The Klu Beetle, Mimosestes sallaei (Sharp), in Hawaii (Coleoptera: Bruchidae)[1]

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(*Submitted for publication January, 1960*)

In 1918, a bruchid new to Hawaii was reared from klu pods collected "in the Punchbowl district of Honolulu" and identified as "*Bruchus sallaei* Sharp" by Bridwell (1919). Two general studies of the Bruchidae, which have included observations on the bionomics and parasites of this species, were those conducted by Cushman (1911) in Texas and Bridwell (1920) in Hawaii. During the period from September 1957 to March 1960, additional notes on the nomenclature, bionomics, competitors and parasites of the klu beetle were made by the present author in connection with research on mortality in natural populations of bean beetles in Hawaii.

NOMENCLATURE

Of the twelve bruchids established in Hawaii, the klu beetle and eight other species have long been treated as members of the genus *Bruchus* (=*Mylabris* or *Laria*), although Bridwell (1918) recognized "the desirability of separating the natural genera confused under the old genus *Bruchus*". Bridwell (1929) partially accomplished the necessary revision by raising *Acanthoscelides* and *Callosobruchus* from subgeneric to generic standing. The revision was continued in another paper by Bridwell (1946), in which Nearctic and Neotropical species were removed from *Bruchus*, several being designated as types of new genera. In that paper, Bridwell also separated the subgenus *Zabrotes* from *Spermophagus* and raised it to generic level. Furthermore, he treated *Caryedon* (=*Caryoborus* or *Pachymerus*) *gonagra* (Fabricius) as a synonym of *C. fuscus* (Goeze). The latter change was strongly opposed by Southgate and Pope (1957) but the other taxonomic reforms have, with some qualifications, generally been accepted (*vide:* Bradley, 1946; Muesebeck *et al.*, 1951; Southgate, Howe and Brett, 1957).

There apparently is another synonym in the literature on bruchids in Hawaii since *Megacerus alternatus* Bridwell was first recorded as "*Bruchus* sp. near *coryphae* Olivier" (Swezey, 1925), and it seems probable that *B. coryphae* variety *lineatipennis* Pic (1938), described from Hawaiian specimens, should be synonymized with *M. alternatus*.

[1] A portion of a dissertation submitted in partial fulfillment of the requirements for the degree Doctor of Philosophy in Entomology at the University of Hawaii.

The accepted names and pertinent synonyms of bruchids in Hawaii are now as follows:

1. **Acanthoscelides obtectus** (Say)
   Bruchus obtectus Say
   Bruchus irresectus Fahraeus, Bridwell 1929
2. **Algarobius prosopis** (Leconte)
   Bruchus prosopis Leconte, Bridwell 1946
3. **Bruchus phaseoli** Gyllenhal
4. **Callosobruchus chinensis** (Linnaeus)
   Bruchus chinensis (Linnaeus)
   Curculio chinensis Linnaeus, Bridwell 1929
5. **Callosobruchus maculatus** (Fabricius)
   Bruchus maculatus Fabricius
   Bruchus 4-maculatus Fabricius, Bridwell 1929
6. **Caryedon gonagra** (Fabricius)
7. **Megacerus alternatus** Bridwell
   Bruchus coryphae Olivier
   var. *lineatipennis* Pic, *new synonym*
8. **Mimosestes amicus** (Horn)
   Bruchus amicus Horn, Bridwell 1946
9. **Mimosestes sallaei** (Sharp)
   Bruchus sallaei Sharp, Bridwell 1946
10. **Stator limbatus** (Horn)
    Bruchus limbatus Horn, Bridwell 1946
11. **Stator pruininus** (Horn)
    Bruchus pruininus Horn, Bridwell 1946
12. **Zabrotes subfasciatus** (Boheman)
    Spermophagus subfasciatus Boheman, Bridwell 1946
    Spermophagus pectoralis Sharp, Bridwell 1940

Numbers 1 and 4 were designated as new genotypes in Bridwell (1929) and numbers 2, 9 and 11 in Bridwell (1946). Numbers 3, 4, 5 and 6 apparently originated in the Palearctic, Oriental or Ethiopian Regions and have become widely distributed through commerce. The other species, including *Mimosestes sallaei*, originated either in the Neotropical Region or in the southern portions of the Nearctic Region.

Bionomics

In Hawaii, *M. sallaei* has been reared from klu, *Acacia farnesiana* (L.) Willd. and kiawe, *Prosopis chilensis* (Molina) Stuntz, both plants being of Neotropical origin. Host lists presented by Zacher (1952) suggest that, in addition, it may

be able to develop on *Caesalpinia coriaria* (Jacq.) Willd. and *Ceratonia siliqua* L., ornamentals uncommonly grown in Hawaii (Neal, 1948:369 and 381). On kiawe, it is associated with three other species of bruchids, *Algarobius prosopis*, *Mimosestes amicus* and *Caryedon gonagra*, but the adults, although all 5 to 6 mm. long, can be distinguished readily. The dorsum of *M. sallaei* is reddish brown with grey lines whereas that of *M. amicus* is uniformly grey. (This difference appeared superficial but unsuccessful attempts to interbreed *M. amicus* and *M. sallaei* supported their specific standing.) Both species of *Mimosestes* can be separated from *Algarobius prosopis* by the scutellum which in *Mimosestes* is broader than long, and in *Algarobius* is longer than broad. The other bruchid reared from kiawe, *Caryedon gonagra*, can be distinguished not only in the imaginal but also in the larval and pupal stages. The larva has functional legs, the pupa is found outside the seed in a heavy cocoon, and the adult has very much enlarged hind femora; all of these characteristics being absent in the other three bruchids.

Since *M. sallaei* is the only bruchid commonly reared from klu, this host was used in most of the following studies. *M. sallaei* apparently first oviposited on the basal end of green klu pods, sometimes as early as the fifth week of pod development. When the pods started turning brown, during the 10th to 12th week, oviposition generally increased. The attack continued for months, oviposition occurring even on pods in which all the seeds had been destroyed.

Eggs were attached to the pod surface by means of a thin lacquer-like film which was most conspicuous around the periphery of isolated eggs and less so at the edge of clusters. Some of the clusters contained more than 10 overlapping eggs. Although the eggs could be laid anywhere on the surface of the pod, certain points, next to ridges or inside wounds, seemed to be favored.

The incubation period for 30 eggs laid in June, 1958, ranged from 5 to 9 days, averaging 7. Those laid in cooler months apparently took a few days longer to develop.

The egg is about 0.8 mm. long and 0.4 mm. wide, one end being slightly pointed. The translucent chorion permitted the following observations to be made during the incubation period: on the first day, many globules and four or five transverse lines could be seen; on the second, there was an apparent concentration of darker embryonic tissue in the pointed end, with varying degrees of concavity in this dark mass by the third day; then on the fourth day the head everted and the embryo began to elongate, a process which continued for the last 2 or 3 days of embryonic development.

Laboratory studies showed that feeding during the adult stage increased oviposition. The maximum number of eggs laid by an unfed female was usually about 80 but a female fed honey could lay up to 140 eggs.

The larva emerged from the blunt end of the egg, boring directly into the pod and filling the chorion with yellow frass. Those larvae emerging from eggs that were not firmly attached apparently found penetration difficult, presumably owing to lack of purchase. When a larva did manage to bore through the thick

shell of a klu pod and reach a seed, it could continue to bore anywhere on the surface of the seed, but quite frequently it entered along the shallow groove in the seed coat which approximately outlines the cotyledons. The whole process of hatching and penetration apparently took several days.

Larval development within the seed usually lasted from 4 to 5 weeks, although it sometimes required as long as 8 weeks when the temperature was low or nutrition was poor. Counts of larval exuvia in a single seed suggested the presence of three instars, but there may be more. Randolph and Gillespie (1958) reported 4 instars for *Bruchus brachialis* Fahr, and de Luca (1956) observed 6 in studies of *Bruchus lentis* Fröhlich.

Cushman (1911) stated that the maximum pupal period for *M. sallaei* in Texas was 8 days. In Hawaii, however, pupation was found to range from 6 to 10 days. The adult, about 5 mm. long, remained in a teneral state for approximately 2 days, then chewed its way out leaving door-like discs about 2 mm. wide in both the seed and the pod.

In summary, the shortest times recorded for the various stages were as follows: egg, 5 days; larva, 24 days; pupa, 6 days; and teneral adult, 1 day. The total minimum period from oviposition to emergence was 36 days. Rearings indicated that males and females developed at similar rates and were equally abundant.

Adults of *M. sallaei* held without food or water died 20 to 50 days after emergence, but when fed with honey, they could survive up to 3 months.

Adults have been observed feeding on klu flowers but not on pods. When disturbed while feeding or ovipositing, adults usually dropped to the ground and frequently went into a state of thanatosis ("death mimicry") which sometimes lasted as long as 2 minutes, but more often ended after 10 to 30 seconds. During thanatosis, the beetle lay on its dorsum with legs and antennae held close to the body. When the state was terminated, either with or without an external stimulus, the beetle righted itself with a hind leg. Subsequent disturbance was more apt to produce flight than renewed "death feigning".

Competitors

Klu pods, at various stages in their development or disintegration, were found to be occupied by many different insects, mites and other organisms. Some were general scavengers or saprophytes, however, and only those organisms, including fungi, which subsisted on intact klu seeds were defined as "competitors".

M. sallaei and its competitors damaged most of the seeds in 510 pods collected at various locations on leeward Oahu during the period from August 1958 to January 1960. The pods contained a total of 7668 seeds: 27.2 per cent apparently undamaged; 39.9 per cent destroyed by grubs of *M. sallaei*; and 32.9 per cent rendered unsuitable for the development of *M. sallaei* by the activity of competitors, principally fungi.

Dr. H. Shirakawa, a mycologist with the U. S. Department of Agriculture Plant Quarantine Division, identified the fungus damaging klu seeds as *Aspergillus* sp. It developed readily within green klu pods and, under wet conditions, continued to grow in brown pods. Seeds upon which *Aspergillus* was growing first exhibited characteristically crinkled ridges in their seed coats and later were covered by a white mycelial mass. In the final stages of fungal development, infected pods were frequently filled with black, powdery sporangia. The pods turned brown prematurely but often remained on the bush for months.

Although it was shown that *M. sallaei* could become contaminated with *Aspergillus* spores during the process of emerging from an infected pod, its feeding and oviposition habits made it an unlikely vector. Infection might have occurred when *M. sallaei* oviposited within a spine wound on a green pod, but usually the bruchid laid its eggs on the surface of brown pods. However, an anthribid, *Araecerus levipennis* Jordan, readily attacked green klu pods even though this host was unsuitable for its development. Furthermore, females of *A. levipennis* collected in the field were found to be contaminated with *Aspergillus* and rotten pods usually had the punctures, distortions, and resin globules characteristic of *A. levipennis* oviposition sites. *A. levipennis* may not be a specific vector of *Aspergillus*, but its attacks apparently increase the chances of fungal infection in klu pods.

Two moths, a pyralid, *Ectomyelois ceratoniae* (Zeller), and an olethreutid, *Cryptophlebia illepida* (Butler), also developed in klu pods. A cerambycid beetle, *Sybra alternans* Wiedemann, was sometimes found in brown pods and, although its larvae did most of their feeding on the pod itself, they sometimes also chewed on the seed coats. Active grubs of the anobiid, *Catorama herbarium* Gorham, usually were found in seeds already damaged by other larvae but occasionally penetrated those previously unattacked. Two bruchids other than *M. sallaei* have sometimes been reared from klu. These were *M. amicus* and *C. gonagra*. Swezey (1931) reported that 37 "ripe" klu pods collected on Maui in August, 1929, yielded 133 *M. sallaei* and 1 *M. amicus*. Swezey (1938) also presented a note on rearings from klu pods gathered at Makapu, Oahu which included 174 *M. sallaei* and 3 *M. amicus*. During the spring of 1959, 68 pods exposed for varying periods at Diamond Head, Oahu, produced 175 *M. sallaei*, 1 *M. amicus* and 1 *C. gonagra*. Furthermore, 623 pods, most of them more than four months old, collected at various locations around Honolulu during the period from August to December, 1959, yielded 572 *M. sallaei*, 11 *C. gonagra* and 1 *M. amicus*.

Mortality

Egg: Both field and laboratory observations suggested that many eggs of *M. sallaei* were removed from klu pods by ants such as *Monomorium* sp. Even more eggs were killed, possibly by high temperature or excessive desiccation, under exposed conditions.

M. sallaei eggs were sometimes parasitized by a trichogrammatid wasp, *Uscana semifumipennis* Girault, which also attacks the eggs of at least six other bruchids in Hawaii. This may be the "very minute chalcid" reared in Texas by Cushman (1911) from "huisache" (klu) pods infested by *M. sallaei*. Bridwell (1920) was the first to record *Uscana* from *M. sallaei* in Hawaii and observed that attacks were "confined to the recently laid (unincubated) eggs". Bionomic studies of the wasp conducted during October, 1958, showed that eggs three days old could be parasitized, but those which had developed five days were no longer susceptible. The wasps pupated about one week after attack, at which time the chorion of the host eggs darkened, although less conspicuously than lepidopterous eggs parasitized by *Trichogramma* sp. *Uscana* required from 13 to 19 (average 15) days to complete its development. One *Uscana* adult, approximately 0.8 mm. long, emerged from each egg, chewing through the chorion and leaving a hole about 0.3 mm. in diameter.

The removal of egg shells by ants and rain made it quite difficult to estimate the effectiveness of *Uscana*. However, 80 klu pods were collected during February and March, 1960, at Diamond Head. Remaining on the pods were 470 eggs: 10.8 per cent parasitized, 19.7 per cent hatched and 69.4 per cent killed by other factors.

Larva: Some larvae hatching from those eggs which have not been eaten, parasitized or killed by other factors died before they penetrated the pod. Others drowned in the exudations of green pods or starved in the nutritionally unsuitable seeds of moldy pods. Larvae surviving these hazards could be parasitized by any one of the following six wasps: the braconids, *Urosigalphus bruchi* Crawford, *Glyptocolastes bruchivorus* Crawford, and *Heterospilus prosopidis* Viereck; a pteromalid, *Lariophagus texanus* Crawford; a eupelmid, *Eupelmus cushmani* (Crawford); or a eulophid, *Horismenus* sp.

Shipments of *Heterospilus* (and possibly *Uscana*) were made from Texas to Hawaii in 1910 (Williams, 1931:370). In 1921, the other parasites were introduced from Texas (Fullaway, 1921) although *Eupelmus* was not established until its introduction from Guatemala in 1934 (Swezey, 1938). These larval parasites had been reared "in considerable numbers" from *M. sallaei* in Texas by Cushman (1911).

Parasitization of *M. sallaei* in Hawaii was first recorded in the following notes: *Lariophagus* (Willard, 1922); *Glyptocolastes* (Bissell, 1923); *Heterospilus* (Swezey, 1924); *Horismenus* (Willard, 1924); *Urosigalphus* (Lutken, 1925); and *Eupelmus* (Swezey, 1938). They (and *Uscana*) are now well distributed, attacking *M. sallaei* throughout the Islands.

Rearings and dissections in the present study, generally using material collected in the field, made possible some observations on the bionomics and effectiveness of these wasps. All three of the braconids apparently are solitary internal parasites of bruchid larvae. The types of legumes in which their hosts were developing seemed to influence the relative abundance of these wasps.

Heterospilus was rarely reared from bruchids in klu although it was the most common parasite obtained from those in kiawe. *Urosigalphus* was the most common braconid on klu in Hawaii (and Texas) and on kiawe it was almost as common as *Heterospilus*. *Glyptocolastes* was usually less common than *Urosigalphus* on both klu and kiawe. When these braconids parasitized *M. sallaei* in Hawaii, their development took from 3 to 7 weeks. *Urosigalphus*, however, took much longer to develop when it parasitized the slow-growing grubs of *C. gonagra*. In one case, this braconid required at least 10 weeks to complete its development on *C. gonagra*, suggesting that it pupates no sooner than the pre-pupal stage of its host. *Glyptocolastes* and *Heterospilus* may not have such close synchronization with their hosts since undersized adults (2 to 3 mm.) were frequently observed. The normal size for braconid adults of all three species was from 4 to 5 mm. During the process of emergence, they chewed capless exit holes about 1 mm. in diameter. These holes and the remains of cocoons within seeds were useful indicators of braconid parasitization.

The adult braconids reared from klu could be distinguished by color characteristics. *Urosigalphus* has a deeply sculptured and uniformly black body, *Glyptocolastes* has black areas on its dark red body, and *Heterospilus* is usually uniformly reddish-yellow. Another distinction which is sometimes useful in identifying darker males of the latter species is the presence of conspicuous stigmata on the hind wings.

Adult female *Urosigalphus* and *Glyptocolastes* were often observed in the field parasitizing grubs within green or brown klu pods, but rarely attacked grubs within brown seeds under laboratory conditions. Counts of exit holes in 3,066 seeds collected on leeward Oahu during 1958 and 1959 suggested that the total parasitaization of *M. sallaei* by *Urosigalphus* and *Glyptocolastes* was approximately 31 per cent. In Hawaii, *Urosigalphus* apparently parasitizes not only the four bruchids infesting kiawe, *A. prosopis*, *M. amicus*, *M. sallaei* and *C. gonagra*, but also *Callosobruchus chinensis*. Hosts of *Glyptocolastes* include, in addition to the kiawe bruchids, *Stator limbatus* and *C. chinensis*. *Heterospilus*, incidentally, has been reared from three bruchids other than those it attacks in kiawe: *Bruchus phaseoli*, *Stator pruininus* and *C. chinensis*. Extensive rearings from various legumes would presumably show that other bruchids in Hawaii are suitable hosts for one or more of the braconids.

The eulophid, *Horismenus* sp. (which apparently is not yet described), seldom parasitizes bruchids other than *M. sallaei*. It is a small (2 mm.), gregarious, and presumably internal parasite. Its development, under Hawaiian conditions, usually took from 4 to 7 weeks, sometimes longer. After casting their thick, black pupal exuvia, the metallic black adults emerged from a single hole in the seed. The number coming from a seed ranged from 6 to 36 and averaged about 16. The sex ratio was approximately 3 females to 1 male in most lots.

The pteromalid, *Lariophagus*, is another small (2 to 3 mm.), gregarious, but presumably external parasite. Unlike the other larval parasites of *M. sallaei*, it

readily parasitized *M. sallaei* grubs (and possibly pupae) in brown klu seeds under laboratory conditions, developing in 3 or 4 weeks. From 3 to 10 *Lariophagus* adults emerged from each seed, the average number being 8. The sex ratio was generally about 4 females to 1 male. Hawaiian and North American host records suggest that *Lariophagus* can parasitize at least three bruchids other than *M. sallaei*: *A. prosopis*, *S. pruininus* and *Callosobruchus maculatus*.

The two small larval parasites can be distinguished easily. The adult *Lariophagus* has darker femora and is usually larger than *Horismenus*. Also, a *Lariophagus* female has a more pointed abdomen and a longer ovipositor. Counts of exit holes in klu seeds collected on leeward Oahu during 1958 and 1959 suggested that the combined parasitization of *M. sallaei* by *Horismenus* and *Lariophagus* was about 17 per cent.

A very interesting, but even less important, source of mortality was *Eupelmus cushmani*. This eupelmid wasp has an unusually wide host range. In Hawaii, it not only attacks anthribids, bruchids and curculionids but also has been reared from larvae of the wasp, *Bracon terryi* (Bridwell), and the fly, *Procecidochares utilis* Stone (Bess and Haramoto, 1959), as well as pupae of a coleophorid moth, *Agonoxena argaula* Meyrick, and (? hymenoptera in) mantid eggs (Weber, 1957).

Eupelmus develops as a solitary external parasite and spins no cocoon. Length of development seemed to be quite variable but may have been as short as 3 weeks when the larvae were feeding on grubs of *M. sallaei*. In dissections, the fuscous pupal fragments of *Eupelmus* were found within braconid cocoons, confirming the hyperparasitic habit noted by Bess and Haramoto (1959). The eupelmid also attacked *M. sallaei* pupae, sometimes unsuccessfully. The large (6 mm.) female could be separated from other members of the parasite complex by its elongate form and white-ringed ovipositor. The smaller (2 to 3 mm.) male might have sometimes been confused with *Horismenus* but could usually be identified by the greater length of its antennae and the metallic green coloration of its body. Rearings from klu pods collected in the vicinity of Honolulu during 1958 and 1959 indicated that parasitization of *M. sallaei* by *Eupelmus* was usually less than 0.5 per cent.

It has already been noted that the destruction of klu seeds by competitors often led to the starvation of early instar *M. sallaei* grubs. Occasionally, however, competitive mortality was more direct. A lepidopterous larva within the same pod or another grub within the same seed sometimes came in contact with a *M. sallaei* grub, wounding it fatally. There was no evidence of "combat" or "cannibalism".

Adult: Teneral adults of *M. sallaei* were occasionally parasitized by the mite, *Pyemotes boylei* Krczal. This is the species that attacks all stages of *A. levipennis* and which was recorded as "*Pyemotes* (=*Pediculoides*) *ventricosus* (Newport)" by Sherman and Tamashiro (1956). The pyemotid female usually entered a klu seed through the crack made by a bruchid chewing out an exit in the seed coat. It developed as a sedentary ectoparasite, paralyzing the beetle and becoming en-

gorged. After a developmental period lasting about one week, a few male and more than a hundred female nymphs usually emerged from the abdomen of each gravid mite.

Adults of *M. sallaei* undoubtedly succumbed to the attack of various predators, although this was hard to observe in the field. The reduviid bug, *Zelus renardii* Kolenati, a known bruchid eater, was sometimes seen on klu bushes. Webs of spiders such as *Argiope* sp. and ootheca of mantids, *Tenodera* sp., were observed frequently. Finally, *M. sallaei* has been recovered from the crop of a California Quail in Hawaii (Swezey, 1937) although this may have been incidental to quails feeding on klu seeds.

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