Diet of *Chamaeleo jacksonii* (Squamata: Chamaeleonidae) in a dry forest on Maui

Hawaii Biological Survey

Final Report

March 2010

FINAL REPORT

Diet of *Chamaeleo jacksonii* (Squamata: Chamaeleonidae) in a dry forest on Maui

Prepared for:
Hawaii Cooperative Studies Unit
Pacific Aquaculture Coastal Resources Center
University of Hawaii, Hilo

Prepared by:
Fred Kraus and David Preston
Hawaii Biological Survey
Bishop Museum
Honolulu, HI 96817

March 2010
Contribution No. 2010-010 to the Hawaii Biological Survey

Diet of *Chamaeleo jacksonii* (Squamata: Chamaeleonidae) in a dry forest on Maui

Introduction

Chamaeleo jacksonii is a medium-sized (snout-vent length up to ~160 mm) arboreal lizard of the family Chamaeleonidae that is native to the humid and wet uplands of Kenya and Tanzania (Eason et al., 1988). It is ovoviviparous, females give birth to 7–51 young (Nečas, 1999), and the species has a potentially high intrinsic population growth rate.

This lizard was released in Hawaii in the early 1970s (McKeown, 1996), and it brings to Hawaii a novel feeding strategy and mechanism to which native species are naive. No diurnal vertebrate ambush predator existed in Hawaii prior to the introduction of this species, and no other animal has the protrusive feeding mechanism that allows prey to be captured at some considerable remove from the predator itself. Consequently, native Hawaiian animals are expected to be highly susceptible to predation by chameleons. Because these lizards can occur at high population densities in Hawaii (FK, pers. obs.), there is concern about the possible conservation impacts that will result as this species expands its range in Hawaii. To begin to assess that impact we provide here a quantitative investigation of prey items consumed by a population released into native dry forest on Maui. Taken together with ecological information from congeners, this allows for an assessment of the likely conservation impact from this lizard in Hawaii.

Materials and Methods

We obtained dietary information from a sample of 34 lizards collected from Auwahi (n = 32), Waikapu Valley (n = 1), and Pukalani (n = 1), Maui. Animals were frozen within a few hours of collection in order to terminate digestion, were transferred to Bishop Museum, fixed in 10% buffered formalin, and stored in 65% ethanol. Digestive tracts were removed from specimens, opened, their contents removed, and these contents sorted by taxon, identified to the lowest taxonomic level possible, and counted under a binocular dissecting scope. Estimated numbers of dietary items are minima and were determined by comparing whole specimens (when present) or diagnostic fragments to authoritatively identified specimens in the Bishop Museum entomology collections. The bulk of removed contents comprised fully to partially digested and disarticulated arthropod prey items mixed with some mashed plant material and other unidentifiable debris. We identified these items by segregating, morpho-sorting, and counting recognizable structures like head capsules, legs, wings, mouth parts, elytra, etc. We then matched these structures to intact specimens in the entomology collections and counted the numbers of individuals for each identified taxon. Because the same individual prey item would be digested into multiple parts, these parts were counted separately and the total number of individuals/taxon was determined by choosing the identifiable part with the highest count. For example if there were 20 pair of elytra from species A but only 5 legs, the total count for sp. A would be 20.

For dietary items that we could identify to species or to a set of very similar species, we estimated prey-volume by (1) measuring from the entomology collection at the Bishop Museum the maximum body length, width, and height (to the nearest 0.05 mm) of ten specimens of the consumed species; (2) averaging these sample body measurements; (3) using these averages to calculate an average volume for each prey species using the equation for a scalene ellipsoid (V=4/3πabc, where a, b, and c are the three body axes); and (4) multiplying those species-averaged volumes by the relevant number of dietary items identified within each stomach to estimate the food volume for each lizard. For the one species of ant recovered, we measured sizes of worker and soldier ants separately. For dietary items that we could not identify to species, we measured the dimensions of the consumed items directly, when numbers were small, or measured a sample of ten individuals and followed the procedure above. The benefit of measuring whole specimens of identified species from the entomology collection is that it provides a more accurate measure of prey volume than estimating the same from partially digested fragments of prey. Only 34 of 1420 prey items were so poorly resolved taxonomically and so fragmented by digestion that we could not obtain volume estimates for them. Taxonomy for all identified dietary items follows Nishida (2002). All recovered and sorted material are labeled, stored in vials with 95% ethanol, and maintained in the collections of the Bishop Museum. Statistical differences were assessed with general-linear-model ANOVA and Mann-Whitney *U* tests implemented in Minitab 14.

Results

A total of 1420 dietary items from 47 taxa was retrieved from our sample of lizards. Twenty-seven of these dietary taxa were identified to species, 11 to genus, and nine to family. This comprised 41.2% of dietary items that were identified to species, 48.9% to genus, 9.1% to family, and 0.8% unidentified at any level.

All chameleons but the one from Pukalani had food items in their digestive tracts (97.1%); all food items were arthropods. Numbers of food items/chameleon ranged from 0–352 (mean = 41.8, SD = 10.41). For stomachs containing food, numbers of prey species/chameleon ranged from 1–13 (mean = 5.8, SD = 0.46) and prey volumes/lizard ranged from 0.016–10.62 ml (mean = 2.3 ml, SD = 0.41). For stomachs containing food, numbers of prey did not differ between sexes (Mann-Whitney $U = 188.0$, $n_F = 12$, $n_M = 21$, $p = 0.56$), but prey volume did, with males containing a median of 2.49 ml of prey while females contained a median of 1.11 ml (Mann-Whitney $U = 140.0$, $n_F = 12$, $n_M = 21$, $p = 0.0175$ two-tailed). This reflects solely the larger size attained by males, with prey volume increasing with size of lizard ($F_{size} = 6.72$, $p = 0.015$; $F_{sex} = 1.06$, $p = 0.311$; $F_{size*sex} = 2.41$, $p = 0.132$; Fig. 1). The largest prey items were 55 mm in length; however, most prey were of small size (Fig. 2).

Most prey items were adventive or intentionally introduced alien species, but a significant portion was endemic (range = 0–79 items, mean = 14.7, SD = 3.08; volume range = 0–7.60 ml, mean = 0.30 ml, SD = 0.229). Numbers of endemic prey did not differ between sexes (Mann-Whitney $U = 221.5$, $n_F = 12$, $n_M = 21$, $p = 0.52$), nor did volumes of endemic prey (Mann-Whitney $U = 211.5$, $n_F = 12$, $n_M = 21$, $p = 0.79$). The Shannon-Wiener index for identified prey items was 2.56, suggesting a fair degree of dispersion among food items at lower taxonomic levels. Food items whose provenance (endemic vs. alien) could not be determined were generally zero, but one lizard had 260 such items in its stomach; the next largest sample of items of unknown provenance in a single stomach was ten.

Analyzed taxonomically, dipterans comprised the greatest numbers of prey items (Table 1), followed by homopterans and coleopterans. Together, these taxa formed 92.1% of all dietary items. Endemic Hawaiian taxa comprised 35.2% of dietary items, adventive aliens comprised 35.7%, intentionally introduced aliens comprised 8.7%, and taxa whose provenance could not clearly be identified comprised 20.4%. The large majority of endemic insects consumed at Auwahi were homopterans of the genera *Nesophrosyne* and *Oliarus* (Table 2), but a few other native species were taken as well. One specimen from Waikapu Valley contained two *Megalagrion blackburni* damselflies.

When analyzed by volume, however, the results are rather different. In that case, dipterans were still important (33.3% of prey volume), but heteropterans comprised an even larger volume of food (42.5%) and native odonates formed the third-largest volume (9.9%). Adventive aliens comprised 80.5% of food items by volume, endemic species comprised 13.0%, intentionally introduced aliens comprised 6.3%, and taxa whose provenance could not clearly be identified comprised 0.22%.

Few shared attributes among prey are evident except that most are fairly active inhabitants of trees and shrubs.

Discussion

Diet. In terms of numbers of individuals, dipterans and homopterans were the most prevalent dietary items in this study, whereas heteropterans and dipterans were the most common dietary items volumetrically. Other studies have also found insects to predominate in chameleon diets, but the taxa comprising dominant dietary items can vary geographically (e.g., Blasco et al., 1985; Burmeister, 1989; Luiselli and Rugiero, 1996; Pleguezuelos et al., 1999), seasonally (Burrage, 1973; Pleguezuelos et al., 1999), or ontogenetically (Keren-Rotem et al., 2006), it seems likely that at least some species of chameleons are opportunistically eating whatever is readily to hand. Our results for *C. jacksonii* are consistent with that interpretation: our Shannon-Wiener index of niche breadth is rather broad at the species/genus level, and all dietary items were active inhabitants of trees and shrubs. Further, it is known that *C. jacksonii* will eat additional prey items (e.g., snails, cf. Holland et al., 2009) not detected in the present study. Hence, it seems likely that *C. jacksonii* is rather opportunistic in its feeding habits, although a certain degree of prey discrimination is not precluded.

We found a much higher number of food items in individual stomachs than have been recorded in previous studies of chameleons. We found a mean of 41.8 dietary items/stomach, with a range from 0–352, whereas other studies have found lower means of 14 and 23.5 (range 5–74) for *C. africanus* and *C. chamaeleon*, respectively (Pleguezuelos et al., 1999; Dimaki et al., 2001). Coupled with this observation is the unexpectedly small sizes of most prey items, the large majority of which were of less than 12 mm size in the longest dimension, with the modal size half that (Fig. 2). This preponderance of small prey is similar to, but more extreme than, results obtained for *C. chamaeleon* (Pleguezuelos et al., 1999), and it is perhaps unexpected for an animal that can clearly capture and consume very large prey.

Our results suggest a high cropping rate on local insects. Studies on other *Chamaeleo* species (Burrage, 1973) indicate that they take between 3–15 meals/day and digest those meals in 2–5 hr, except for the last meal of the day, which is held until defecated the following morning (~12 hr). There is no reason to expect *C. jacksonii* to deviate from this general pattern of frequent feeding and quick digestion, the latter of which is supported by the uniformly high rate of prey maceration seen in our samples. If prey represented a mix of divergent capture times, we would have expected to see a greater range of prey-preservation quality instead. Hence, it seems reasonable to assume that each stomach's contents represent only a portion of a single day's predation success.

Conservation implications. Chamaeleo jacksonii has a wide diet and appears to opportunistically eat most invertebrate species that happen to present themselves. We failed to find vertebrates in the stomachs examined by us, but other species of similar-sized chameleons are known to eat them (Burrage, 1973; Luiselli and Rugiero, 1996; Keren-Rotem et al., 2006), and larger species will eat adult passerines (Schmidt and Inger, 1965; García and Vences, 2002), sometimes catching them on the wing (C. Raxworthy, pers. comm.). Furthermore, *C. jacksonii* is known to eat bird eggs, with many herpetoculturists using this as a food source for their pets. This, and the fact that *C. jacksonii* also consumes native landsnails (which are typically inactive diurnally) clearly indicates that although this lizard eats primarily active prey, it is capable of identifying and consuming inactive food items as well. The largest dietary item in our study (*Megalagrion blackburni*) is one of the largest native insects in Hawaii, so it seems that few, if any, native arboreal invertebrates will be immune to predation by virtue of their size. In conclusion, most arboreal native animals within this lizard's potential range will be liable to some form of predation pressure. This includes a variety of invertebrate species already officially recognized as endangered (e.g., *Achatinella*, cf. Holland et al., 2009; *Megalagrion*, this study) and others that are biologically endangered but not officially recognized (e.g., *Auriculella*, cf. Holland et al., 2009). Native passerines may be affected as well, primarily via egg or nestling predation, but direct evidence of that remains to be found.

Further research is required is to quantify cropping pressures exerted by chameleons. Evidence is currently circumstantial but suggests that predation pressures will be high. First, *C. jacksonii* probably consumes several meals/day, as do its only two relatives that have been studied (Burrage, 1973). Second, each meal can comprise a large number (up to 352 prey items) or volume (up to 10.6 ml) of prey. Third, preliminary evidence indicates these lizards can occur at high densities: one informal census found 173 chameleons in 0.2 ha area of dense mesic vegetation in one day (F. Duvall, pers. comm.). Taken together, these lines of evidence suggest that *C. jacksonii* is capable of exerting high predation pressure on a diversity of native invertebrates in Hawaii and possibly on some of the native passerines. The exact degree of pressure will, of course, depend on the population size of each targeted prey species and the population densities achieved in native forests by the chameleons. These quantifications would be a worthwhile avenue of further research.

Literature Cited

Blasco, M., J. Romero, J.M. Sánchez, and E. Crespillo. 1985. La biología alimentaria y reproductiva del camaleón común, *Chamaeleo chamaeleon* (L.). (Reptilia, Chamaeleonidae) de la Península Ibérica y norte de Africa. Monografías ICONA 43: 121–148.

Burmeister, E.G. 1989. Eine Walzenspinne (Solifugae, Galeodidae) als Nahrung des Gemeinen Chamäleons (*Chamaeleo chamaeleon* Linnaeus, 1758). Herpetofauna (Wien) 11: 32–34.

Burrage, B.R. 1973. Comparative ecology and behaviour of *Chamaeleo pumilus pumilus* (Gmelin) and *C. namaquensis* A. Smith (Sauria: Chamaeleonidae). Annals of the South African Museum 61: 1–158.

Dimaki, M., E. D. Valakos, A. Legakis, B. Chondropoulos, and A. Bonetti. 2001. Preliminary results on the feeding ecology of the African chameleon *Chamaeleo africanus* Laurenti, 1768 from the southwestern Peloponnese, Greece. Pp. 57–63 *in* Lymberakis, P., E. Valakos, P. Pafilis, and M. Mylonas (eds.), Herpetologia Candiana. Societas Europaea Herpetologica, Irakleio, Greece.

Eason, P., G.W. Ferguson, and J. Hebrard. 1988. Variation in *Chamaeleo jacksonii* (Sauria, Chamaeleontidae): description of a new subspecies. Copeia 1988: 580–590.

García, G., and M. Vences. 2002. Natural history notes: *Furcifer oustaleti*: diet. Herpetological Review 33: 134–135.

Holland, B.S., S.L. Montgomery, and V. Costello. 2009. A reptilian smoking gun: first record of invasive Jackson's chameleon (*Chamaeleo jacksonii*) predation on native Hawaiian species. Biodiversity and Conservation DOI 10.1007/s10531-009-0773-5.

Keren-Rotem, T., A. Bouskila, and E. Geffen. 2006. Ontogenetic habitat shift and risk of cannibalism in the common chameleon (*Chamaeleo chamaeleon*). Behavioral Ecology and Sociobiology 59: 723–731.

Luiselli, L., and L. Rugiero. 1996. Natural history notes: *Chamaeleo chamaeleon*: diet. Herpetological Review 27: 78–79.

McKeown, S. 1991. Jackson's chameleons in Hawaii are the recently described Mt. Kenya subspecies, *Chamaeleo jacksonii xantholophus*. Bulletin of the Chicago Herpetological Society 26: 49.

McKeown, S. 1996. A field guide to reptiles and amphibians in the Hawaiian Islands. Diamond Head Publishing, Inc., Los Osos, CA.

Nečas, P. 1999. Chameleons – nature's hidden jewels. Edition Chimaira, Frankfurt am Main, Germany.

Nishida, G. M. (ed.). 2002. Hawaiian Terrestrial Arthropod Checklist. 4th Edition. Bishop Museum Technical Report No. 22,. 313 pp. [http://hbs.bishopmuseum.org/hbsdb.html]

Pleguezuelos, J.M., J.C. Poveda, R. Monterrubio, and D. Ontiveros. 1999. Feeding habits of the common chameleon, *Chamaeleo chamaeleon* (Linnaeus, 1758) in the southeastern Iberian Peninsula. Israel Journal of Zoology 45: 267–276.

Schmidt, K.P., and R.F. Inger. 1965. Living reptiles of the world. Hamilton, London.

Table 1. Composition of food items in diets of 34 *Chamaeleo jacksonii* from Maui.

ORDER	FAMILY	# PREY ITEMS	% PREY ITEMS	% PREY VOLUME
Araneae		**16**	**1.13**	**1.51**
	Araneidae	1	0.07	0.33
	Salticidae	3	0.21	1.15
	unknown	12	0.85	0.03
Blattodea		**15**	**1.06**	**1.42**
	Blattelidae	15	1.06	1.42
Coleoptera		**207**	**14.57**	**6.17**
	Coccinellidae	119	8.38	5.71
	Curculionidae	2	0.14	0.07
	Dermestidae	1	0.07	0.00
	Elateridae	5	0.35	0.34
	Staphylinidae	73	5.14	0.05
	Tenebrionidae	3	0.21	0.00
	unknown	4	0.28	0.00
Diptera		**609**	**42.88**	**33.28**
	Calliphoridae	236	16.62	31.06
	Drosophilidae	4	0.28	0.01
	Ephydridae	11	0.77	0.00
	Muscidae	1	0.07	0.06
	Psychodidae	3	0.21	0.00
	Sciaridae	178	12.54	0.07
	Sphaeroceridae	65	4.58	0.02
	Syrphidae	100	7.04	1.99
	Tachinidae	2	0.14	0.04
	Tephritidae	9	0.63	0.03
Heteroptera		**39**	**2.75**	**42.49**
	Lygaeidae	2	0.14	0.01
	Pentatomidae	37	2.61	42.48

Homoptera		**492**	**34.64**	**2.38**
	Cicadellidae	201	14.15	1.14
	Cixiidae	290	20.42	1.24
	Membracidae	1	0.07	0.00
Hymenoptera		**24**	**1.69**	**0.93**
	Apidae	2	0.14	0.46
	Formicidae	17	1.20	0.01
	Ichneumonidae	1	0.07	0.11
	Sphaecidae	3	0.21	0.15
	Vespidae	1	0.07	0.20
Lepidoptera		**8**	**0.56**	**1.59**
	Gracillariidae	4	0.28	0.01
	Nymphalidae	4	0.28	1.58
Neuroptera		**1**	**0.07**	**0.13**
	Chrysopidae	1	0.07	0.13
Odonata		**2**	**0.14**	**9.95**
	Coenagrionidae	2	0.14	9.95
Isopoda		**7**	**0.49**	**0.12**
	Porcellionidae	7	0.49	0.12
TOTAL		**1420**	**100.00**	**100.00**

Table 2. Endemic Hawaiian insects comprising dietary items in a sample of 34 *Chamaeleo jacksonii* from Maui.

ORDER	FAMILY	SPECIES	# PREY ITEMS	% PREY ITEMS	% PREY VOLUME
Heteroptera	Lygaeidae	*Nysius* sp.	2	0.13	0.01
Heteroptera	Pentatomidae	*Coleoticus blackburniae*	1	0.07	0.42
Homoptera	Cicadellidae	*Nesophrosyne* sp.	199	13.42	1.14
Homoptera	Cixiidae	*Oliarus* sp.	291	19.61	1.24
Hymenoptera	Ichneumonidae	*Echthromorpha agrestoria*	1	0.07	0.11
Lepidoptera	Gracillariidae	*Philodoria* sp.	4	0.27	0.01
Neuroptera	Chrysopidae	*Anomalochrysa* sp.	1	0.07	0.13
Odonata	Coenagrionidae	*Megalagrion blackburni*	2	0.13	9.95

Fig. 1. Regressions of prey volumes against body size for male (open circles) and female (closed circles) *Chamaeleo jacksonii*.

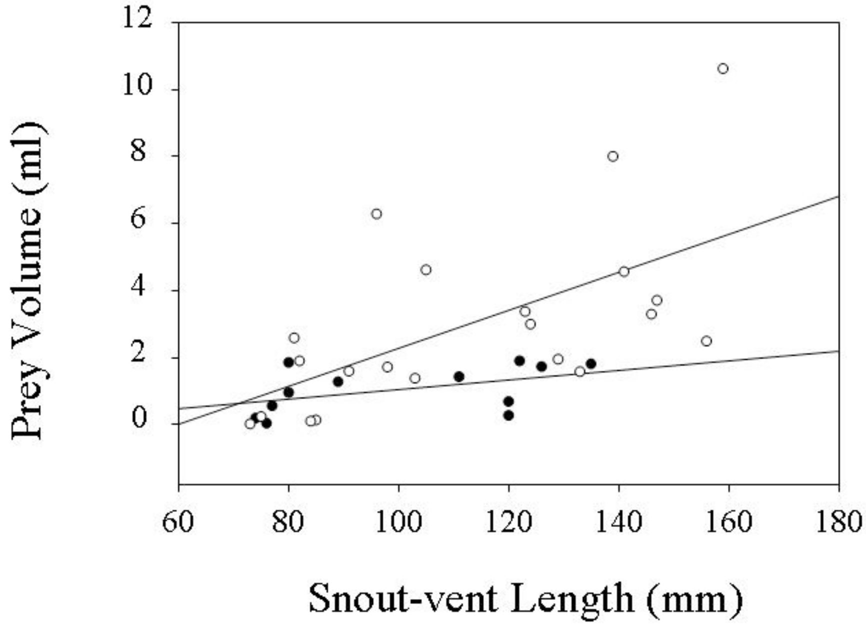
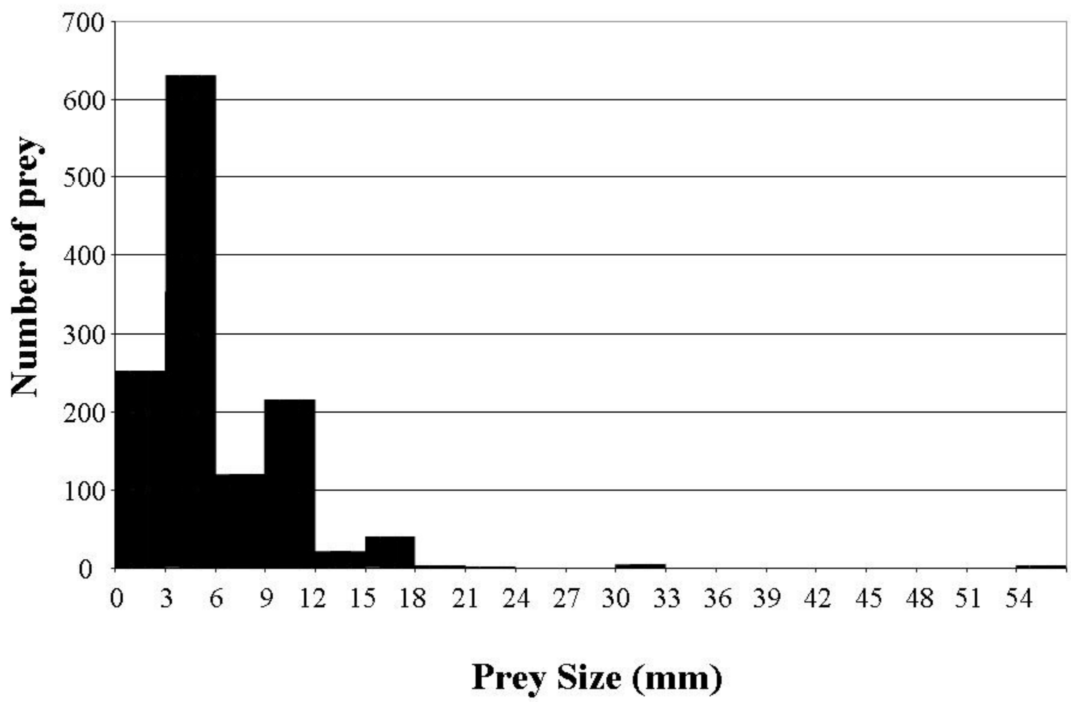


Fig. 2. Size distribution of prey retrieved from 33 *Chamaeleo jacksonii* on Maui. n = 1386 measurable prey items.



Appendix I. Stomach contents of individual chameleons.

Lizard				Prey				
Specimen	**Locality**	**Size (mm)**	**Sex**	**Order**	**Family**	**Species**	**Status in Hawaii**	**Numbers eaten**
FK 12093	Auwahi	120	F	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	3
				COLEOPTERA	Elateridae	Conoderus exsul	adventive	2
				DIPTERA	Calliphoridae	Unknown	adventive	9
				DIPTERA	Tachinidae	Unknown	adventive	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	1
FK 12094	Auwahi	77	F	ARANEAE	Salticidae	Phidippus audax (Hentz, 1845)	adventive	1
				COLEOPTERA	Dermestidae	Trogoderma anthrenoides (Sharp, 1902)	adventive	1
				DIPTERA	Muscidae	Unknown	unknown	1
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	13
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	6
FK 12095	Auwahi	76	F	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	1
				DIPTERA	Tephritidae	Eutreta xanthochaeta Aldrich, 1923	purposely introduced	1
				HOMOPTERA	Cicadellidae	Unknown	unknown	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	2
FK 12096	Auwahi	123	M	BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	2
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	3
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	2
				DIPTERA	Calliphoridae	Unknown	adventive	3
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	7
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	3
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	14
FK 12097	Auwahi	74	F	DIPTERA	Calliphoridae	Unknown	adventive	3
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	6
				HOMOPTERA	Cicadellidae	Nesophrosyne sp.	endemic	4
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	3

Specimen	Locality	Size (mm)	Sex	Order	Family	Species	Status in Hawaii	Numbers eaten
FK 12098	Auwahi	80	F	COLEOPTERA	Coccinellidae	Curinus coeruleus (Mulsant, 1850	purposely introduced	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	6
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	2
				DIPTERA	Calliphoridae	Unknown	adventive	6
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	9
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	51
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	7
FK 12099	Auwahi	80	F	HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	19
FK 12101	Auwahi	129	M	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	4
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	2
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	8
FK 12102	Auwahi	111	F	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	4
				COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	2
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	17
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	8
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	9
FK 12103	Auwahi	75	M	COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	3
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	24
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	5
FK 12104	Auwahi	146	M	COLEOPTERA	Coccinellidae	Cryptolaemus montrouzieri Mulsant, 1853	purposely introduced	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	6
				DIPTERA	Calliphoridae	Unknown	adventive	7
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	4
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	3
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	11
				LEPIDOPTERA	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	adventive	1
FK 12105	Auwahi	147	M	ARANEAE	Salticidae	Phidippus audax (Hentz, 1845)	adventive	1

Specimen	Locality	Size (mm)	Sex	Order	Family	Species	Status in Hawaii	Numbers eaten
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	7
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	3
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	3
				HOMOPTERA	Cicadellidae	Nesophrosyne sp.	endemic	1
				LEPIDOPTERA	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	adventive	1
FK 12106	Auwahi	105	M	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	3
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	7
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	4
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	18
				HYMENOPTERA	Ichneumonidae	Echthromorpha agrestoria (Fabricius, 1781)	endemic	1
FK 12107	Auwahi	120	F	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	3
				DIPTERA	Ephydridae	Scatella sp. 2	unknown	6
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	47
FK 12108	Auwahi	103	M	BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	1
				COLEOPTERA	Coccinellidae	Curinus coeruleus (Mulsant, 1850	purposely introduced	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	1
				DIPTERA	Tephritidae	Eutreta xanthochaeta Aldrich, 1923	purposely introduced	1
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	66
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	13
FK 12109	Auwahi	89	F	ARANEAE	Unknown	Unknown	unknown	1
				BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	1
				COLEOPTERA	Coccinellidae	Curinus coeruleus (Mulsant, 1850	purposely introduced	1
				COLEOPTERA	Tenebrionidae	indet. sp.	adventive	1
				DIPTERA	Calliphoridae	Unknown	adventive	4
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	16
				ISOPODA	Porcellionidae	Porcellio laevis Latreille, 1804	adventive	1

Specimen	Locality	Size (mm)	Sex	Order	Family	Species	Status in Hawaii	Numbers eaten
FK 12110	Auwahi	85	M	COLEOPTERA	Staphylinidae	indet. sp. 1	unknown	6
				COLEOPTERA	Staphylinidae	indet. sp. 2	unknown	67
				DIPTERA	Drosophilidae	Drosophila sp.	adventive	4
				DIPTERA	Ephydridae	Scatella sp.1	unknown	1
				DIPTERA	Ephydridae	Scatella sp. 2	unknown	2
				DIPTERA	Psychodidae	Psychoda sp.	adventive	3
				DIPTERA	Sciaridae	c.f. Bradysia sp.	unknown	178
				DIPTERA	Sphaeroceridae	Letocera abdominiseta (Duda,1925)	adventive	65
				DIPTERA	Tephritidae	Unknown	unknown	6
				HETEROPTERA	Lygaeidae	Nysius sp.	endemic	2
				HOMOPTERA	Membracidae	Vanduzeae segmentata (Fowler, 1895)	adventive	1
				HYMENOPTERA	Formicidae	Pheidole megacephala (Fabricius, 1793)	adventive	17
FK 12111	Auwahi	73	M	DIPTERA	Calliphoridae	Unknown	adventive	3
				HOMOPTERA	Cicadellidae	Unknown	unknown	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	5
FK 12112	Auwahi	126	F	ARANEAE	Salticidae	Unknown	unknown	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	2
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	3
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	3
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	17
				LEPIDOPTERA	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	adventive	1
FK 12113	Auwahi	98	M	COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	3
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	6
				DIPTERA	Ephydridae	Scatella sp. 2	unknown	2
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	1
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
FK 12114	Auwahi	91	M	ARANEAE	Unknown	Unknown	unknown	6
				COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	1
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	5

Specimen	Locality	Size (mm)	Sex	Order	Family	Species	Status in Hawaii	Numbers eaten
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	8
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	13
				LEPIDOPTERA	Gracillariidae	Philodoria sp.	endemic	4
FK 12115	Auwahi	81	M	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	3
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	12
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	8
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	20
FK 12117	Auwahi	84	M	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	3
FK 12118	Auwahi	156	M	COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	2
				DIPTERA	Calliphoridae	Unknown	adventive	7
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	12
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	2
				HYMENOPTERA	Vespidae	Vespula pensylvanica (Saussure, 1857)	adventive	1
				LEPIDOPTERA	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	adventive	1
FK 12119	Auwahi	133	M	COLEOPTERA	Curculionidae	Asynonychus godmanni Crotch, 1867	adventive	2
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	13
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	3
				ISOPODA	Porcellionidae	Porcellio laevis Latreille, 1804	adventive	1
FK 12120	Auwahi	135	F	COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	2
				COLEOPTERA	Elateridae	Conoderus exsul	adventive	3
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	12
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	6
				HYMENOPTERA	Apidae	Apis mellifera (Linnaeus, 1758)	purposely introduced	1
FK 12184	Pukalani	130	F	EMPTY	Empty	EMPTY		0
FK 12185	Auwahi	96	M	ARANEAE	Unknown	Unknown	unknown	1
				BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	8
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	10

Specimen	Locality	Size (mm)	Sex	Order	Family	Species	Status in Hawaii	Numbers eaten
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	38
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	13
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	28
				ISOPODA	Porcellionidae	Porcellio laevis Latreille, 1804	adventive	3
FK 12186	Auwahi	159	M	COLEOPTERA	Tenebrionidae	indet. sp.	adventive	2
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	92
				ISOPODA	Porcellionidae	Porcellio laevis Latreille, 1804	adventive	1
FK 12187	Waikapu	139	M	ARANEAE	Unknown	Unknown	unknown	4
				BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	2
				COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	1
				COLEOPTERA	Unknown	indet. Family sp. A	unknown	4
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	7
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	6
				HYMENOPTERA	Sphecidae	Ampulex compressa (Fabricius, 1881)	purposely introduced	1
				HYMENOPTERA	Sphecidae	sp. nr. Dolichurus stantoni (Ashmead, 1904)	unknown	2
				ODONATA	Coenagrionidae	Megalagrion blackburni McLachlan, 1883	endemic	2
FK 12188	Auwahi	82	M	COLEOPTERA	Coccinellidae	Azya orbigera Mulsant, 1850	adventive	2
				COLEOPTERA	Coccinellidae	Curinus coeruleus (Mulsant, 1850	purposely introduced	1
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	1
				DIPTERA	Tephritidae	Eutreta xanthochaeta Aldrich, 1923	purposely introduced	1
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	2
FK 12189	Auwahi	124	M	BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	3
				COLEOPTERA	Coccinellidae	Coelophora inequalis (Fab., 1775)	purposely introduced	1
				DIPTERA	Tachinidae	Unknown	adventive	1
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	3
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	8
FK 12190	Auwahi	122	F	ARANEAE	Araneidae	Gasterachantha cancriformis (Linnaeus, 1758)	adventive	1

Specimen	Locality	Size (mm)	Sex	Order	Family	Species	Status in Hawaii	Numbers eaten
				BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	4
				COLEOPTERA	Coccinellidae	Coelophora inequalis (Fab., 1775)	purposely introduced	1
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	2
				DIPTERA	Calliphoridae	Chrysosoma megacephala (Fabricius, 1774)	adventive	2
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	7
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	1
FK 12191	Auwahi	141	M	BLATTODEA	Blattellidae	Balta similis (Saussure, 1869)	adventive	2
				COLEOPTERA	Coccinellidae	Coelophora inequalis (Fab., 1775)	purposely introduced	3
				COLEOPTERA	Coccinellidae	Curinus coeruleus (Mulsant, 1850	purposely introduced	2
				COLEOPTERA	Coccinellidae	Olla v-nigrum (Mulsant, 1866)	purposely introduced	8
				COLEOPTERA	Coccinellidae	Orcus australasiae (Boisduval, 1835)	purposely introduced	12
				DIPTERA	Syrphidae	Allograpta obliqua (Say, 1823)	adventive	1
				HETEROPTERA	Pentatomidae	Coleoticus blackburniae White, 1881	endemic	1
				HETEROPTERA	Pentatomidae	Nezara viridula (Linnaeus, 1758)	adventive	3
				HOMOPTERA	Cicadellidae	Nesophrosyne spp.	endemic	4
				HOMOPTERA	Cixiidae	Oliarus spp.	endemic	25
				HYMENOPTERA	Apidae	Apis mellifera (Linnaeus, 1758)	purposely introduced	1
				ISOPODA	Porcellionidae	Porcellio laevis Latreille, 1804	adventive	1
				NEUROPTERA	Chrysopidae	Anomalochrysa sp.	endemic	1
					Total			1420