larvae on *Eragrostis*.

Spodoptera litura Fabricius) (Det. by E. L. Todd): 1923; 1964, North I., Southeast I., several adults at light (Southeast) and one in flight (North). Bryan listed this species as "*Prodenia litura* (Fabr.)?" on

basis of a single abraded specimen taken in 1923, and determined by Swezey.

Spodoptera exempta (Walker); 1923. Misidentified in Bryan's list as *S. mauritia* (Boisduval).

Sphingidae

**Celerio lineata* (Fabricius); 1964, North I., Southeast I., several seen flying in daylight but not captured.

Pyralidae

**Hymenia recurvalis* (Fabricius); 1964, Southeast I., adults flying, larvae feeding on *Sesuvium*.

Tineidae

Ereunetis incerta Swezey; 1923; 1964, North I.) on *Eragrostis*.

Cygnodiidae (Det. by E. C. Zimmerman)

**Petrochroa dimorpha* Busck; 1964 Southeast I.), adults at light.

Plutellidae

Plutella maculipennis Curtis; 1923, 1964 North I.)

COLEOPTERA

Coccinellidae

Scymnus loewii Mulsant; 1923; 1964, North I., Southeast I., adults and larvae feeding on mealybugs on *Eragrostis*. Listed by Bryan as *S. kinbergi*.

Dermestidae

Dermestes ater De Geer; 1923. Listed by Bryan as *D. cadaverinus* Fabricius.

**Dermestes maculatus* De Geer; 1964, Southeast I., under dead birds.

Tenebrionidae

Alphitobius laevigatus Fabricius; 1923; 1964, Southeast I.

Cleridae

**Necrobia rufipes* De Geer; 1964, Southeast I., under dead birds.

Anthribidae

**Araecerus fasciculatus* (De Geer); 1964, Southeast I., on *Eragrostis*.

DIPTERA

Phoridae

Diplonerva peregrina Wiedemann; 1923. Misidentified in Bryan's list as *Megaselia scalaris* (Loew).

Syrphidae

**Ischiodon grandicornis* (Macquart); 1964, North I.

Ephydridae

**Hecamede persimilis* Hendel; 1964, North I., Southeast I.

Agromyzidae

**Liriomyza* sp.; 1964, North I., adults flying, larvae mining leaves of *Lepidium*.

Milichiidae

*[illegible]metopa n. sp. Det. by C. W. Sabrosky); 1964, North I., Southeast [illegible]. Bryan lists an "undertermined Milichiinae" collected in 1923. [illegible] specimens were not located.

Chloropidae

*[illegible]phunculina signata (Wollaston); 1964, North I.

Tethinidae

[illegible]ronia insularis Aldrich: 1923. Not listed by Bryan (1926) but two [illegible]mens in type series were from Pearl and Hermes material [illegible]ected by Tanager Expedition.

Sarcophagidae

[illegible]ophagia bryani Souza Lopez: 1923: 1964, North I., Southeast I. [illegible]ted by Bryan as an undetermined species.

Calliphoridae

[illegible]ucilia graphita Shannon: 1923: 1964, North I.

Muscidae

Musca domestica L.: 1923.

HYMENOPTERA

Braconidae

Chelonus blackburni Cameron: 1923; 1964, North I., Southeast I.

[illegible]panteles sp., probably *marginiventris* Cresson; 1964, Southeast I., numerous empty cocoons on *Sesuvium* infested with *Hymenia* larvae.

Encyrtidae

[illegible]yrus sangwani Rao?: 1964, Southeast I., larvae and pupae of which [illegible] probably this species found within parasitized specimens of *Icerya [illegible]gramina*.

Formicidae

[illegible]ndomyrma nuda Mayr: 1964, North I., Southeast I.

[illegible]heidole megacephala Fabricius: 1964, North I., Southeast I., tending *Aphis* on *Tribulus*.

Tetramorium guineense Fabricius : 1923: 1964, North I., Southeast I.

KURE ATOLL

A brief stopover was made at Kure Atoll, en route to Midway, on 14, September 1964. About three hours were spent collecting insects in the area surrounding the U. S. Coast Guard Station on Green Island. Butler and Usinger 1963b have listed the insects taken by them during a three-day stay in September, 1961. The new records listed below probably are mostly recent immigrants which became established during the three-year interval between the Butler-Usinger collections and my own.

HOMOPTERA

Cicadellidae

*[illegible]adulifer [illegible]neilus Baker: 1964, on *Boerhavia*.

**Deltocephalus sonorus* Ball: 1964, on grass.

**Empoasca solana* Delong; 1964, on *Solanum nigrum*.

Pseudococcidae

**Antonina graminis* (Maskell); 1964, on *Eragrostis* stem.

Diaspididae

**Hemiberlesia lataniae* (Signoret): 1964, on *Lepidium*

**Odonaspis ruthae* Kotinsky; 1964, *Eragrostis* stems.

LEPIDOPTERA

Noctuidae

**Spodoptera mauritia* (Boisduval); 1964, adults on mess-hall screen.

Gelichiidae

**Stoberhinus testaceus* Butler: 1964.

COLEOPTERA

Coccinellidae

**Scymnus notescens* (Blackburn); 1964.

DIPTERA

Ceratopogonidae

*undetermined genus and species; 1964.

Agromyzidae

**Pseudonapomyza spicata* (Malloch); 1964.

Chloropidae

**Siphunculina signata* (Wollaston); 1964.

Sphaeroceridae

**Leptocera hirtula* (Rondani)?; 1964.

HYMENOPTERA

Mymaridae

Polynema reducioli Perkins; 1923; 1964.

Eulophidae

**Euderus metalicus* Ashmead (?); 1964.

Encyrtidae

**Anagyrus swezeyi* Timberlake; 1964.

**Blepyrus insularis* (Cameron); 1964. This species is a parasite of *Ferrisia virgata*. The latter was stated to be heavily infesting *Boerhavia*, and apparently was abundant on other hosts as well, in 1961. In 1964 this mealy bug was scarce.

LAYSAN ISLAND

New records in my June, 1962 collections from Laysan have been cited by Butler and Usinger (1963a). Half a day was spent collecting on Laysan in September, 1964. An apparently recently established immigrant spider was found, but no new insects.

Also taken in 1964 and not previously reported from Laysan was a small lizard of the family Scincidae, *Cryptoblepharus boutoni poecilopleurus* Wiegmann. (Det. by W. O. Wirtz II), several of which were seen.

ARANEIDA

Clubionidae Det. by T. W. Suman)

**Chiracanthium diversum* L. Koch; 1964, plentiful.

The following insects collected in 1964 seem worthy of note.

COLEOPTERA

Coccinellidae

Scymnus loewi Mulsant (Det. by E. A. Chapin); 1912; 1964, feeding on *Trionymus insularis* on *Eragrostis*.

This is probably the species collected by Butler in 1959 on *Eragrostis*, the specimens of which were lost. (Butler & Usinger 1963a: 15) Listed by Bryan as *S. kinbergi* (Boheman).

Cleridae

Necrobia rufipes De Geer; 1912; 1964.

Curculionidae

Dryotribus mimeticus Horn; 1912, 1964, numerous specimens on underside of driftwood on beach.

DIPTERA

Milichiidae

**Leptometopa* n. sp. (Det. by C. W. Sabrosky); 1962; 1964. Same species from Nihoa, Necker, Lisianski and Pearl and Hermes Atoll, not previously recorded.

HYMENOPTERA

Pteromalidae Det. by C. M. Yoshimoto)

Spalangia drosophilae Ashmead; 1962; 1964. Recorded as *Spalangia* sp. by Butler & Usinger (1963a).

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TICK DISTRIBUTION IN THE CENTRAL PACIFIC AS INFLUENCED BY SEA BIRD MOVEMENT[1,2]

By **A. Binion Amerson, Jr.**[3]

Abstract: Tick distribution in the Central Pacific region reflects the influence of 2 distinct sea bird breeding populations — northern, Hawaiian Is. area, and southern, Line Is.-Phoenix Is. area. Four tick species — *Ixodes amersoni*, *I. laysanensis*, *Ornithodoros denmarki*, and *O. capensis* — are associated with birds nesting on Central Pacific islands. *I. amersoni* is known from Phoenix I. and Enderbury I., although in time it probably will be found on other islands of the southern Central Pacific area as well. *I. laysanensis* and *O. denmarki* are presently known from certain islands in the northern Central Pacific area, but these also are expected to be found eventually on all of the islands in this area as well. *O. capensis* is widely distributed throughout tropical and subtropical oceans, including the entire Central Pacific region; it is suggested that sea birds may have brought this species to both northern and southern Pacific areas from other parts of the world. It is further suggested that the *O. capensis* population in the northern Central Pacific area does not normally mix with the southern Central Pacific population, due to the limited sea bird movement between these 2 areas. Although the tick-dissemination potential of sea birds which migrate annually into and through the Central Pacific is great, tick deposition is minimized, since these birds normally remain at sea during their nonbreeding periods and seldom stop on islands.

The role of land birds in transporting ticks and other parasitic arthropods has recently been studied by Hoogstraal et al. (1961, 1964), Nuorteva & Hoogstraal (1963), Pavlov (1964), Semashko (1959), and Vshivkov (1956). These studies show that birds do transport ticks over varying distances and that in some cases birds do account for the distribution of ticks.

The role of sea birds in transporting ticks is rather poorly known since (1) many sea birds breed over wide ranges; (2) their breeding grounds are often on isolated and seldom-visited islands; (3) the migration routes of many are unknown; and (4) in some instances their postbreeding grounds are either poorly understood or completely unknown. Furthermore, the distribution of sea bird ticks is also poorly understood. This deficiency is due mainly to a lack of collection over the ranges of the various hosts.

Schulze (1938) and Zumpt (1952) suggest that sea birds have influenced the distribution of *Ixodes uriae*. This species is known from the Arctic and sub-Antarctic areas, and Schulze has called it a "bipolarly distributed" tick since it shows a circumpolar distribution in both areas. Zumpt indicates that attached ticks could be carried between the 2 regions by sea birds such as Wilson's Storm Petrel (*Oceanites oceanicus*) which breeds in the Antarctic and migrates northward to the Arctic, or the Arctic Tern (*Sterna paradisaea*) which breeds in the Arctic circumpolar region and then migrates to the southern regions. In addition, Zumpt states that dispersal may be accomplished by adherence of tick eggs to the feet of the host, and suggests that "the explanation is more likely to be an ecological than a historical one."

The Central Pacific (FIG. 1) is a unique region for studying the sea bird-tick relationship. The islands throughout this region are low-lying coral atolls characterized by low rainfall and sparse vegetation (except for the main Hawaiian Is. and a few of the Line Is. where high rainfall has created luxuriant vegetation). Until recently very little was known about the sea birds of the Central Pacific region, and similarly, very little was known about sea bird ticks in that region. In 1960 published records indicated that *Ornithodoros capensis* was known on only 11 of the 42 islands or atolls in the Central Pacific region. Only 1 other sea bird tick (an *Ixodes* species) was known to exist—and this only on 1 island.

The Smithsonian Institution is presently conducting an ecological survey in the Central Pacific Ocean which includes a study of the fauna and flora of most of the islands as well as a survey of the open ocean to determine the distribution and abundance of sea birds (Humphrey 1965). By examining the arthropod collections made by the survey through December 1966 and by correlating this with data on bird movements resulting from a banding program of the same survey, it is possible to present at this time a preliminary interpretation of the role that sea birds play in the distribution of ticks in the Central Pacific region.

To study bird movement successfully, enormous numbers of birds must be banded and subsequently recaptured. Through December 1966 U.S. Fish and Wildlife Service bands have been placed on the

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(see also Butler & Usinger 1963, Wilson 1964) and was also collected on Laysan I. in March 1961 from Laysan Albatross (Woodside & Kramer 1961, unpublished Hawaiian Fish and Game Division report). Smithsonian Institution personnel recorded this species on Pearl and Hermes Reef, French Frigate Shoals, and Gardner Pinnacles in 1963 (Kohls 1966) and have since added Lisianski I. to the list of infested islands. *I. laysanensis* appears to be restricted to no one host group (TABLE 3), as the host list now includes 10 sea and shore bird species and 2 endemic land bird species. *I. laysanensis* has been collected as well from humans (crawling on the skin) and from ground litter. No specimens have yet been collected from Sand I., Johnston Atoll, despite continuous surveillance since the summer of 1963. One *I. laysanensis* larva was collected at sea from a Sooty Tern (*Sterna fuscata*) on 20 May 1965 at 16°18' N by 172°57' W. This location is approximately 320 km west of Johnston Atoll and 960 km south of the nearest *I. laysanensis* infestation (Laysan I.). Since Sooty Terns and other sea birds from the Hawaiian Is. frequently visit Johnston Atoll, it is suspected that this hard tick will eventually be carried to this atoll. No males have been recorded in nature; however, Dr Glen M. Kohls has been able to rear and obtain males from the progeny of a live female collected by me (Kohls & Clifford 1967).

A second tick species, found so far only in the northern part of the Central Pacific region, is *Ornithodoros denmarki*. The known distribution of this soft tick is from Bush Key, Dry Tortugas, Florida (type locality), associated with Sooty Terns; from Morant Cay, Jamaica, West Indies, from Brown Boobies (*Sula leucogaster*); from Solado Rock, Trinidad, West Indies, associated with nesting Sooty Terns and Brown Noddies (*Anous stolidus*); from Raza I., Gulf of Baja California, Mexico, associated with nesting gulls and terns; from Calaveras I., Gulf of Baja California, associated with gulls and cormorants; and from Manana (Rabbit) I., Oahu, Hawaii, on a Brown Noddy (*Anous stolidus*) collected 24 November 1946 (Kohls et al. 1965, Denmark & Clifford 1962). An *Ornithodoros* sp. near *denmarki* has been recorded on South I., Farallon Is., California, from nests of Western Gulls (*Larus occidentalis*) and off a European rabbit (*Oryctolagus cuniculus*) (Radovsky et al. 1967, Marshall & Nelson 1967). The range of *O. denmarki* in the Central Pacific region has now been extended to include Sand I., Johnston Atoll, where 13 specimens were collected in 1965 and 1966 from 2 Brown Noddy nests, 1 Sooty Tern nest, and 1 Wedge-tailed Shearwater nest, and it seems likely that this species will eventually be found on other islands in the northern area besides Oahu and Johnston, since the host species are known to move between the islands in the area. *O. denmarki* may already occur in such small numbers on these other islands in the Hawaiian area that it has been overlooked during collecting.

Kohls et al. (1965) state that postlarval stages of *Ornithodoros denmarki* cannot be definitely distinguished from those of *O. capensis*. Therefore, those collections containing solely postlarval stages can be identified only as *O. capensis* group. The actual distribution of the 2 species cannot be determined until numerous larvae are collected from each atoll; nevertheless, in Dr Kohls' opinion most of the material identified as *O. capensis* group is probably *O. capensis* Neumann rather than *denmarki*, since the latter species is so uncommon in the Smithsonian Institution's collection (Kohls, pers. commun., February 1965). TABLE 4 indicates those islands from which ticks identified as *O. capensis* Neumann and *O. capensis* group were collected.

Ornithodoros capensis is associated with nesting sea birds over the entire Central Pacific region. This soft tick was described from several specimens taken from nests of penguins on islands off Cape Colony, South Africa (Neumann 1901). Since 1901 *O. capensis* has been recorded around the world in the tropical and temperate regions (FIG. 2) and has been associated with 29 species of sea and shore birds throughout the world (from published and unpublished records). According to Munro (1946), it was known in the Hawaiian Is. as early as 1891, and nymphs were reported from Laysan (no collection date given) by Neumann (1901). It is presently known from 32 islands and at sea in the Central Pacific and immediate surrounding areas from 22 sea and shore bird species, as well as from man, the European rabbit, sea turtles (*Celonia mydas*), and ground litter (see TABLE 4). The hosts most frequently associated with this species in the Central Pacific region are the Sooty Tern (189 collections on 21 islands and 8 at sea) and Brown Noddy (131 collections on 15 islands). Bird movement undoubtedly has influenced the distribution of *O. capensis*, and it is suggested here that sea birds may have brought it to both areas of the Central Pacific and from other parts of the world. Further, it is suggested that the *O. capensis* population in the northern Central Pacific area does not mix with the southern Central Pacific population because of the limited sea bird movement between the 2 areas. Shore birds do move between the 2

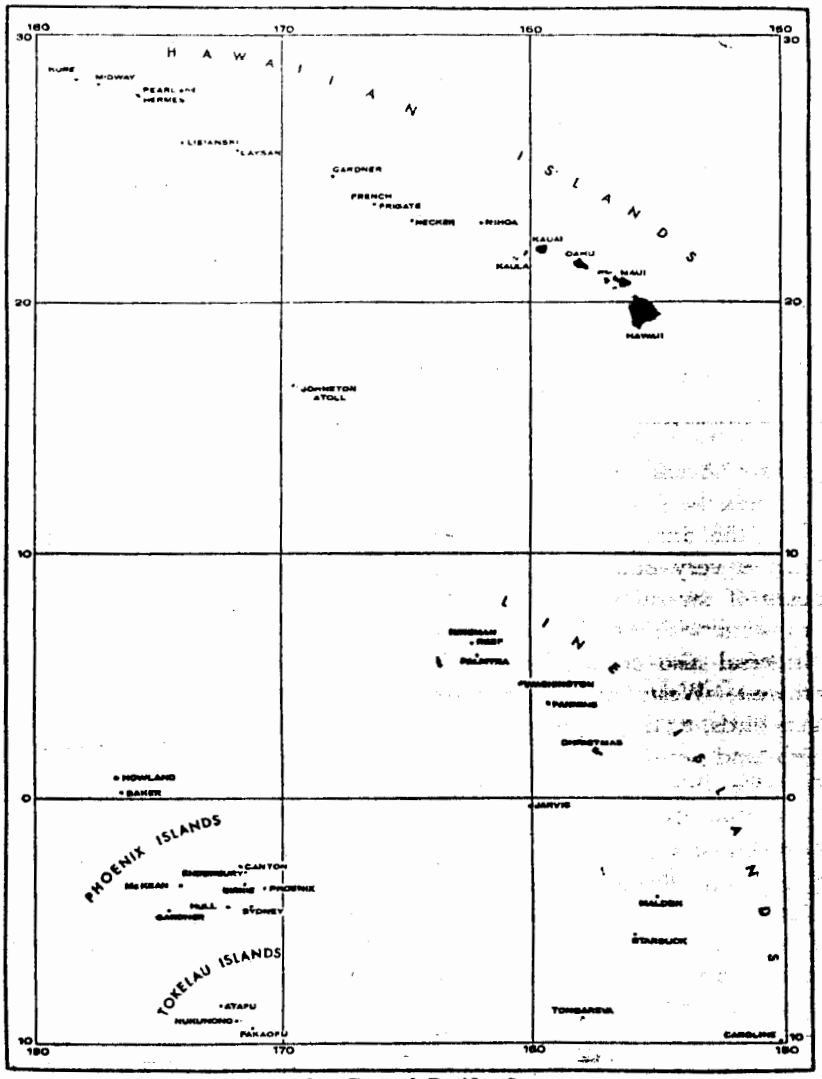

FIG. 1. Central Pacific Ocean.

legs of more than 1,350,000 birds of over 50 species. Although recaptures of banded birds number above 65,000, only a very small percentage are recaptured away from their nesting island. Nevertheless, some general distribution patterns have begun to develop from data obtained.

About 110 sea and shore bird species are known to occur in the Central Pacific. Of this number, 27 sea bird species are known to breed on islands in this region; 15 of the 27 breed throughout the region (TABLE 1), while 7 breed only in the Hawaiian Islands area and 5 breed only in the Line Is.-Phoenix Is. area (TABLE 2). Those species which breed only in 1 area do not occur on islands of the other area. In addition, 25 sea and shore bird species occur as regular migrants into or through the entire region, while the remaining 58 species are accidentals (King 1967, Clapp & Sibley 1967, Clapp & Woodward 1968).

Since 15 sea bird species breed throughout the entire Central Pacific region, one might suspect that inter-island movement of these species would be customary among all parts of the region. However, inter-island movement of nesting sea birds is not ordinarily common between certain parts of the region. Instead, 2 populations exist—northern

TABLE 1. List of sea bird species which breed over the entire Central Pacific region.

Puffinus pacificus	*Fregata minor*
Puffinus nativitatus	*Sterna lunata*
Bulweria bulwerii	*Sterna fuscata*
Phaethon lepturus	*Procelsterna cerulea*
Phaethon rubricauda	*Anous stolidus*
Sula dactylatra	*Anous tenuirostris*
Sula leucogaster	*Gygis alba*
Sula sula	

TABLE 2. List of sea bird species which breed in specific areas of the Central Pacific region.

Species	Hawaiian Area	Line-Phoenix Area
Diomedea nigripes	×	—
Diomedea immutabilis	×	—
Puffinus puffinus newelli	×	—
Puffinus lherminieri	—	×
Pterodroma alba	—	×
Pterodroma phaeopygia	×	—
Pterodroma hypoleuca	×	—
Nesofregetta albigularis	—	×
Oceanodroma castro	×	—
Oceanodroma markhami	×	—
Fregata ariel	—	×
Thalasseus bergii	—	×

(Hawaiian Is., Johnston Atoll, and Wake) and southern (Line Is.-Phoenix Is., including Howland I. and Baker I.)—and the amount of movement between these 2 areas is very limited. Extensive inter-island movements of several species (namely terns and boobies) do occur within each major area and postbreeding dispersal also occurs from both areas to the Southwest, West, and Northwest Pacific Ocean. Shore birds, as transients, do move between the northern and southern areas of the Central Pacific region, but this occurs during their migration when little time is spent on islands. Thus, from the standpoint of sea bird populations, the Central Pacific region is divided into 2 major areas—the Hawaiian Is. and the Line Is.-Phoenix Is. areas.

If sea bird movement is a prime factor in the dispersal of ticks, then the present distribution of ticks and other medically important arthropods in the Central Pacific should reflect this separation in sea bird populations. To gain further information on tick distribution in this region, large numbers of hosts and their nests were examined. A total of 924 tick samples representing over 5000 specimens has been taken in 8264 arthropod collections from the Central Pacific region. These field collections have been taken from 96 host species on 43 islands and at sea.

From these collections 4 tick species—*Ixodes amersoni* and *I. laysanensis* in the family Ixodidae, and *Ornithodoros denmarki* and *O. capensis* in the family Argasidae—have been found to be associated with sea birds breeding on islands in the Central Pacific region. The distribution of the first 3 of these tick species does support evidence uncovered by bird-banding of the separation that exists between bird populations in the Hawaiian area and the Line-Phoenix area.

The first of the 4, *Ixodes amersoni*, is known only from the southern part of the Central Pacific region. It was described from 1 adult female collected from a White Tern (*Gygis alba*) at Phoenix I. on 4 [illegible] 1965 (Kohls 1966). Additional specimens have now been collected from White Terns at Phoenix I. on 15 April and 10 October 1966, and from a Red-footed Booby (*Sula sula*) at Enderbury I. on 25 September 1966. Despite an extensive search for this species on the other islands of the Phoenix group, none has been recovered. Nevertheless, this species may occur on these islands in such small numbers that it has been overlooked. If sea birds are responsible for the transfer of ticks, *I. amersoni* should also be found on the other islands in the Phoenix-Line Is. area since there is frequent movement of sea birds between these islands.

Ixodes amersoni superficially resembles *I. laysanensis;* however, the 2 species occur in separate areas. Both species also resemble *I. murreleti* which is known only from a Xantus' (Scripps') Murrelet (*Endomychura hypoleuca scrippsi*) taken on Los Coronados Island, Baja California, Mexico (Cooley & Kohls 1945).

Ixodes laysanensis has been found only in the northern area of the Central Pacific, namely in the leeward Hawaiian Is. This hard tick was described from female and nymphs taken in December 1963 on Laysan I. from 3 host species: Laysan Albatross (*Diomedea immutabilis*), Wedge-tailed Shearwater (*Puffinus pacificus*), and Ruddy Turnstone (*Arenaria interpres*) (Wilson 1964). Actually, *I. laysanensis* was discovered on Laysan I. as early as April and July 1959 by Butler (1960) from the endemic Laysan Teal (*Anas wyvilliana laysanensis*)

TABLE 3. Known hosts and localities for *Ixodes laysanensis*.

Species	Locality: French Frigate Shoals	Gardner Pinnacles	Laysan	Lisianski	Pearl and Hermes Reef	At Sea (Northern Area)
Diomedea nigripes	—	—	—	—	×	—
Diomedea immutabilis	—	—	×	—	×	—
Puffinus pacificus	—	—	×	—	—	—
Phaethon rubricauda	×	—	—	—	—	—
Sula dactylatra	×	—	×	—	—	—
Sula sula	×	—	—	—	—	—
Fregata minor	—	—	—	—	×	—
Anas wyvilliana laysanensis	—	—	×	—	—	—
Arenaria interpres	—	—	×	—	—	—
Sterna fuscata	—	—	×	×	—	×
Anous stolidus	×	—	×	—	×	—
Psittirostra cantans	—	—	×	—	—	—
*Homo sapiens**	×	—	—	—	—	—
Ground Litter	—	×	—	—	—	—

*Crawling on the skin only.

TABLE 4. Distribution and hosts of *Ornithodoros capensis* Neumann (*) and *Ornithodoros capensis* group (+) in the Central Pacific.

Localities	Hosts																							
	Diomedea nigripes	*Diomedea immutabilis*	*Puffinus pacificus*	*Puffinus nativitatus*	*Pterodroma alba*	*Bulweria bulwerii*	*Nesofregetta albigularis*	*Oceanodroma markhami*	*Phaethon rubricauda*	*Sula dactylatra*	*Sula leucogaster*	*Sula sula*	*Fregata minor*	*Fregata ariel*	*Arenaria interpres*	*Sterna lunata*	*Sterna fuscata*	*Thalasseus bergii*	*Procelsterna cerulea*	*Anous stolidus*	*Anous tenuirostris*	*Gygis alba*	*Orycotalagus cuniculus*	*Homo sapiens*	*Chelonia mydas*	Ground Litter
HAWAIIAN AREA																								
Oahu																				*				
Nihoa																			+				+	+
Necker																								+
French Frigate Shoals	+	+							+		*						*			*				+
Gardner Pinnacles																	+							+
Laysan	+	*	+						+	+		+					*			+	+		+	+
Lisianski									+			+		*			*			+	+		+	+
Pearl & Hermes Reef	*	*					+			+							+			+				+
Midway																	*							
Kure	*	*	*						*	*	+	+	+				*				*			
Johnston			*						*		+	+	+		*		*			*	*		+	*
At Sea (Northern area)	+																+							
LINE-PHOENIX AREA																								
Howland									+	*	*	*		*		+	*						+	*
Baker										+										*				
Canton																+				+				+
Enderbury											+	*				+	+							
McKean			+						+	+	+		+				+			+	+		+	+
Birnie																					*			
Phoenix						+	+		+	+	+	*	+	+		+	*		*	*		*	+	+
Hull																				*				
Sydney																	+			+				
Christmas				+	+																+			
Jarvis											+	+												
Malden										+				+			+			+	+			
Starbuck																	+							
Caroline																	+							
Tongareva																				+				
MARSHALL																								
Wake															*		+							
Taongi																	+							
Bikar																	+							
Taka																	*							
Erikub											+							+						
Eniwetok																	*			*				

areas during migration periods, but their chances of transporting *O. capensis* are small, since they spend relatively little time on islands during these periods.

The possibility of sea birds carrying ticks to other parts of the Pacific is of great zoogeographic and medical importance. Smithsonian banding data indicate that some sea birds from both areas disperse to almost all parts of the western and northern Pacific Ocean after breeding on islands in the Central Pacific region. Thus, if ticks stay attached to their hosts (as has been indicated by 10 larval collections by the present survey from sea birds at sea), there is a possibility of their being transported great distances. Although the tick dissemination potential of sea birds during postbreeding migration is high, the possibility of ticks being carried to distant islands or continents is minimal since most sea birds normally remain at sea during their nonbreeding period. Even if a tick should be carried to a distant point, however, its survival depends on the environment and the available hosts.

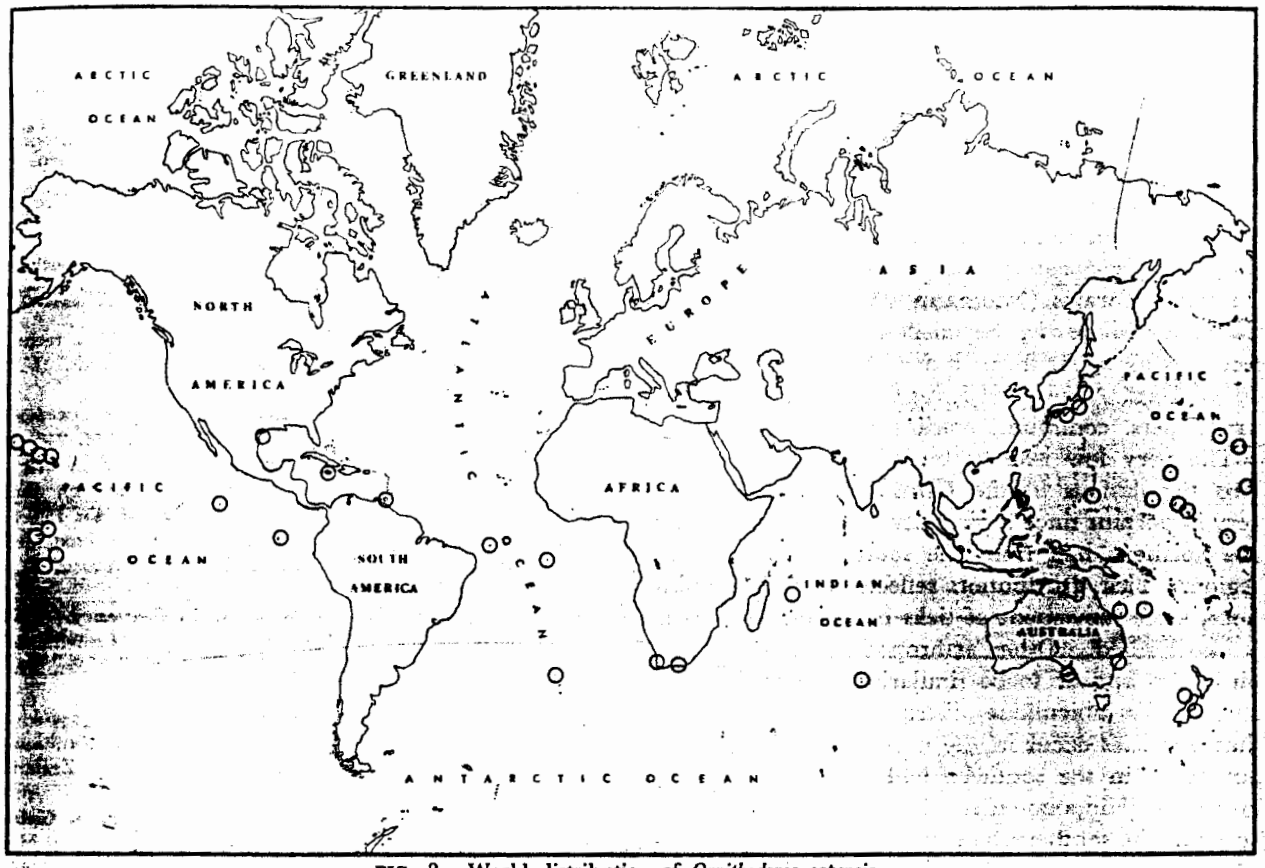

FIG. 2. World distribution of *Ornithodoros capensis*.

Many sea birds migrate annually into and through the Central Pacific region from other parts of the Pacific, although they seldom, if ever, stop on the islands of the Central Pacific. Many of these sea birds are from the Australia-New Zealand area, and the several tick species associated with them include: *Ixodes auritulus zealandicus*, *I. eudyptidis*, *I. jacksoni*, *I. kohlsi*, *I. pterodromae*, and *I. uriae* (Dumbleton 1961; Maskell 1885; Hoogstraal 1967; Arthur 1955, 1960; White 1852). The influence of migrating sea birds on the bipolar distribution of *I. uriae* has already been discussed here. Dumbleton (1961: 767) suggests that "although one of the New Zealand hosts of [*I. a.*] *zealandicus* (*Puffinus griseus*) migrates to the Northern Hemisphere the tick is not recorded there and it would appear that carriage of the tick outside the area or hemisphere in which nesting occurs, whether by regular migration or by stragglers, is seldom followed by permanent colonisation of the tick." Smithsonian Institution personnel collected a female *Ixodes pterodromae* from the ear of a northward-migrating Sooty Shearwater (*Puffinus griseus*) on 23 May 1965 in the Central Pacific at 03°10' N by 173°45' W. This tick had been attached for about 4800 km, showing the dissemination potential of the host, as well as its possible point of origin. The chances of this tick being deposited on a Central Pacific island was, as pointed out above, very low. Even if it had been deposited, however, that it would have survived is questionable, since its normal environment is a temperate rather than a tropical region.

Some of the sea bird species which breed in the Central Pacific region also breed in the Coral Sea off the northeast tip of Australia. Among them are: Wedge-tailed Shearwater, Red-tailed Tropicbird (*Phaethon rubricauda*), Blue-faced Booby (*Sula dactylatra*), Brown Booby, Red-footed Booby (*Sula sula*), Great Frigatebird (*Fregata minor*), Lesser Frigatebird (*Fregata ariel*), Sooty Tern, Crested Tern (*Thalasseus bergii*), Brown Noddy, and Black Noddy (*Anous tenuirostris*) (Hindwood et al. 1963). Near the Great Barrier Reef, the Coral Sea has a tropical environment somewhat comparable to that of the Central Pacific region. In this area *Ornithodoros capensis* again is associated with these hosts, which also harbor *Amblyomma loculosum* (Neumann 1907; Roberts 1953, 1964; Hindwood et al. 1963). The 2 *Ixodes* species occurring on nesting sea birds in the Central Pacific region have

not been found in the Coral Sea region, and *A. loculosum* is not known from the Central Pacific. Bird-banding data have shown that there is no movement between the 2 regions of sea bird species which breed in both regions. These data suggest that the Coral Sea is biologically isolated from the Central Pacific. There is evidence that sea birds from the Coral Sea may move to the Indian Ocean since *A. loculosum* occurs at Establishment I., Cargados Carajos (Neumann 1907) and at Pointe Capucin, Mahe I., Seychelles. This latter collection was taken from under the feet of a dying Sooty Tern, August 1965, by Guy Lionnet (Hoogstraal, pers. commun., April 1966).

The very low rate of interchange between sea bird populations in the Central Pacific region is very important since it virtually isolates faunistically the northern half from the southern half of that region. Tick distribution reflects these 2 populations, since movement of ticks between the 2 areas is also limited. Other arthropods parasitic on sea birds also appear to be similarly influenced. The chigger (Trombiculidae) distribution, to date, shows that 4 species occur in the northern half which do not occur in the southern half; also, 1 species of louse fly (Hippoboscidae) is presently known to occur in the southern half but has not been recorded in the northern half.

Much still remains to be learned about the distribution of sea bird ticks in the Pacific Ocean. Field personnel of the Smithsonian Institution are continuing their collection of ticks from sea birds occurring in the Central Pacific in hopes that the ticks' overall distribution and relationships to their hosts can be further elucidated. It is hoped that this paper will stimulate other workers, acarologists and entomologists as well as ornithologists, to examine sea birds and their nests for ticks, not only in the Pacific Ocean, but over the entire world.

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RELATIONSHIPS BETWEEN INSECT REPELLENCY AND CHEMICAL AND PHYSICAL PARAMETERS—A REVIEW[1]

By **Lorrin R. Garson[2] and Mary E. Winnike[2,3]**

Abstract: The pertinent literature has been reviewed from January 1940 through October 1967. The relationships between molecular constitution and insect repellency are described as well as the role of such physical parameters as boiling point and vapor pressure, molecular weight, partition coefficient, and concentration effect. The desirable properties of an ideal repellent substance are summarized, and definitions of repellency relative to this discussion are presented.

As part of our program to develop a long-lasting insect repellent and other prophylactic agents effective against pathogenic or physical impairments inflicted through the skin, we have undertaken this literature search on the relationships between chemical and physical parameters and insect repellency. Using appropriate subject headings, 5 indices (*Bibliography of Agriculture*, *Biological Abstracts*, *Biological and Agricultural Index*, *Chemical Abstracts*, and *Index Medicus*) were exhaustively searched from 1 January 1940 to 31 October 1967. While it was our intent to cover exhaustively the literature of all nations, one feels compelled to admit that the indices used in our survey may be, possibly, in a better position to maintain awareness of publications emanating from the North American Continent than from other parts of the world. Therefore, should we have failed to refer to some papers outside this region, we wish to assure the reader that any such omission was not intentional.

In our search, we have come across several items (Bibliography: 41, 44, 45, 56, 59, 73) directly or indirectly pertinent to the subject matter under consideration; since we experienced considerable difficulty in procuring translations, reprints, or copies of these communications or reports, we were compelled to limit ourselves to abstracts only for the purpose of this review. Because the major work in insect repellent development had been accomplished during and subsequent to World War II, we felt justified in limiting our search retroactively to 1940.

Before describing the present status of insect repellents as related to chemical and physical factors, it is necessary to enumerate the desirable qualities for these materials. Granett (1, 2), Hall and his

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