DISTRIBUTION AND VARIATION OF ACHATINELLA MUSTELINA MIGHELS IN THE WAIANAE MOUNTAINS, OAHU

BY
D'ALTE A. WELCH

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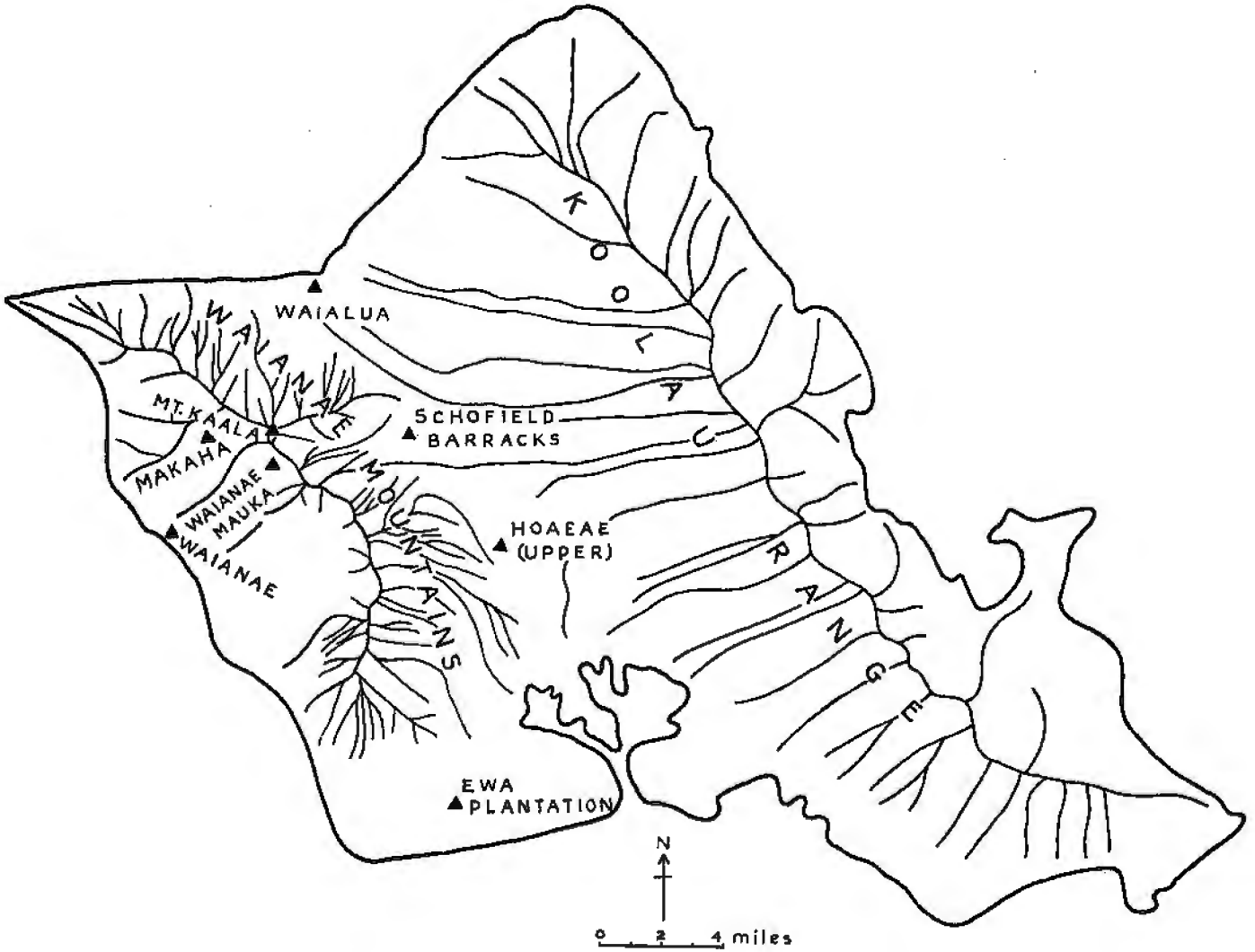
TABLE OF CONTENTS



Map A.—Island of Oahu with location of rain gauge stations plotted in the Waianae Mountain region.

Distribution and Variation of Achatinella mustelina Mighels in the Waianae Mountains, Oahu*

By D'ALTÉ A. WELCH

INTRODUCTION

HISTORICAL

A single valley on Oahu may contain a number of different color races of tree shells of the genus *Achatinella*. A locality may contain shells of one particular pattern, while a neighboring locality in the same valley may have a mixture of one or more kinds. Do these color patterns occur in definite places at random, or are they arranged according to a definite plan? Is it possible to ascribe this variation to any probable cause?

Early collectors and students of land shells up to 1850 were interested in new species rather than in the localities from which they came. They gave their specimens general place names such as "Sandwich Islands", "Oahu", or "Molokai." Pilsbry and Cooke have presented a very complete account of the historical background of *Achatinella* (5)[1]. About 1850, John Gulick made a great advance in the work by carefully noting the valleys from which his shells came, and in so doing, he noted that shells from different valleys varied in color pattern. Dr. C. M. Cooke, Jr. carried the work further by giving more detailed locality citations. Under his stimulus, a number of fine collections were built up, all carefully annotated, which formed the foundation for Pilsbry and Cooke's work on this genus (5). In this volume, Pilsbry states:

> In the typical group of *Achatinella* (*Apex*), a certain correlation seems to exist between pattern and elevation, banded forms occupying higher situations than streaked forms of the same species, at least in many cases. I believe that the relation is an indirect one. Banded patterns have been evolved from streaked, as stated on p. xx; evolution in more humid stations would naturally be more rapid than in lower, less abundantly watered places, since resting periods would be shorter, and the succession of generations would be faster.

A study of his discussion of *A. apexfulva* (5, pp. 321-330, map, p. 277) shows that on one or more ridges in the Koolau Range, different color races occur on different parts of the ridge or at different elevations. Whether this

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* Submitted to the Board of University Studies of Johns Hopkins University in conformity with the requirements for the Ph.D. degree.

[1] Numbers in parentheses refer to Literature Cited, p. 154.

was purely a random or a constant differentiation due to or occurring at different elevations could not then be determined due to lack of material.

When my work began in 1931, little further advance had been made, because there were little or no accurately plotted data concerning these shells or their localities in any museum, to my knowledge, with the exception of a few lots from localities in the district of Mokuleia, plotted on rough outline maps by Dr. Cooke. Before 1931, no suitable map of Oahu was available to collectors on which to plot localities easily. In 1931, I procured a set of advanced sheets of the United States Geological Survey of Oahu through the kindness of Mr. C. S. Judd, Territorial Forester, to use in field work. Another set of maps, a gift of Mr. Robert King of the Territorial Survey Office to Bishop Museum, also proved invaluable to me.

The first plotted collection of *Achatinella* was formed in 1932 by G. W. Russ, then Assistant Forester on Oahu. The collection is particularly rich in shells from the northern section of the Waianae Mountains and is the foundation of this paper. Soon after this collection was plotted, the W. Meinecke collection was received by Bishop Museum, and was plotted by Mr. Meinecke. Later, Dr. Cooke plotted his Waianae Mountain localities.

Since the plotting of the Museum's three major collections still left the picture of the distribution of *Achatinella* incomplete as far as the Waianae Mountains were concerned, efforts were made to increase the collections. Mr. G. W. Russ, Mr. W. Meinecke, Mr. H. Lemke, Mr. H. Lemke, Jr., Marshal and Mrs. O. F. Heine, all collected large numbers of shells and gave many to Bishop Museum. Other collectors to whom I am indebted are Mr. C. S. Judd, Mr. G. P. Wilder, Mr. I. Spalding, Major and Mrs. Charles Steel, Mr. F. R. Fosberg, Mr. E. H. Bryan, Jr., Dr. Erling Christophersen, Mr. C. W. Isle, Mr. Otto Degener, Mr. E. J. Meadows, Miss Jane L. Winne, and many others. All doubtfully plotted localities were personally checked as far as possible, and their work supplemented by my own weekly trips into the field.

In addition to the highly localized material collected since 1931, the Museum collections contained many Waianae shells collected by D. D. Baldwin, E. D. Baldwin, E. Lyman, E. W. Thwing, C. M. Cooke, Jr., R. A. Cooke, W. D. Wilder, O. H. Emerson, A. F. Judd, C. S. Judd, Henry Judd, L. A. Thurston, and others.

The portion of the Gulick collection in Bishop Museum is one of the most valuable parts of the shell collection. According to Mr. Addison Gulick, it was originally divided into 20 separate collections. In 1913, Dr. Pilsbry and Dr. Cooke bought collections 5, 6, 7, 8, and 9, and divided each lot of a single species into equal halves, Dr. Cooke's portion going to Bishop Museum as a gift. Later, Mr. Addison Gulick presented Bishop Museum with collections 14 and 15. The J. S. Emerson collection also in Bishop

Museum is especially outstanding as it contains many shells collected at about the same time as many of Gulick's. Thus, many very rare shells now believed to be extinct are represented in the collection by large series.

I wish to thank Mr. W. J. Clench of the Museum of Comparative Zoology at Cambridge for allowing me to study types of *Achatinella* and to have photographs made of type specimens. I am grateful to Mr. G. C. Robson and Mr. W. T. Calman of the British Museum for similar courtesy. I am also indebted to Mr. J. R. le B. Tomlin and Colonel A. J. Peile of the British Museum for assistance they gave me while I worked there. Above all I wish to express my appreciation to Dr. C. M. Cooke, Jr. for the advice and encouragement he has given me. I am deeply indebted to Dr. H. A. Pilsbry and Dr. E. A. Andrews for advice and help towards the completion of this work. Dr. H. B. Baker, Dr. T. Sonneborn, and Dr. Gardner Lynn also aided me in completing the paper. Dr. Henry Crampton has given me many ideas concerning the value of biometrically treating distribution problems. Finally I wish to acknowledge the encouragement and support of the Trustees of Bernice P. Bishop Museum and of the Museum's successive Directors, Dr. H. E. Gregory and Dr. P. H. Buck.

Scope of the Work

The genus *Achatinella* of the Waianae Mountains is particularly adapted to the study of variation, because there are few species to be dealt with, and the shells occur in abundance in nearly every section. Because of their abundance, fairly representative samples of shells can be obtained from nearly every valley at different elevations.

The Waianae Mountains are about 20 miles long measured along the backbone or central division ridge, while most of the branch ridges have a maximum collecting area of not over two miles. The problem of collecting and studying distribution here is a comparatively simple one in comparison with the vast ridge system of the Koolau Range, which is about 50 miles in extent and has a collectable area along the numerous, long ridge systems varying from two to seven miles in distance. The tree shell fauna of the Koolau Range is much more complex, each variety having a number of color forms on a single ridge.

The main objects of investigation in this paper follow:

1. To organize as far as possible the forms of the species *Achatinella mustelina* Mighels of the Waianae Mountains, Oahu.
2. To seek answers to the following questions:
   a. Can forms of *A. mustelina* be grouped in a logical manner into subspecies following their order in nature?

b. Is there any size differentiation notable between shells collected 20 years ago and forms found in the same localities today?
c. Do forms of *A. mustelina* show evidences of migration?
d. Is there any order in the distribution of dextral and sinistral specimens?
e. Do barometrical or climatological conditions influence color pattern, with respect to shade, streakedness, and bandedness?
f. Can differences in form and color pattern be correlated with altitude, humidity, and temperature?
g. Are size differences correlated with altitude, moisture, and temperature?

Place Names

The work of distribution has been hampered up to the last five years by the lack of an accurate map on which to designate localities. The advanced sheets of the United States Geological Survey Topographic Sheets of Oahu, Hawaiian islands, 1/20,000, have been of great aid to me, but they are lacking in many place names, especially of the Waianae Mountain region. For this reason, valleys have been described by counting the number of valleys they are from a known peak or valley. This usually leads to confusion through errors of interpretation. I cannot emphasize too strongly the necessity for great accuracy in citing localities, and the importance of plotting all localities on a map to eliminate such confusion.

I have therefore availed myself of every possible authority. The Hawaiian Survey Department kindly gave me access to their manuscript maps, and I am indebted to Mr. Robert King for his assistance. I also wish to express gratitude to Mr. Louis Warren, Mr. Manuel Rodriges, Mr. Thomas McGuire, and the late Marshal Oscar P. Cox. In addition, gratitude is due Dr. E. S. C. Handy and Mr. K. P. Emory for help in obtaining place names and assistance in checking their spellings, in which respect also Mrs. E. Lahilahi Webb has been of service.

Most of the names of gulches and valleys were obtained from three informants: Jokea Kaehukalani (Pulu), an Hawaiian cowboy of the Honouliuli Ranch; Kaaimoku, an old Hawaiian who lived in the district of Kawaihapai, conceded to be the unquestioned authority for the region between Makaleha and Kaena Point; and the late Marshal Oscar P. Cox, one of the greatest authorities on native lore on the island. Another informant was Mr. Manini Silver, a native of the town of Waialua.

Next to direct information from natives, the manuscript maps of the Hawaiian Survey Department were my most valuable aids, and Mr. J. S. Emerson's maps have assisted materially in checking names given me by the

natives. I am grateful to Mr. C. H. Bischoff of the Waialua Plantation Company and to Mr. Robert Fricke of the Waianae Plantation Company for the use of their maps.

The Waianae Mountains are divided into 15 large land grants or districts which have been numbered in succession, starting with Nanakuli Valley on the southwest and continuing around the mountains in clockwise fashion to the large district of Honouliuli on the southeast (map 1).

Within the large districts are smaller ones extending over several valleys. In map 1 (p. 8), the main districts are indicated by roman numerals, while the valleys are numbered in arabic. In the following discussion, all names not published on the U. S. G. S. Topographic advanced sheets will have in brackets the names of the authorities after them. If no name for a valley can be found, the district name is used for the valley name and the main gulches divided up into north, south, east, west, or central. These main valley subdivisions are again broken up into branches, and subdivided into forks.

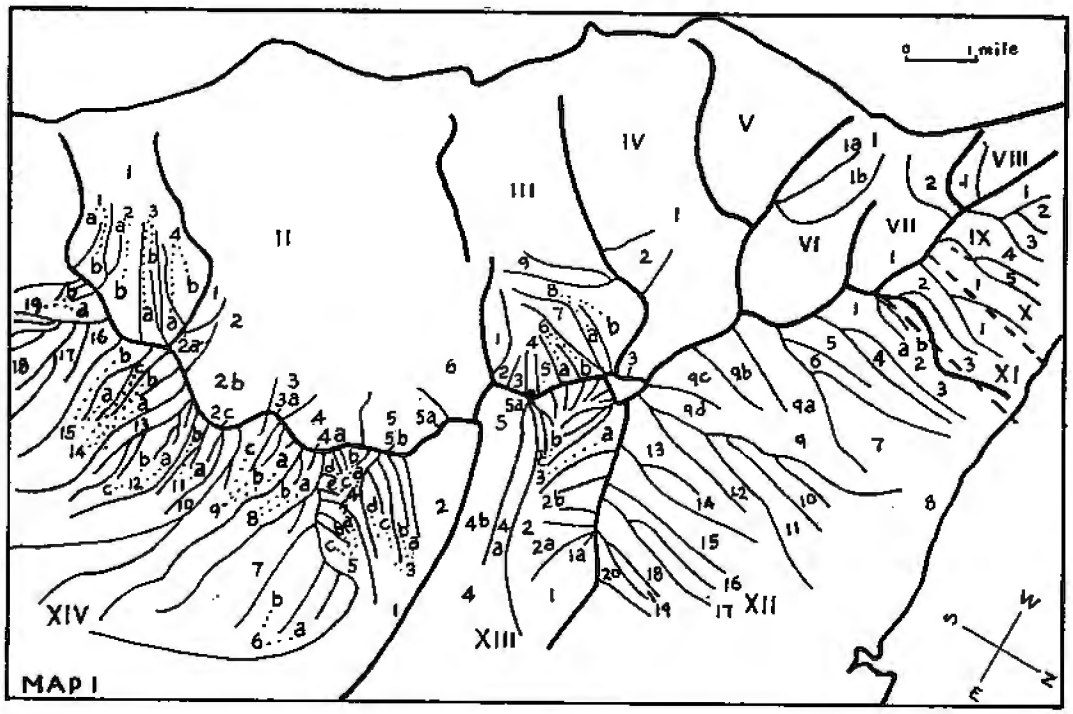
Climatological Data

The various forms of *Achatinella mustelina* in the Waianae Mountains can be grouped into three separate sections. The first or northern section includes all the region north of Kolekole Pass, and centers about the high peak of Mount Kaala, with an elevation of 4,025 feet. The second or central section covers the central portion of the mountains between Kolekole Pass and Pohakea Pass. The southern section of the Waianae Range makes up the third faunistic division, south of Pohakea Pass (map 2).

The following tables (1 and 1a) have been compiled from climatological data published by the Weather Bureau of the United States Department of Agriculture.

Table 1. Annual precipitation records in the Waianae Mountain region (map A).

Station	Elevation in feet	1933	1934	1935	Prevailing wind
Makaha	1,400	63.56	74.59	77.88	
Mount Kaala	4,000	99.81	96.03	86.66	
Waianae Mauka	1,575	63.53	71.06	75.77	
Waianae	6	20.35	15.68	18.13	
Ewa Plantation	50	18.25	17.05	21.22	N. E.
Upper Hoaeae	705	33.49	27.27	38.54	N. E.
Schofield Barracks	864	40.17	33.88	47.21	E.
Waialua Mill	30	29.14	26.20	34.84	N. E.



MAP 1.—Key map to place names in the Waianae Mountains.

I. **Nanakuli.** 1, South Nanakuli Gulch; 1a, South Branch; 1b, North Branch; 2, South Central Nanakuli Gulch; 2a, South Branch; 2b, North Branch; 3, North Central Nanakuli Gulch; 3a, South Branch; 3b, North Branch; 4, North Nanakuli Gulch; 4a, South Branch; 4b, North Branch. (Valleys subdivided by Welch.)

II. **Lualualei.** 1, Ulehawa Stream; 2, Subdistrict Halona; 2a, South Halona (Welch); 2b, North Halona (Welch); 2c, Pohakea Pass; 3, Subdistrict Pahoa; 3a, Puu Kaua; 4, Subdistrict Kaukiuhi (Alexander ms. map); 4a, Puu Kanehoa; 5, Subdistrict Mikilua; 5a, Kolekole Pass; 5b, Puu Hapapa; 6, Subdistrict Puhawai.

III. **Waianae Kai** (Waianae Valley). 1, Kawapuu Gulch; 2, Kaneamimi Gulch; 3, Kukaki Gulch; 4, Niolopua Gulch; 5, Kanewai Gulch; 6, Kalalua Gulch; 6a, South Kalalua (Welch); 6b, North Kalalua (Welch); 7, Hiu Gulch; 8, Kumaipo Gulch; 8a, South Kumaipo (Welch); 8b, North Kumaipo (Welch); 9, Punanaula Gulch. (Nine place names from map of Waianae Plantation Company.)

IV. **Makaha.** 1, Makaha Stream; 2, Kamaili (land section or subdistrict obtained from natives of Makua); 3, Mount Kaala.

V. **Keaau.** (The northwestern portion of Keaau is named Ohikilolo, but for simplification the entire district is considered Keaau.)

VI. **Makua.** 1, Koiahi Gulch; 1a, South Koiahi Gulch (Welch); 1b, North Koiahi Gulch (Welch).

VII. **Kahanahaiki.** 1, Kahanahaiki Stream (Welch); 2, Punapohaku Stream.

VIII. **Keawaula.** 1, Kaluakauila Stream.

IX. **Kuaokala (Kaena,** a district just below or north of Kuaokala is not shown on the map. The streams run through both districts.) 1, Manini Gulch; 2, Uluhulu Gulch; 3, Nihoa Gulch; 4, Keekee Gulch; 5, Haili Gulch.

X. **Kealia.** 1, Kawaiu Gulch (Kaaimoku).

XI. **Kawaihapai.** 1, Kalepeamoa Gulch; 2, Kapuhi Gulch; 3, Waikoekoe Gulch (three place names obtained from Kaaimoku).

XII. **Mokuleia.** 1, Pahole Gulch (Kaaimoku); 2, Kapuahikahi Gulch (Kaaimoku); 2a, East Kapuahikahi (Welch); 2b, West Kapuahikahi (Welch); 3, Kukuiula (lower section of Pahole Gulch according to Cox, a Gulick place name); 4, Kamimi Gulch (Kaaimoku); 5, Kapuna Gulch (Kaaimoku); 6, Keawapilau Gulch (Kaaimoku); 7, Western Subvalleys of Makaleha (Welch); 8, Kaeleku (a district on the plains below Makaleha and Kapuna Gulches, a Gulick place name) (Kaaimoku); 9, Makaleha Valley; 9a, West Makaleha Valley (Welch); 9b, Central Makaleha Valley (Welch); 9c, East Makaleha Valley West Branch; 9d, East Makaleha Valley East Branch (Welch); 10, Kaupakuhale Gulch; 11, Pamoa Gulch; 12, Kaawa Gulch; 13, Kaumokunui Gulch; 14, Kaumokuiki Gulch; 15, Manuwai Gulch (Gulches 10-15, Waialua Plantation map, Silver, Cox, Emerson maps); 16, Alaiheihe Gulch (Silver, Emerson map); 17, Kaimuhole Gulch; 18, Palikea Gulch; 19, Kihakapu Gulch; 20, Puulu Gulch (17-20, Emerson ms. map). The large flat ridge between Pahole and Kapuna Gulches is often called Peacock Flats, Kaaimoku tells me that the Hawaiian name is Kamai. But this place name is not used because all ridges are described from the valleys on either side of the ridge.

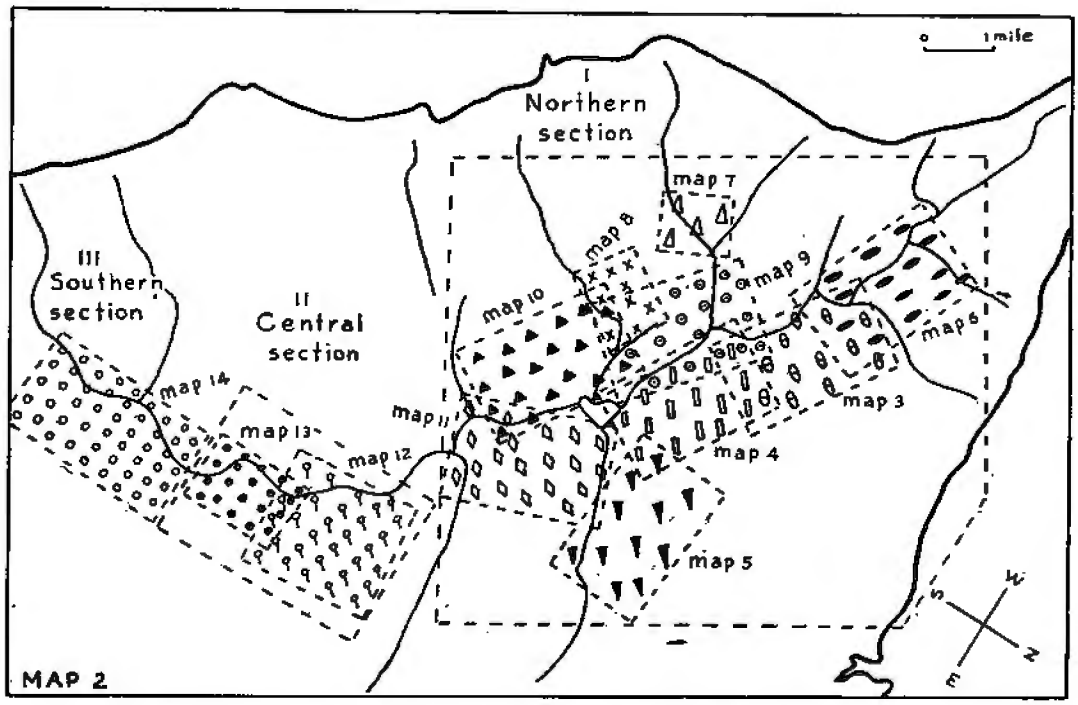
XIII. **Waianae Uka.** 1, Subdistrict Maili; 1a, Puu Pane; 2, Subdistrict Pulee; 2a, East Pulee Gulch (Welch); 2b, West Pulee Gulch (Welch); 3, Haleauau Gulch (wrongly spelled Haleanau on U. S. G. S. Top. Sheets) (Cox); 3a, North Haleauau Gulch (Welch); 3b, Central Haleauau Gulch (Welch); 3c, South Haleauau; 4, Mohiakea Gulch; 4a, North Mohiakea Gulch (Mohiakea Gulch in this paper) (Welch); 4b, South Mohiakea Gulch (Welch); 5, Pukaloa Gulch (Cox) (a name applying to the head of South Mohiakea Gulch which is of such long standing among shell collectors that it is used in preference to South Mohiakea Gulch); 5a, Puu Kalena.

XIV. **Honouliuli District.** 1, Waieli Gulch; 2, North Waieli Gulch; 3a, Central Waieli Gulch North Branch; 3b, Central Waieli Gulch South Branch; 3c, South Waieli Gulch North Branch; 3d, South Waieli Gulch South Branch (2, 3a, 3b, 3c, 3d, Welch); 4, Kaluaa Gulch (Pulu); 4a, North Kaluaa Gulch; 4b, Central Kaluaa North Branch; 4c, Central Kaluaa South Branch; 4d, South Kaluaa Gulch; 4e, South Kaluaa Gulch second East Fork; 4f, South Kaluaa Gulch first East Fork (4a-4f, Welch); 5, Maunauna Gulch; 5a, West Maunauna Gulch; 5b, Central Maunauna Gulch; 5c, East Maunauna Gulch (5-5c, Welch); 6, Waikele Gulch; 6a, North Waikele Gulch; 6b, South Waikele Gulch (6a-6b, Welch); 7, Manuwaielelu Gulch (Pulu); 8, Huliwai Gulch; 8a, North Huliwai Gulch; 8b, South Huliwai Gulch (8a-8b, Welch); 9, Ekahanui Gulch; 9a, North Ekahanui; 9b, Central Ekahanui; 9c, South Ekahanui (9a-9c, Welch); 10, Puumaialau Gulch (Pulu); 11, Pohakea Gulch (Pulu); 11a, North Pohakea Gulch; 11b, South Pohakea Gulch (11-11a, Welch); 12, Pualii Gulch (Pulu); 12a, North Pualii Gulch; 12b, Central Pualii Gulch; 12c, South Pualii Gulch (12a-12c, Welch); 13, Napepeiauolelo Gulch (Pulu); 14, Palawai Gulch; 14a, North Palawai Gulch North Branch; 14b, North Palawai Gulch South Branch; 14c, South Palawai Gulch (14a-14c, Welch); 15, Kaaikukai Gulch; 15a, North Kaaikukai Gulch; 15b, South Kaaikukai Gulch (15a-15b, Welch); 16, Manuwaikaalae Gulch (Pulu); 17, Namoopuna Gulch (Welch, named after the peak Namoopuna); 18, Pouilihale Gulch (Pulu); 19, Kaloi Gulch; 19a, North Kaloi Gulch; 19b, South Kaloi Gulch.

NOTE: 3a-4-5 include the subdistrict of Popouwela. The subdistrict Lihue on the U. S. G. S. Top. map includes gulches 8-9. According to Pulu, Lihue was a corral situated in Waikele Gulch (6). Gulick's "Lehui" comprised the entire district of Waianae Uka and possibly Honouliuli, but his shells are those of the subdistrict of Popouwela.

Table 1a. Annual mean temperature records in Waianae Mountain area.

Station	Elevation in feet	1933	1934	1935
Waianae	6	75.0	76.4	76.1
Ewa Plantation	50	72.6	74.5	74.1
Hoaeae (upper)	705	71.2		72.0
Schofield Barracks	861	69.8	71.3	71.2
Waialua Mill	30	72.7	74.0	73.7



MAP 2.—Key map showing the section of the Waianae Mountains covered by maps 3 to 14, and also the three major sections of the mountains.

Table 1 shows that the greatest amount of annual precipitation is at high elevations in Section I which includes all the stations except Ewa Plantation at the extreme southern end of the Waianae Mountains below Section III and Hoaeae (upper) which is in the district of Honouliuli below Section II. These sections are indicated on map 2, the rain gauge stations on map A. The precipitation at the top of Mount Kaala is from three to four times greater than that near sea level. The lowland mountain forest from about 900 to 2,000 feet is made up of kukui trees (*Aleurites moluccana*), *Sapindus oahuensis*, and other trees characteristic of the lowland or dryland forest.

Above 2,200 or 2,400 feet, the usual highland or wet forest is encountered. The term, wet forest, is not used here in exactly the way it is used in the Koolau Range where a true wet forest exists, but, since the flora is markedly different at this elevation and there are many forms present which live in a moist atmosphere, for present purposes I have termed it wetland forest.

At Kolekole Pass, the backbone or division ridge of the Waianae mountains drops from Puu Kalena (map 1, XIII, 5a), with an elevation of 3,504 feet to 1,723 feet, and then rises again in Section II to 2,885 feet at Puu Hapapa (map 1, II, 5b). From Puu Hapapa, the ridge to the south gradually rises with minor depressions to 3,113 feet at Puu Kaua (map 1, II, 3a). South of Puu Kaua, at the end of Section II (map 2) at Pohakea Pass (map 1, II, 2c), the division ridge decreases in altitude to 2,170 feet. Section II is drier than Section I, although there are no rain gauge stations at high elevations in either section to substantiate this statement, which is deduced from field observation. The forest is mostly the usual lowland one although a fringe of wet highland forest exists above 2,400 feet. From Puu Hapapa to Ekahanui Gulch, the region above 2,400 feet has an approximate linear distance of less than a half mile on the east slope of the range, while the west slope or Lualualei side is precipitous. Below the precipices or palis, there is a remnant lowland forest extending from 1,700 to 2,000 feet in elevation. Below Puu Kaua the west slope is also a series of high cliffs. On the east side of the range above Ekahanui all the way to Pohakea Pass, the division ridge is very precipitous, rocky, and mostly lacking in forest. The cliffs range in height from an approximate maximum of 363 feet directly below Puu Kaua to 100 feet at lower elevations. Therefore the major part of the area above 2,500 feet is barren so far as shells are concerned, and the existing forest is limited in extent.

The climate of Section III (map 2) is very dry also, increasingly so as one goes south along the ridge. The west slope is largely precipitous, and shells are recorded from localities near the backbone above 2,500 feet. The eastern slope supports a dryland forest up to about 2,400 feet elevation, above which a wet highland forest exists along the upper fringe of the range. The division ridge rises south of Pohakea Pass to 2,775 feet above Napepeiauolelo Gulch (map 1, XIV, 13) and increases in elevation to 3,098 feet at Palikea Peak at the head of South Palawai Gulch (map 1, XIV, 14c). South of Palikea Peak, the ridge decreases in elevation until at Kaloi Gulch (map 1, XIV, 19a) it is 2,500 feet in elevation.

Methods

The shells are all collected in limited areas usually not over an acre in extent. Each locality is carefully plotted on map tracings from the U.S.G.S. topographic advance sheets of the map of Oahu and given a locality number.

The shells are cataloged, marked with a catalog number, and labeled by a slip of paper bearing the name of the valley, locality number, and catalog number.

Bishop Museum houses its shells in standard size, covered trays which form units in themselves. Each contains 48 open box compartments 40 mm. square, and in them the shells are placed with a label after each lot from a single locality. This system of storage is almost "fool proof" for in addition to the carefully labeled boxes, each shell bears the catalog number of the lot to which it belongs.

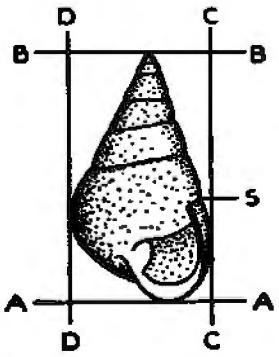


FIGURE 1.—Diagram of shell showing portions measured.

Each lot of shells that came in was measured for length; the total number measured was 15,176. The frequency of each length class was noted, and the biometric mean obtained for each locality. The shells are measured to the nearest millimeter by a special measuring instrument which enables the worker to measure a great many shells in a short time.

This instrument is a square brass rod 290 mm. long and 15 mm. square, into which 11 grooves are cut, each 9 mm. deep, and ranging in length from 15 to 23 mm. Each groove is one millimeter longer than the groove above it, if the rod is held upright, with the top groove being 15 mm.

After sorting the shells into length classes, the most common or typical form of shell is selected for each species or subspecies. If a species has been described, the usual form found at present is selected. If the subspecies is new, the usual form is considered to be the typical one for the holotype. In selecting the usual form, three measurements are taken (fig. 1): length, AA-BB; greatest diameter including the lip, CC-DD; and spire height, BB-S. Shells from each length class from a known locality are measured for greatest diameter and spire height. The final specimen chosen is that with the modal diameter and spire height of the shells of the mean length class and having the most common or modal color pattern and form of the entire lot.

Explanation of Maps

In order to determine shell distribution as accurately as possible, all localities recorded by written data were excluded unless the collector was able to plot the locality on the large U. S. G. S. maps of Oahu. All localities not plotted on maps either in the field or shortly after the collection was made were discarded or the elevation considered only approximate or in the general region of the outlined area. In making my own collections, I took a map with me in the field and plotted each locality as it was collected. Every locality reported by a collector was checked as far as possible on my own field trips. When material was studied, if a series of shells brought in differed in color pattern, size, and form from other shells from the same locality, that locality was checked. It was found in most cases that these shells had been wrongly plotted.

To show the exact location of these plotted localities without reducing the size of the plotted areas to a point where separate localities would be difficult to see, the map of the Waianae Mountains has been subdivided into sections numbered 3 to 14 inclusive. Map 2 is a key map showing the portions of the mountains covered by the sectional maps. Each sectional map is made in duplicate, one having only localities plotted on it (as map 3), and the other with areas of the various races of *A. mustelina* plotted (as map 3a).

The ridges on all maps published in this paper are outlined in black, and the areas over which a certain locality extends are outlined by a closed curve. Sometimes the place of collection is so small that an error is made in making a circle on the map, the plotted region being greater than the actual locality. The plotted localities in this paper are not considered infallible; and many of them may have an error of 100 feet more or less in elevation or 100 yards in linear distance.

Since 1931, a large number of localities have been plotted on the Bishop Museum maps, 582 of which are localities of *A. mustelina* used in this paper. In order to systematize all plotted material, each district, subdistrict, large named gulch, or large branch gulch is given a number preceded by the letter "W" to show that it is a Waianae Mountain locality, and distinct from a locality in the Koolau Range, the number of which would be preceded by no letter. These gulch or district numbers range from W1 to W490. Some of the numbers are not used in this paper, but are reserved for localities not yet collected. After the gulch or district number and separated from it by a hyphen is the locality number; for example, W30-1 or W400-6. On the locality maps, it is impossible to use a large district number and locality number for each locality due to lack of space. Therefore the locality number is used alone, and all the locality numbers within a certain district are

enclosed by a circle of broken lines, and the district number is placed outside the circle.

Species Concept

Pilsbry, in the introduction to the Manual of Conchology (5, p. xxv), considers the *Achatinella* species to be of three types.

> Grade I.—Races having certain seemingly permanent associations of characters (though usually with other variable characters), and co-existing with allied races without forming hybrid colonies.
>
> Grade II.—Geographic races (i.e. with a definite and consistent distribution), having moderately coherent associations of characters, but blending with other like races through hybrid or undifferentiated colonies where the geographic ranges meet.
>
> Grade III.—Forms characterized by the possession of one or more special characters (usually of color), but which occur for the most part in hybrid colonies with other diverse forms; the characters seem to be freely interchangeable and occurring in different combinations, as in Mendelian hybrids.

Pilsbry considers the races under Grade I to be species because there are no intergrading or hybrid forms between two races, A and B, in the same valley. The forms belonging to Grade II he also considers species, but not having the same validity as those belonging to Grade I, because race A in a certain valley will be found to have intermediates between it and race B in another valley. Pilsbry says that the species of Grade II might be more logically considered as subspecies, but he believes that in the genus *Achatinella* it is more practical to recognize as species a certain number of races which admittedly intergrade at their limits, than to make the species concept so broad that no definite idea is conveyed. Moreover, the term subspecies is needed for subdivisions of a lower rank.

My study of the Waianae Mountain fauna leads me to believe that Pilsbry's Grade I is the most logical definition of a species. I do not consider his Grade II races to be species, for any two *Achatinella* that intergrade are not distinct species; one is a subspecies of the other. I do not believe it is possible to obtain in a single colony a species and a subspecies, or two subspecies of the same species unless the locality is a border one between two pure races. If shells considered to be two subspecies are never found to intergrade in any region and the forms are sufficiently distinct, the two subspecies are considered separate species. The species concept, I believe, seems to be more obscured by a multiplicity of species than by keeping numerous forms within narrow confines. Therefore all forms that hybridize with other forms are considered to be subspecies.

However in some localities two color forms occur which are apparently distinct, though they may intergrade in the same colony and are never found in pure colonies, which is the criterion of a subspecies. In these localities there is a dominance of one color, A pattern, over another, B. Possibly if more collecting were done, a pure colony of pattern A could be found where B is

entirely lacking. If such were the case, forms A and B would be considered subspecies. Now, since certain colonies are known where form A is the dominant pattern on 75 percent or more of the shells, the pattern A is believed to be of a taxonomic value and is named a color race or subspecies. The same difficulty that Pilsbry encountered in naming the lower orders of the forms of *Achatinella* presents itself to me. In order to get lower groupings to describe further differentiation, all subspecies which are like a certain subspecies X will be grouped under subspecies X. Therefore instead of using *Achatinella mustelina lymaniana* var. *a*, variety *a* will be put under the subspecific group of *A. m. lymaniana* and only the three names *Achatinella mustelina* variety *a* will be used. Wherever the term variety is used after a subspecific name, it denotes that the particular form is closest to a certain subspecies but not sufficiently distinct to make a separate subspecies.

TAXONOMY

Species and Subspecies Included in This Paper

Species *Achatinella mustelina* Mighels.

1. *Achatinella mustelina* subspecies of the northern section of the Waianae Mountains (map 2).

Achatinella mustelina mustelina Mighels (pl. 1, figs. 1-7).

Achatinella mustelina Mighels: Proc. Boston Soc. Nat. Hist., 2:21, 1845.—Reeve, Conch. Icon., Achatinella, pl. 3, fig. 21, 1850.—Pfeiffer, Monogr., 3:458, 1853.—Thwing, B. P. Bishop Mus., Occ. Papers, 3(1):33, pl. 1, fig. 9, 1907.—Pilsbry and Cooke, Man. Conch., 22:342, pl. 63, fig. 5, 1912-14.

Apex mustellina Mighels: Hartman, Proc. Acad. Nat. Sci. Phil., p. 39, 1888.

?*Achatinella vestita* Mighels: Proc. Boston Soc. Nat. Hist., 2:20, 1845.

Achatinella multilineata Newcomb: Proc. Zool. Soc., London, (21):138, pl. 22, fig. 23, 1853.

B(ulimella) multilineata Newcomb: Hartman, Proc. Acad. Nat. Sci. Phil., p. 30, 1888.

Shell dextral, conical, dark brown, with a light revolving band at the suture, perforate; whorls seven, convex; aperture oblong; lip simple, acute. Length 1 inch, diameter, 9/20 inch. *Hab.* Waianai (Mighels).

The typical form of *mustelina* is that found in Mokuleia district, in the northwestern flank of the Kaala Mass. The typical color is a deep shade of carob-brown or blackish chestnut brown, the embryonic whorls white, pale brownish towards the apex, or entirely cartridge buff. The dark color begins on the fourth or fifth whorl. The lip is thickened within as usual, and is either vinaceous buff or nearly white. Shell either dextral or sinistral. The size assigned by Mighels, "1 inch", was probably approximate, as the largest Mokuleia specimen I have seen is a little over eighteen-twentieths of an inch. A more usual size is length 21, diam. 12 mm. (Pilsbry), Acad. Nat. Sci. Phil., Cat. No. 92249, Mokuleia, Gulick (pl. 1, fig. 1).

The holotype of *A. mustelina* was probably destroyed by fire at the same time the type of *A. vestita* Mighels was lost (5, p. 344). Pilsbry's identifica-

tion of *A. mustelina* is followed and specimen 92249 in the collection of the Academy of Natural Sciences of Philadelphia is considered the typical form. This specimen was recently examined and further notes made about it.

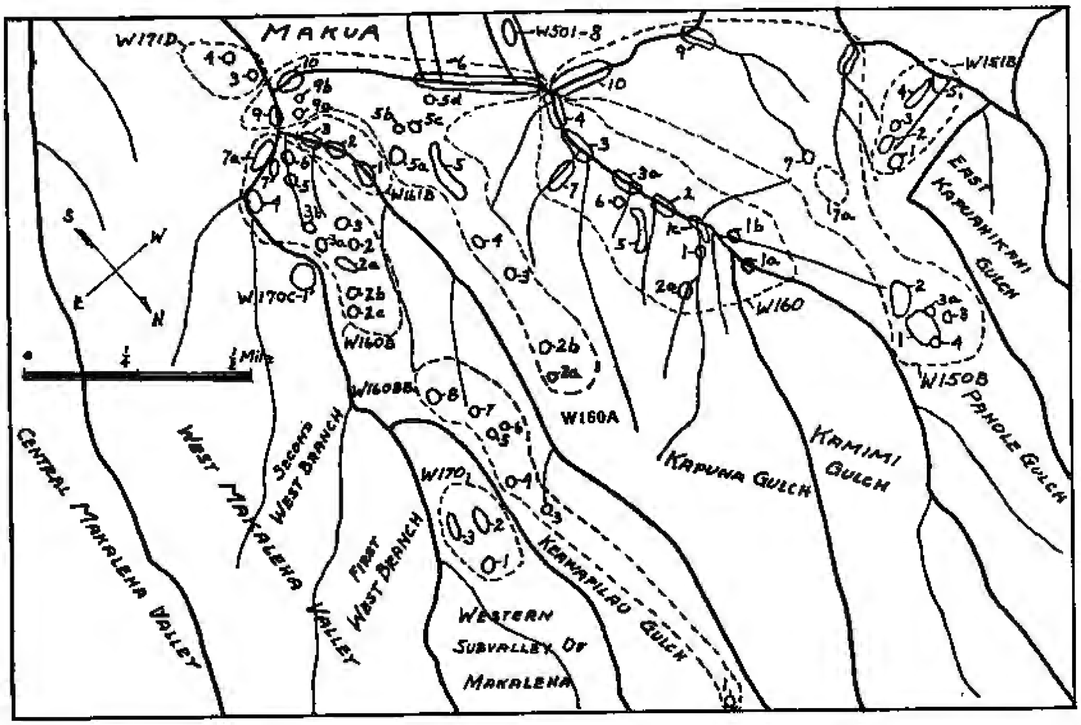
The shell is dextral, imperforate, impressed suture approximately 1.0 mm. in diameter (measured on the last whorl directly above the aperture), spire conical, straight in outline, whorls weakly convex, the embryonic whorls with the enamel worn off are cartridge buff. The post-embryonic whorls shade from white to army brown, ecru drab with axial streaks of cinnamon drab, drab gray with axial streaks of carob brown, light drab with axial streaks of carob brown, on the last whorl chestnut brown above the periphery; below the periphery chestnut brown tinged or axially streaked with carob brown, the last quarter darkening to solid carob brown. The edge of the periphery is slightly angular, callus and lip pinkish buff. Length 21.2 mm., greater diameter 12.8 mm., lesser diameter 11.7 mm., number of whorls 6½ (pl. 1, fig. 1).

Distribution, area 1: **Western Subvalley of Makaleha West Branch,** localities W170-3, elevation 1,500-1,650 ft., G. W. Russ 1933, W170-2, elevation 1,400-1,500 ft., W. Meinecke 1933, on kukui trees (*Aleurites moluccana*).

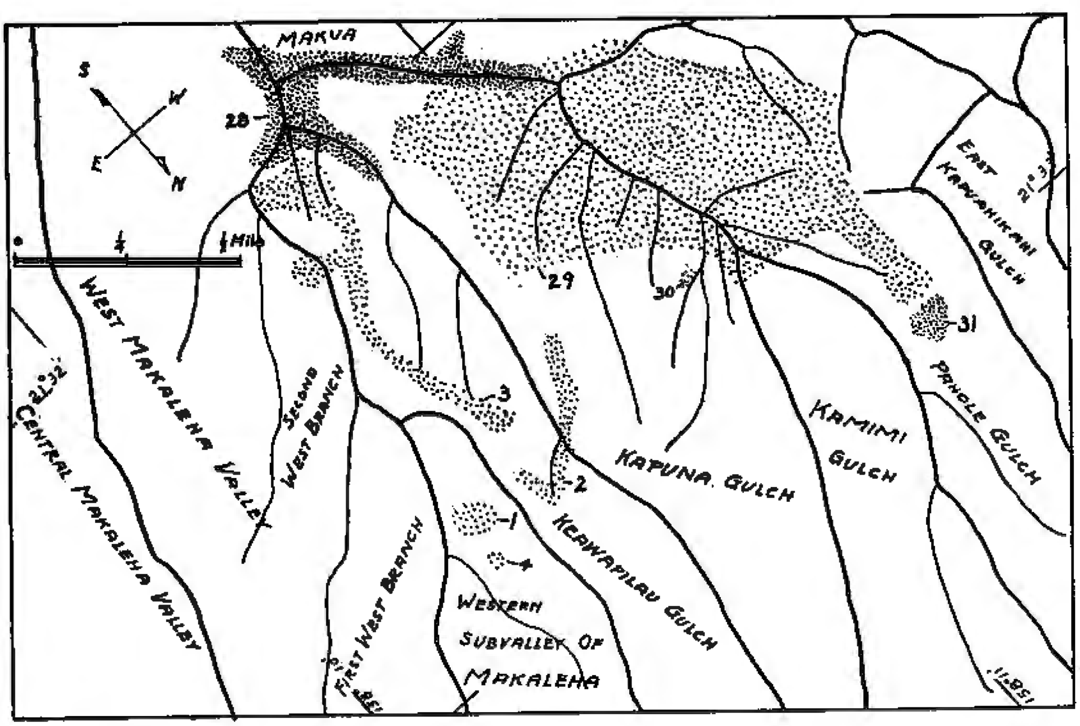
The typical form and color pattern collected by Gulick was undoubtedly collected in the region of Keawapilau and Makaleha Valleys in Mokuleia district. The Gulick specimens have surely faded considerably for brown shells collected twenty years ago in the Makaleha region by Cooke and Spalding are lighter in color than recently collected material from approximately the same localities.

The type locality of *A. mustelina* not being known, locality W170-3 in the Western Subvalley of Makaleha West Branch, collected by Russ, is selected for the typical locality, because it is the only colony known consisting of 100 percent dextral shells with the typical color pattern dominant on 72 percent. Locality W170-2, collected by Meinecke, although 100 percent dextral, has 66 percent of the shells of the typical *mustelina* pattern. The localities are so close to each other that they may be considered the same (maps 3, 3a, area 1, p. 18).

The typical form of the shell in area 1 measures, length, 20.8 mm., greater diameter, 12.2 mm., spire height, 11.7 mm., number of whorls 6½, first embryonic whorl tinted with pinkish buff, remainder of the embryonic whorls white shading to chamois on the last half embryonic whorl, first half of the first post-embryonic whorl white faintly banded with vinaceous fawn, last two whorls and a half carob brown, faintly axially streaked with ochraceous buff on the last two whorls, faintly spirally lined on the penultimate and last half of the first post-embryonic whorl with light mouse gray, impressed sutural band pale pinkish buff or white, lip not fully developed (pl. 1, fig. 4). Figure 4a is a more usual color form; the embryonic whorls are light buff, post-embryonic whorls are entirely carob brown with two fine spiral bands on the last two whorls above the periphery and one below the periphery of cinnamon, and faint axial streaks of cinnamon, lip and columella callus vinaceous fawn, lip fully developed typical. A common form in locality W170-2 is shown in figure 5, plate 1, length 20.8 mm., greater diameter 12.2 mm.,


MAKUA
W171D
W501-8
W151B
W170C-1
W160B
W160BB
W170
W160A
W160
W150B
S
W
E
N
0
¼
½ Mile
Central Makalena Valley
West Makalena Valley
Second West Branch
First West Branch
Western Subvalley of Makalena
Keawapilau Gulch
Kapuna Gulch
Kamimi Gulch
Pahole Gulch
East Kapuahikahi Gulch

Map 3.


MAKUA
S
W
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½ Mile
28
29
30
31
3
2
1
4
West Makalena Valley
Central Makalena Valley
Second West Branch
First West Branch
Western Subvalley of Makalena
Keawapilau Gulch
Kapuna Gulch
Kamimi Gulch
Pahole Gulch
East Kapuahikahi Gulch

Map 3a.

spire height 10.7 mm., with a shorter spire and more pointed embryonic whorls than figure 4, embryonic whorls white, post-embryonic whorls carob brown tinted and axially streaked with mouse gray, lip and columella callus vinaceous buff.

Present in all localities of *A. m. mustelina* Mighels is a light, lineate color form named *A. multilineata* by Newcomb.

Shell dextral or sinistral, solid, elongately conical, whorls 6, rounded, margined above; lip expanded below and slightly subreflected, above acute and thickened within; columella short, stout, slightly twisted, with a callus spread over and nearly closing the umbilicus; aperture oblong-ovate; colour of columella, lip and suture white, sometimes tinged with yellow; shell white, with or without numerous transverse lines of a brown or black colour. Long. [length] 19/20; [24.04 mm.], lat. [width] 10/20 poll [inch] [12.65 mm.]. Hab. Koolau Poko. Oahu.

This species makes a near approach to *A. mustelina* of Mighels, but is more elongate in form, with lineations much stronger, and never passes into the variety of *mustelina* with the depressed spire and obese body whorl. The locality also is different, which is always worthy of particular remark when examining shells of this genus (Newcomb). [Original figure reproduced (pl. 1, fig. 3).]

The type lot of *A. multilineata* Newcomb was examined in the Museum Cuming in the British Museum. There are two specimens. One marked with a red spot of sealing wax (pl. 1, fig. 2) agrees best in form with Newcomb's original figure. The color pattern differs in that the bands in Newcomb's figure are much narrower than those on the actual shell, which may be merely an artist's error. This specimen, however, agrees so closely that it may be considered the type. The embryonic whorls white, post-embryonic whorls lined and axially streaked with white, cartridge buff, and liver brown, lip and columella callus faded to white (pl. 1, fig. 2).

The other specimen in the type lot, I marked "A" in black ink when in London. The shell is white, spirally banded with ochraceous tawny lines which shade to hazel, spotted with liver brown, lip and columella callus seashell pink. Newcomb's locality of Koolau Poko is doubtlessly wrong, for as Pilsbry points out, the only shell occurring in that entire district which belongs to the section, *sensu strictu,* is *A. lorata* Férussac. The type of *multilineata* was most probably collected in a colony with typical *mustelina* because it is merely a lined form of *A. mustelina.* No shell with the same color pattern as the type of *A. multilineata* has been collected to my knowledge in recent years from any known locality. The color pattern of specimen A of the type lot can be approximately matched with the shells found in the region of Keawapilau and Makaleha Valleys inclusive, probably the type locality. From my present knowledge of the Waianae fauna, the lineate form of *A. mustelina,* which closely resembles *A. multilineata,* never occurs as a dominant pattern; for this reason it is not considered a valid subspecies.

These lineate patterns range from shells with a white ground to those

with a yellowish ground variously lined with different shades of brown. The shell can be white, axially streaked with pallid mouse gray, the last whorl lined above the periphery with wood brown, below with snuff brown, vinaceous buff, pale mouse gray, edge of the lip tinted with cinnamon buff, lip near the umbilical callus and the umbilical callus vinaceous fawn (pl. 1, fig. 6). Light patterns such as this are comparatively rare. The sinistral white lined form of the lineate pattern is very similar in form and color pattern to shells found in Kalalua Valley (pl. 8, fig. 6), but the dextral shells are distinctly separable in form.

The embryonic whorls shade from pale pinkish buff to cartridge buff, ground of the post-embryonic whorls cartridge buff, spirally lined with drab gray, hair brown, deep grayish olive, pale smoke gray, and sayal brown (pl. 1, fig. 6a). Last three whorls pinkish buff, spirally lined with hair brown, sutural band white, outer margin of the lip cream buff, inner margin white and umbilical callus white (pl. 1, fig. 7).

The constant length range and mean length of the shells in area 1 is shown in table 2.

Table 2. Achatinella mustelina mustelina Mighels. Area 1.

Collector	Locality	Live adults	Mean length in mm.	Length range in mm.	Dextral
Russ	W170-3	45	21.0	18.5-23.5	66
Meinecke	W170-2	50	21.0	18.5-23.5	70

Following Pilsbry, *A. vestita* Mighels has been dropped since the holotype was destroyed by fire and the locality is doubtful. *A. vestita* has page priority over *A. mustelina* and it would be unwise to drop a name used with certainty for many years for a name of doubtful identification. Pilsbry correctly points out that if *A. vestita* is a Waianae shell, it would probably be *A. multilineata* of Newcomb. Mighels' description of *A. vestita* is given below.

Shell sinistral, acuminate-conical, light brown, or white, with beautiful, narrow, dark brown bands, more or less numerous; imperforate; whorls six, convex; aperture semilunate; lip reflected. Average length, 1 inch, diameter, ½ inch. *Hab.* Waianai and Hawaii (Mighels).

Achatinella mustelina griseipicta, new subspecies (pl. 1, figs. 11-13).

Shell more slender, with a longer spire and different color pattern than *A. m. mustelina* which it resembles closely in form. Embryonic whorls white, post-embryonic whorls pale smoke gray shading to drab on the last whorl, axially streaked with cinnamon drab and benzo brown, impressed sutural band white, lip and columella callus light vinaceous cinnamon, length 22.6 mm., greater diameter 11.7 mm., spire height 12.9 mm., number of whorls 7 (pl. 1, fig. 11).

Distribution, area 2: **Kapuna Gulch,** type locality, W160A-2a, el. 1,450 ft., W160A-2b, el. 1,450 ft., Russ 1932-33, Welch and Yamaguchi 1935, on kukui (*Aleurites moluc-*

cana) and *Ceodes* trees; **Keawapilau Gulch,** localities W160BB-3, el. 1,250 ft., all dead shells, W160BB-4, el. 1,350 ft., on kukui trees, Welch and Yamaguchi 1935 (maps 3, 3a, p. 18).

Ninety-five percent of the shells from the type lots, 133217-18, have the typical color form and shape of the holotype. The other five percent are of a light color similar to that illustrated (pl. 1, fig. 12): embryonic whorls white, post-embryonic whorls white, spirally banded and axially streaked with pallid mouse gray and pale ecru drab, first half of last whorl spirally banded with mouse gray, last half darkens to pale mouse gray spirally lined with light mouse gray, impressed sutural band white, lip and columella callus light pinkish cinnamon. While the shell is usually entirely dextral, sinistral forms are found in locality W160BB-3 (pl. 1, fig. 13) with the same color pattern as that of figure 11. The shells in locality W160BB-5 are intermediate forms between *mustelina* and *griseipicta,* but closer to *griseipicta.* The upland limit of *griseipicta* is locality W160A-3 in Kapuna Gulch where the dominant form is that of *A. m. waianaeensis* var., but mixed with one or two specimens of the typical *griseipicta* form and color pattern.

Table 3. Achatinella mustelina griseipicta Welch. Area 2.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ and Welch	W160A-2a,2b	19		22.0	20.5-23.5	26	
Welch	W160BB-3		5	20.5	17.5-22.5		14
Welch	W160BB-4	7		21.0	19.5-21.5	12	

The number of shells in table 3 is so small that the actual length variation may not be indicated by the figures. Taking the number of specimens on hand as sufficient for discussion purposes, the shells show a decrease in size with decrease of altitude from one valley to the next, unlike those in areas 1, 3, and 4. This size difference of shells between area 2 and adjacent areas to the east may be entirely due to the small numbers collected. More collecting should be done in order to obtain larger series of shells to determine whether there is a size decrease with altitude in this region. The change of coil in area 2 from sinistral to dextral parallels the condition in areas 1 and 4 (p. 18).

Achatinella mustelina mustelina var. (pl. 1, figs. 8-10a).

Area 3: **Keawapilau Gulch,** localities W160BB-5, el. 1,400 ft., W160BB-6, el. 1,400 ft., W160BB-7, el. 1,450-1,500 ft., Welch and Yamaguchi 1935, W160BB-8, el. 1,500 ft., Russ 1932, W160B-2c, el. 1,800 ft., W160B-2b, el. 1,800 ft., W160B-2a, el. 1,850-2,000 ft., on kukui trees, Welch and Winne 1934, W160B-2, el. 1,850 ft., Russ 1932, region of W160B-3 (?), Cooke [1]1908, W160B-3, el. 1,900 ft., Russ 1932, W160B-3a, el. 2,000 ft.,

[1] When material is cited as having been collected by "Cooke", Dr. C. M. Cooke, Jr. is referred to.

W160B-3b, el. 1,950-2,000 ft., Lemke and Lemke, Jr. 1933, W160B-4, el. 2,250 ft., W160B-5, el. 2,200 ft., Meinecke 1933, region of W160B-5-6-7 (?), Cooke 1908; West Makaleha Valley Second West Branch, region of locality W170C-1 (?), el. 1,950-2,100 ft. (?), Cooke 1908 (map 3, 3a, p. 18).

In area 3, typical *mustelina* patterns occur mixed with the *griseipicta* color form. Some specimens are pure *mustelina* patterns. The majority are dark *griseipicta* color forms but with so much of the brown of the typical *mustelina* patterns in them that it is better to call them *mustelina* rather than dark *griseipicta*. The usual color pattern of the shell is that shown in figure 8, plate 1. The last three whorls shade from chocolate, spirally lined and axially streaked with pinkish buff and white, to fuscous black on the last whorl, axially streaked with chocolate, spirally lined with black, above the periphery spirally lined with pale pinkish buff.

The usual lineate patterns in area 3 are shown in figures 9, 10, 10a, plate 1. Ground white shading to pinkish buff on the last whorl, last whorl lined and axially streaked with cinnamon (pl. 1, fig. 10). Figure 9 is similar to 10 but is lined and banded with carob brown. Banded forms similar to figure 9 are not usual, only a few specimens occurring here and there in different localities. The usual color patterns are similar to figures 6a, 7, and 8, plate 1. The yellow color patterns of figures 7, 9, and 10 are the common patterns. White shells are more rare in this region.

The early post-embryonic whorls are pale drab lined with light brownish drab and banded with drab, last whorl banded with drab, buffy brown; below the periphery there are bands of cinnamon buff and tawny olive (pl. 1, fig. 10a). The two gray lined or banded color patterns of figures 7 and 10a are rarer in the lower localities than in the upper ones which border the region of *A. m. waianaeensis*.

The color pattern is found to be grayer the higher the locality. All the shells at the backbone overlooking Makua are gray forms of *A. m. waianaeensis*. The carob brown pattern of typical *A. m. mustelina* is rare at higher altitudes in area 3. Localities W160B-4 and W160B-5 are intermediate between the *mustelina* and *waianaeensis* forms both in color and shape of the shell.

In locality W170C-1, specimens of the typical *mustelina* and lineate patterns have less gray in them and more carob brown than the shells of Keawapilau.

The sequence of dextrality and sinistrality (table 4) is puzzling and at present does not show logical order, dextral and sinistral forms occurring at random. The lowest locality is, however, sinistral changing at higher elevations to dominantly dextral areas. The turn of the shell appears to change again to sinistral prior to completely changing or grading into the

upper race. Possibly a clearer conception of the regions or places where shells change direction of coil will be obtained when more localities are studied in area 3.

At the lower edge of area 3, the first locality W160BB-5 is composed of 97 percent sinistral forms. Five hundred yards away, locality W160BB-6 contains 91 percent of dextrals, which shows how easily varying proportions of dextrals and sinistrals can be obtained from a single area when visiting the immediate vicinity of a locality on successive collecting trips.

Table 4. Achatinella mustelina mustelina var. Area 3.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W160BB-5	7	10	20.0	18.5-21.5	1	32
Welch	W160BB-6	2	1			11	1
Welch	W160BB-7	23	18	20.5	18.5-22.5	64	23
Russ	W160BB-8	19		20.0	17.5-22.5	1	19
Welch	W160B-2b-2c		4		19.5-22.5	8	
Welch	W160B-2a	5	5	20.5	19.5-21.5	13	
Russ	W160B-2	13		19.5	16.5-21.5	16	
Russ	W160B-3	52		19.0	17.5-20.5	68	1
Meinecke	W160B-4	49	3	19.5	17.5-22.5	1	92
Meinecke	W160B-5	5		20.0	18.5-21.5		5
Cooke	W170C-1(?)	33		20.5	19.5-22.5	56	

The mean length of the shells in Keawapilau Gulch, area 3, is 20 + mm. in all localities below 1,900 feet. Above 1,900 feet the shells have a mean length of 19 + mm. except locality W160B-5 (table 4). The larger mean length there may be due to the small number of shells. Locality W170C-1 is not considered, since the exact elevation is not known. Shells in area 3 decrease in size with increase in elevation.

Achatinalla mustelina mustelina var. (pl. 3, figs. 17-17c).

Area 4: **Western Subvalley of Makaleha West Branch,** locality W170-1, el. 1,300-1,350 ft., Russ 1932, 22 alive on kukui and 29 dead, all sinistral (maps 3, 3a, p. 18).

A series of shells from this locality is quite distinct from series from areas 1 or 3 differing in that the dark shells from W170-1 rarely have any solid carob brown color or shade but another shade of brown; no *griseipicta* pattern occurs in this lowland locality and the lineate color pattern has a white ground, never yellow. Even with these differences the color pattern of many of the shells from the three areas is so similar that mixed lots are impossible to separate completely.

The usual form of the shell, length 21.9 mm., greater diameter 12.6 mm., spire height 11.4 mm., is shown by the dead specimen in figure 17, plate 3.

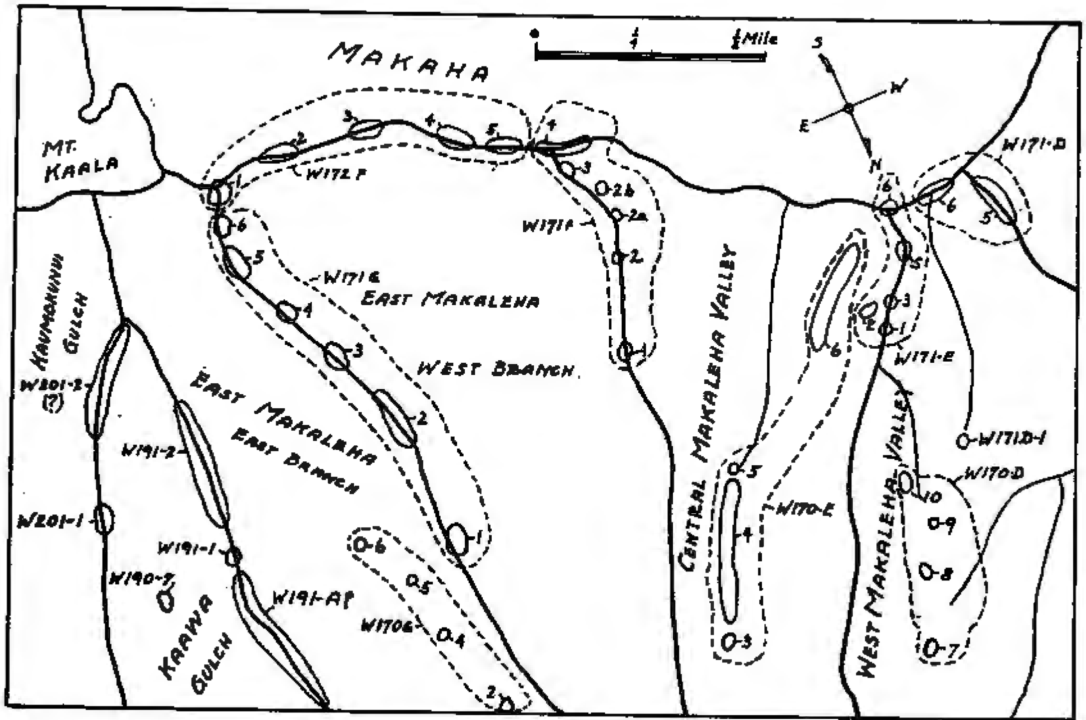
Embryonic whorls white banded on the lower half of the whorl with buckthorn brown, post-embryonic whorls sayal brown spirally lined and heavily, axially streaked with warm sepia, below the periphery two bands of sayal brown, impressed sutural band white, subsutural band white tinted with cinnamon buff on the last two whorls, shell faded. The shell may be more slender, length 21.5 mm., greater diameter 12.3 mm., spire height 11.2 mm. post-embryonic and penultimate whorls olive brown spirally lined with white and axially tinted or streaked with verona brown, last whorl shades to warm sepia axially streaked with cinnamon buff and tinted on the last half whorl with snuff brown, impressed sutural band white, lip and columella callus pale vinaceous fawn (pl. 3, fig. 17b).

The usual color pattern on 84 percent of the 51 shells is the lineate pattern shown in figure 17a, plate 3. Ground white, last three whorls banded with verona brown, lip and columella callus white. Possibly this color pattern occurs or did occur as a pure lineate race at a lower elevation, the darker color forms in W170-1 being a mixture of the upper with a lower race. The color pattern may be lighter, embryonic whorls white, post-embryonic whorls white, axially streaked and spirally lined with ecru drab on the penultimate whorl, last whorl axially streaked with pallid mouse gray, above the periphery on the last two whorls is a band of snuff brown, below the periphery the base is lined with seven lines of sayal brown, lip white shading to avellaneous at the columella callus, impressed sutural band white (pl. 3, fig. 17c). This light color pattern also shows the form of a short spired specimen, length 21.3 mm., greater diameter 12.6 mm., spire height 10.5 mm. The locality is 100 percent sinistral, the mean length of the shells 21.0 mm., length range 18.5-24.5 mm., the number of live adults 12, dead 13.

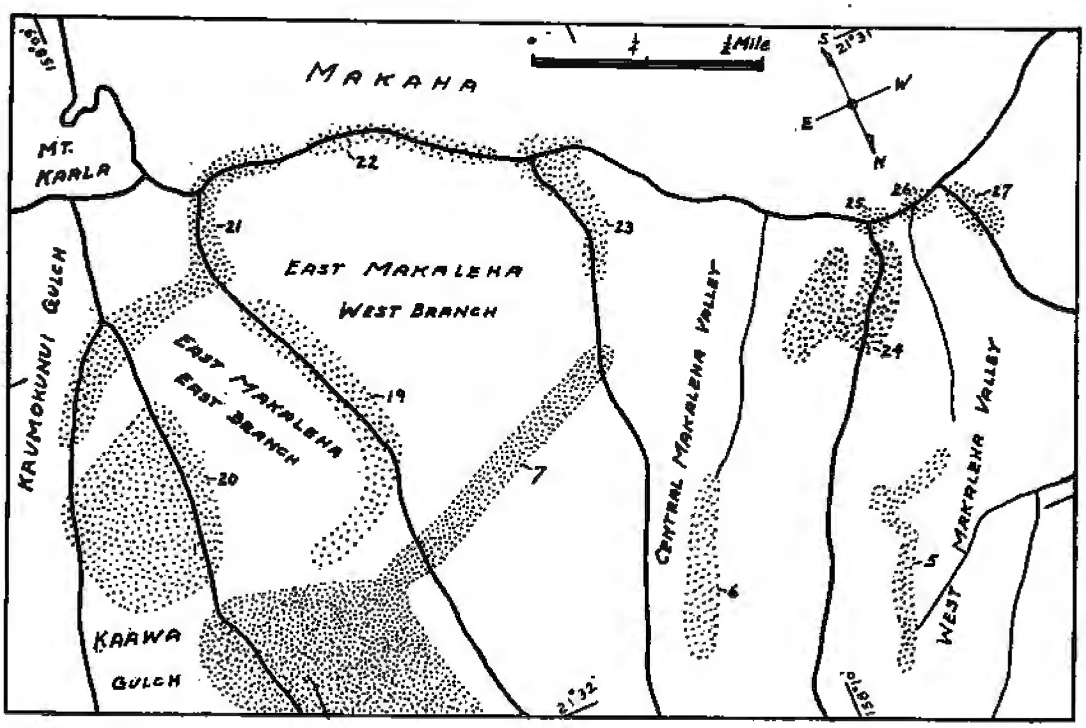
Achatinella mustelina mustelina var. (pl. 1, fig. 14).

Area 5: **West Makaleha Valley,** localities W170D-7, el. 1,250 ft., W170D-8, el. 1,300-1,350 ft., W170D-9, el. 1,450-1,500 ft., W170D-10, el. 1,500-1,550 ft., W171D-1, el. 1,700-1,750 ft., Russ 1932, have shells similar to those found in Keawapilau Gulch (map 4, 4a, p. 25).

The *mustelina* pattern is rare in West Makaleha; only six specimens were found, one of which has the typical carob brown pattern, the other four, grayish forms with the last three whorls olive brown banded with clove brown and similar to figure 8, plate 1. The dominant pattern is a lineate form (pl. 1, fig. 14). The shell is narrower, with a more elongate spire than the usual lineate forms found in the gulches to the west, embryonic whorls white, lined at the suture with clove brown, post-embryonic whorls streaked with pallid mouse gray and lined on the lower half of the whorl with chaetura drab, last whorl and a half pinkish buff above the periphery banded with hair brown, below the periphery cinnamon buff deepening to cinnamon on the last half whorl, axially and spirally lined with chaetura


MAKAHA
MT. KAALA
EAST MAKALEHA
WEST BRANCH
EAST MAKALEHA
EAST BRANCH
KAUMOKUNUI GULCH
KAAWA GULCH
CENTRAL MAKALEHA VALLEY
WEST MAKALEHA VALLEY
½ Mile

MAP 4.


MAKAHA
MT. KAALA
EAST MAKALEHA
WEST BRANCH
EAST MAKALEHA
EAST BRANCH
KAUMOKUNUI GULCH
KAAWA
GULCH
CENTRAL MAKALEHA VALLEY
WEST MAKALEHA VALLEY
½ Mile

MAP 4a.

drab and sayal brown. The color of the ground may be white and the shell may have a similar pattern to figure 6a, plate 1, or have a gray pattern like that of figure 10a, with a white ground instead of a yellowish one.

Table 5. Achatinella mustelina mustelina var. Area 5.

Collector	Locality	Live adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ	W170D-7	25	20.0	18.5-21.5	7	28
Russ	W170D-8	17	19.5	17.5-21.5	2	21
Russ	W170D-9	14	20.5	19.5-22.5	10	5
Russ	W170D-10	5	19.5	18.5-20.5	2	7
Russ	W171D-1	13	20.5	19.5-22.5		

No correlation between altitude and size is found in area 4, the mean value of the shells varying between 19 + and 20 + mm. Nor does the census of dextral and sinistral forms give a clue to any possible order in their distribution. After more work has been done in this region in obtaining plotted localities, possibly some order can be made out. This is an exceptional area, for most localities below 1,900 feet have shells with a mean length of 20 mm.

Achatinella mustelina mustelina var. (pl. 1, figs. 15-15b).

Area 6: **Central Makaleha Valley,** locality W170E-3, el. 1,100-1,150 ft., W170E-4, el. 1,100-1,250 ft., W170E-5, el. 1,300 ft., Russ and Welch 1932, on kukui, *pua* and other native trees (maps 4, 4a, p. 25).

A peculiar gray lined race occurs here which is quite distinct from the typical yellowish pattern of area 3 and contains specimens resembling *A. m. griseipicta.* This race, however, is so like *A. m. brunicolor* var. from Makaha and even color patterns from Ekahanui that it would be impossible to separate mixed lots completely. In general, the Makaha shells (p. 69) from locality W30B-1 have forms which are less strikingly ornamented with clear cut, dark lines against a light background as in figure 15a, plate 1. A lot of Ekahanui shells can usually be separated from a lot of area 6 shells by the usually distinct patterns peculiar to each locality. The form of the shell in area 6 is the usual intermediate form of *A. mustelina* which occurs between a highland and a lowland race, closer to that of *A. m. mustelina* than to the upper race of *A. m. altiformis.*

The typical form and color pattern of the shell in area 6 measures, length 20.7 mm., greater diameter 12.2 mm., spire height 11.3 mm., embryonic whorls white, post-embryonic whorls white shading to pale smoke gray on the last whorl, spirally banded on the last whorls with hair brown shading to buffy brown on the last whorl, sutural band white, subsutural band pale pinkish buff shading to pinkish buff on the last whorl, lip and columella callus cin-

namon pink (pl. 1, fig. 15a). The typical dextral form and the usual, dark lined color pattern is shown in figure 15b of plate 1, length 20.8 mm., greater diameter 12.3 mm., spire height 11.9 mm., first post-embryonic whorl white spirally lined and axially streaked with deep livid brown shading to pale drab gray and light grayish olive on the last two whorls, spirally lined with olive brown, lip and columella callus buff pink. Twenty percent of the shells may have a sparsely lined drab color pattern similar to figure 15, plate 1. First post-embryonic whorl natal brown, faintly, spirally lined with white shading to light drab on the penultimate with subsutural line and a line just above the periphery of drab, the last whorl buffy brown spirally banded with a subsutural band and two peripheral bands of olive brown, sutural band white and extending about a quarter of a millimeter below the impressed sutural groove.

The mean length of the shells is 21 or 20 + mm. The altitude of the highest locality is 1,300 feet. Locality W170E-4 is 100 percent sinistral in the Welch lot and only 66 percent sinistral in the Russ lot. The small number of specimens collected by Welch may account for this difference; or else the Welch shells came from a portion of locality W170E-4 which had dominantly sinistral shells, while Russ collected over a slightly different region and obtained dextral shells as well. All the localities in area 6 are only approximate because the valley is not well differentiated by side gulches, which makes it difficult to plot localities with any degree of accuracy.

Table 6 shows that probably a change from dextral to sinistral forms exists between locality W170E-4 and W170E-3. More careful future collecting will determine the exact points of change.

Table 6. Achatinella mustelina mustelina var. Area 6.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W170E-3	9	2	20.5	18.5-21.5	11	17
Welch	W170E-4		5	21.5	20.5-23.5		6
Russ	W170E-4	17		21.0	18.5-22.5	16	8
Russ	W170E-3-4	56		20.5	18.5-22.5		
Russ	W170E-5	3			19.5-20.5	2	4

Achatinella mustelina mustelina var. (pl. 1, figs. 17-17c; pl. 3, figs. 18-18a).

Area 7: **East-Central Makaleha Ridge,** locality W171F-1, el. 2,000-2,100 ft., Russ 1933, 3 live sinistrals, also collected on the same ridge by A. F. Judd, localized by Welch from the Russ lot; **East Makaleha Valley, East-West Branch Ridge,** locality W171G-1, el. 1,450-1,500 ft., Meinecke 1933, 16 dead, 41 live adults, mean length 19.5 mm., length range 17.5-22.5 mm., 1 dextral and 81 sinistrals; **East Makaleha Valley, East Branch,** W170G-2, el. 1,000 ft. 1 sinistral, W170G-4, el. 1,150 ft., 7 dextrals, W170G-5, el. 1,300 ft., 5 sinistrals, Russ and Welch 1932, all dead, poor specimens use-

ful only for indicating the former lowland distribution of *Achatinella* in this gulch, only one or two in each locality (maps 4, 4a, p. 25).

The usual form of the shell in locality W171G-1 is illustrated in figure 17a, plate 1; embryonic whorls pale pinkish buff, penultimate and first half of the last whorl deep brownish drab, spirally lined with white, last whorl pale drab gray spirally lined with fuscous, and fine lines of cinnamon about the periphery, lip and columella callus light vinaceous fawn, length 19.2 mm., greater diameter 11.6 mm., spire height 10.0 mm. The strikingly lineate pattern of figure 17, plate 1, and a typical obese specimen has a length of 19.7 mm., greater diameter 12.2 mm., spire height 10.5 mm., post-embryonic whorls white lined and banded with black and snuff brown. A narrow form of the shell and a light color pattern similar to figure 15, plate 1, measures, length 19.4 mm., greater diameter 11.1 mm., spire height 10.5 mm. (pl. 1, fig. 17b). The embryonic whorls white, first post-embryonic whorl and a half pale gull gray, spirally lined and streaked with light vinaceous drab, last whorl and a half pale gull gray spirally lined with black and verona brown, in the umbilical region of the base a band of white, impressed sutural band white (pl. 1, fig. 17b). An unusual, rare color pattern in area 6a is a yellow streaked form found only in locality W171G-1. The color pattern, however, is also found in the upper localities of area 19. The embryonic whorls are white tinted with pale vinaceous fawn, first half post-embryonic whorl natal brown, streaked and lined with white, shading to pale pinkish buff on the penultimate and white on the last whorl, spirally lined and axially streaked on the last two whorls with ochraceous tawny, tawny, and cinnamon buff, impressed sutural band white (pl. 1, fig. 17c).

The shells of area 7 are similar in form to the shells of area 6 of Central Makaleha. The three shells of locality W171F-1 have been linked with locality W171G-1 because the color patterns appear to be closer than to the Central Makaleha forms. Further collecting in this entire region may change the conception of shell distribution and enable future students to single out forms of subspecific rank.

In the Meinecke collection, lots 124019 and 124020, there is a total of 61 live adults, with a mean length of 19.0 mm. and a length range of 16.5-21.5 mm. collected on the Makaleha-Kaawa ridge. The shells probably represent a large locality extending from a point below locality W191-1 to one above it. These lowland forms which for the sake of speculation may be plotted somewhere in the region of W191-A are closer to *A. m. mustelina* Mighels than to the higher race of *A. m. griseitincta,* new subspecies, in area 20 and are considered part of area 7. Intermediate forms between *A. m. griseitincta* and *A. m. mustelina* as well as *A. m. griseitincta* occur in this lot. The typical color patterns of these lowland forms are shown in figures 18 and 18a, plate 3. The embryonic whorls are white, first half of first post-embryonic

whorl white, tinted with pale pinkish buff, last half of whorl and penultimate whorl pale pinkish buff shading to pale mouse gray axially streaked and spirally banded with chocolate, last whorl pale pinkish buff finely axially streaked and lined with cinnamon buff and banded with ochraceous tawny (pl. 3, fig. 18). This pattern is a modification of the yellow pattern of locality W171G-1 (pl. 1, fig. 17c). Possibly the mixture of this color pattern with the dark *sordida* var. pattern of Kaawa Gulch produces the subperipheral yellow band characteristic of the shells of Kaawa Gulch (pl. 1, fig. 19a; pl. 2, fig. 13a). The shell of figure 18a, plate 3 is a modified color form of figure 17, plate 1, the spiral bands being broken by fine axial streaks of white, post-embryonic whorls white shading to pale mouse gray, spirally banded and lined with sepia, sutural band white.

Achatinella mustelina decolor, new subspecies (pl. 1, figs. 20-23).

Shell sinistral, larger with more convex whorls than typical *mustelina,* columella callus weak, straight in outline. The embryonic whorls are worn on the first whorl and a half, what remains of the enamel white, last two embryonic whorls white tinted with cream buff, post-embryonic whorls avellaneous, faintly, spirally banded with white above the periphery, impressed sutural band and subsutural band white, lip white, outer margin cream buff, length 22.7 mm., greater diameter 13.6 mm., lesser diameter 12.3 mm., spire height 11.5 mm., number of whorls 6½, lot 102346, Emerson collection, **Makaleha Valley** (pl. 1, fig. 20).

A color pattern similar to this is shown in figure 21, plate 1. The color is the same in both shells, but in figure 21 the specimen is white banded, the columella callus is more usual than that of the holotype. The pattern of figure 21 may be the accompanying lineate form of typical *decolor*. These banded forms occur on only a small percent of the shells. A rare, dark color pattern found on only five specimens from the type lot is shown in figure 21b, plate 1. The first four whorls are white, banded with chamois on the lower half of the whorl, next whorl banded with white and carob brown, penultimate whorl axially streaked with zigzag blotches of white, last whorl banded above the periphery with vinaceous buff axially streaked with carob brown, below and just above the periphery banded with carob brown, so that the color is almost solid, axially streaked with vinaceous buff. An obese form of the shell, length 22.1 mm., greater diameter 13.2 mm., spire height 11.4 mm., has the embryonic whorls pale pinkish buff, first post-embryonic whorl fawn color, last whorl and a half wood brown, impressed sutural band white, lip and columella callus white tinted with cartridge buff (pl. 1, fig. 21a).

The original lot 102346 was composed of one dextral and 56 sinistral shells, with which were mixed four sinistral shells undoubtedly from Waianae Kai or Makaha Valley, typical *A. m. mixta* forms. These *mixta* forms were confused with the Makaleha *A. m. decolor* form because of the somewhat similar shade of the color pattern. These four shells of *A. m. mixta* are nevertheless

so distinct that they were readily separated on form, smaller size, and concave spire, taken out of this lot, and recataloged under another number.

A. m. decolor to my knowledge was collected only by Emerson and was distributed by him to many collectors in exchange for other shells. In Bishop Museum the subspecies is found in the collections of C. M. Cooke, Jr., A. F. Judd, D. D. Baldwin, and C. F. Ancey.

A. m. decolor is often confused with *A. leucophaea* Gulick from Waialee in the northern section of the Koolau Range of Oahu. Mr. Baldwin exchanged specimens of *A. m. decolor* and marked them *A. leucophaea*. While the color patterns of the two subspecies are somewhat similar when casually observed, the forms of the shells are quite distinct when closely studied. *A. leucophaea* usually has a more obese and convexly outlined spire with the first post-embryonic whorl darker than the last one.

Lot 102347 contains one sinistral and 24 dextral shells. In the same lot are 14 dextral shells of the *A. m. mixta* form, undoubtedly from Waianae Kai in the general region of Kalalua Gulch. These shells are easily separated and put under another catalog number. Table 6a gives the results of the measurements on the two lots of shells. The dextral specimens have a smaller mean length than the sinistrals. From what is known of the shells in areas 1, 4, and 3, larger shells seem to come from the lower localities. Using these data as criteria, *A. m. decolor* probably came from some elevation below locality W170-1, and the sinistral shells being larger may have occurred at a lower elevation than the dextral specimens. It must be remembered, however, that the entire original lot of Emerson is not available for study, many of the shells having been exchanged, so that we cannot get a true picture of what occurred in individual lots. Then again the dextral and sinistral shells may have been separated out by Emerson. Figure 22, plate 1, shows a typical dextral form of the 22.5 mm. class from lot 102347, length 22.5 mm., greater diameter 12.5 mm., spire height 12.6 mm., last two whorls army brown shading to fawn color, banded with white.

Table 6a. Achatinella mustelina decolor Welch.

Cat. No.	Live adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
102346	62	22.0	20.5-24.5	1	64
102347	19	21.5	19.5-23.5	21	1

In the Gulick collection, lot 70391, there are four specimens of *A. mustelina* labeled "Mokuleia". The shells are close to the color pattern of *A. m. decolor* (pl. 1, fig. 21) but more gray. Figure 23, plate 1, shows the typical pattern of one of the Gulick shells, last three whorls above the periphery white tinted with pale gull gray lined with light drab, below the periphery

light drab lined with white, lip and columella callus white. A pattern similar to figure 23 is found in lot 102347, the shell above the periphery white, below the periphery drab gray profusely lined with white (pl. 1, fig. 22a). Five specimens of this gray pattern of *decolor* are in lot 102347 and one dextral in lot 102346. This gray form of *A. m. decolor* possibly occurred as a pure race, but the color pattern is so close to that of *A. m. decolor* that I do not consider it sufficiently distinct to be separated out as a distinct subspecies.

At what elevation Emerson collected these shells is unknown. The lowest recorded *Achatinella* locality in this general Makaleha region is locality W160BB-1, elevation 750 feet, in Keawapilau Valley, Welch and Yamaguchi 1935 (map 3). Only the base of a single fragment of a sinistral *Achatinella* is known. The color, badly faded, is avellaneous. The main value of this record is the indication that other fossil records may exist under stones in gulch slopes at similar elevations, and that the possible *A. m. decolor* was obtained in the immediate vicinity at a similar elevation.

Achatinella mustelina sordida Newcomb (pl. 2, fig. 1-5a).

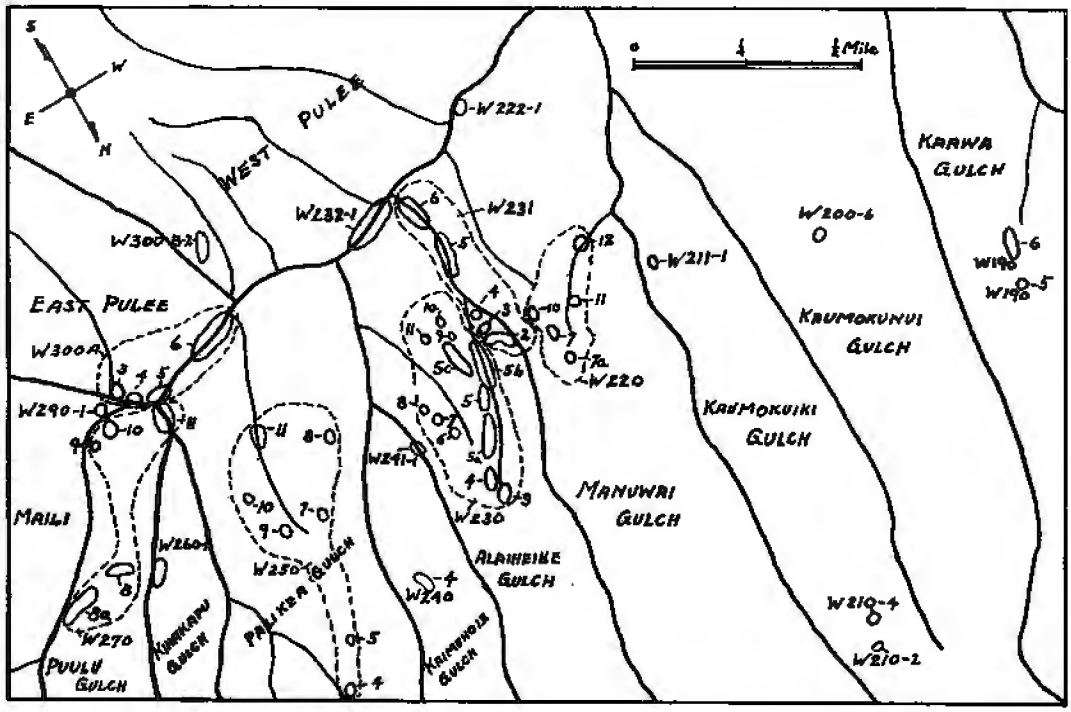
Achatinella sordida Newcomb: Proc. Zool. Soc., London (21) : 139, pl. 23, fig. 27, 1853.—Pfeiffer, Monogr., 4:523, 1859.

Achatinella mustelina sordida Newcomb: Pilsbry and Cooke, Man. Conch., 22:349, pl. 30, fig. 27, pl. 62, figs. 5-11, 1912-1914.

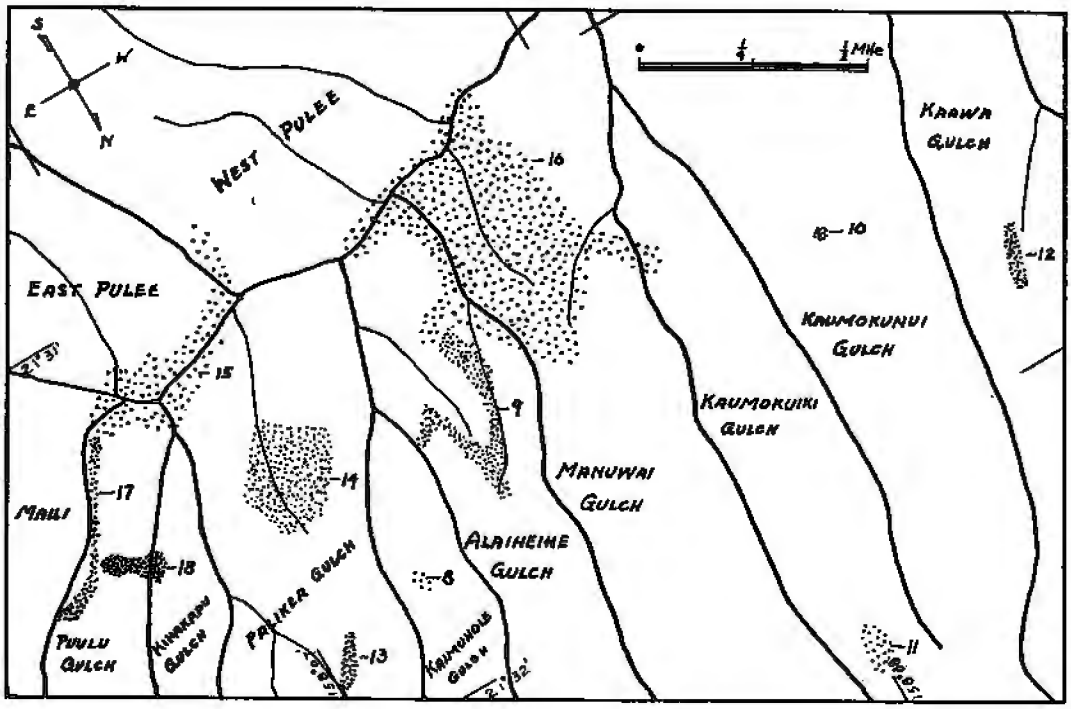
Shell elongately conical, solid; whorls 7, slightly rounded, margined above; aperture small, somewhat contracted; lip subreflected below, acute above, thickened within; columella short, slightly twisted, with an expanded callus partially covering a shallow small umbilicus; color variable; ground white variously banded and striped transversely with brown or black. Long. 18/20 [length, 22.7 mm.]; lat. 9/20 poll [greater diameter, 11.4 mm.]. (Newcomb.)

Hab.: Lettui [Lihue] Oahu (Newcomb; pl. 2, fig. 1).

The type of *A. sordida* Newcomb could not be found in the British Museum. All specimens labeled "*sordida*" and "M. C." (Museum Cuming) were examined, but no specimen in the entire museum was found which even faintly resembled Newcomb's figure reproduced here (pl. 2, fig. 1), nor could the type be located in the Newcomb collection at Cornell University. There is, however, in the Cornell collection, lot 30118, a series of five shells labeled "*A. sordida* Newc.", glued on a card. Each shell in the row starting from left to right was marked respectively "A", "B", "C", "D", and "E". Specimen A is definitely *A. multilineata* of Newcomb, the color on the last two whorls chocolate, spirally lined with pinkish buff. Specimen B resembles figure 6, plate 2; specimens C and D are similar to figure 4, and specimen E has a pattern like that of figure 10. All these shells are definitely Mokuleia patterns, which proved to be true of all Newcomb specimens of *A. mustelina* with the exception of one lot of *A. m. bicolor* Pfeiffer.


S
W
E
N
0 ¼ ½ Mile
PULEE
WEST
EAST PULEE
W222-1
W232-1
W231
W300-B2
W300A
W290-1
W241-1
W230
W220
W211-1
W200-6
W190-6
W190-5
KAAWA GULCH
KAUMOKUNUI GULCH
KAUMOKUIKI GULCH
MANUWAI GULCH
ALAIHEIHE GULCH
MAILI
W260-1
W250
PALIKEA GULCH
W240
W270
PUULU GULCH
KUNKAPU GULCH
KAUMOHOLI GULCH
W210-4
W210-2

MAP 5.


S
W
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0 ¼ ½ Mile
WEST PULEE
EAST PULEE
KAAWA GULCH
KAUMOKUNUI GULCH
KAUMOKUIKI GULCH
MANUWAI GULCH
ALAIHEIHE GULCH
MAILI
PALIKEA GULCH
PUULU GULCH
KUNKAPU GULCH
KAUMOHOLI GULCH

MAP 5a.

According to Newcomb the type locality is "Lettui" (Lihue). The exact area considered Lihue by Newcomb is not known, but to judge from Gulick's map in "Evolution, Racial and Habitudinal" (4), it was a general name applied to the district of Waianae Uka and probably Honouliuli. Gulick's Lihue shells, however, come from a very limited area about the subdistrict of Popouwela in Honouliuli, where *A. m. bicolor* is found. However, while Newcomb has specimens of *A. m. bicolor* in his collection, none of the upper forms, occurring at higher elevations above *bicolor*, such as *A. m. lathropae* var. or any characteristic pattern of *A. m. christopherseni* can be found in his collection. Usually older collectors obtained their shells at comparatively low elevations because the forest existed at lower altitudes than it does today. Therefore, although elongate forms of *A. m. christopherseni* var. area 68 resemble the shape of *A. m. sordida* Newcomb, I do not believe that Newcomb ever collected at a sufficient altitude to obtain *christopherseni*; I believe that *sordida* did not come from Lihue but was obtained in Mokuleia.

In Newcomb's original figure reproduced in figure 1, plate 2, the embryonic whorls are white, post-embryonic whorls with a line of yellow ocher below the white impressed sutural band, last whorl lined just above the periphery and at the periphery with yellow ocher, below the periphery banded with ochraceous tawny and mars brown, lip pale purplish vinaceous.

In the Bishop Museum collection there is no shell with identically the same form and color pattern as Newcomb's figure. The nearest approach is the specimen figured in figure 2, plate 2, from locality W240-4, which will be considered typical *A. m. sordida*. First embryonic whorl deep mouse gray shading to white, remaining two embryonic whorls white, post-embryonic whorls white, faintly tinted with pale cinnamon pink, last whorl faintly axially streaked with pale gull gray, spirally banded with pale pinkish cinnamon above the periphery, below the periphery ornamented with a band and three lines of snuff brown, and two basal bands of bister, lip and columella callus light vinaceous fawn, lip weak, not fully developed, length 22.2 mm., greater diameter 12.0 mm., spire height 12.8 mm. The embryonic whorls are quite large, height 2.5 mm., greater diameter 3.1 mm.

Distribution, area 8: **Kaimuhole Gulch,** locality W240-4, el. 1,300 ft., Russ 1932, 1933, Winne and Welch 1934, found on lantana (maps, 5, 5a, p. 32).

The banding on the last whorl of figure 3d, plate 2, is similar to that on the last whorl of Newcomb's figure, embryonic whorls white, larger and more rounded (height 3.7 mm., greater diameter 3.6 mm.), than in the shell of figure 2, plate 2, first post-embryonic whorls deep brownish drab spirally lined and axially streaked with pale drab gray, penultimate and last whorls white spirally banded with snuff brown, below the periphery the ground is light buff, shell adult, lip light vinaceous fawn, impressed sutural band white.

The usual form and color pattern of the shell in locality W240-4 is that of figure 2a, plate 2, length 21.5 mm., greater diameter 11.1 mm., spire height 12.2 mm., embryonic whorls as in figure 2, post-embryonic whorls white, spirally banded on the first post-embryonic whorl with benzo brown, last two whorls above the periphery banded with hair brown, below the periphery bister and sepia, just below the edge of the periphery above the aperture a band of drab tinted with sayal brown fades out, but is strong on the remainder of the last whorl. The spire may be shorter, length 21.2 mm., greater diameter 11.7 mm., spire height 11.0 mm., post-embryonic whorls smoke gray spirally lined with sepia; below the periphery the base is bister, faintly, spirally lined with snuff brown (pl. 2, fig. 3). The usual form of a dextral shell measures, length 21.2 mm., greater diameter 11.6 mm., spire height 11.7 mm., post-embryonic whorls white tinted and banded with pale smoke gray, banded below the white sutural band and about the base with sepia, the last one fourth whorl tinted or streaked with tawny olive (pl. 2, fig. 3b). The post-embryonic whorls may be white tinted with pale gull gray, last whorl faintly banded with pale gull gray, the last fourth of the whorl, or 7 mm. behind the edge of the lip, the shell is broken, and the part of the shell beyond the break is light gull gray spirally lined with smoke gray (pl. 2, fig. 3a). A rare pattern, found on one specimen, is colored on the post-embryonic whorls with warm sepia lined and streaked with clay color, at the edge of the periphery a band 1.5 mm. wide of light buff axially streaked with ochraceous tawny, on the last quarter of the last whorl, which fades out, the ground being tinted with sepia (pl. 2, fig. 2c). This subperipheral banded pattern, rare in Kaimuhole, is very common in old collections of *A. m. sordida*. Figure 4, plate 2 shows a specimen of *A. m. sordida* bought at Sowerby and Fulton in London in 1933, which has the usual *sordida* pattern found in old collections from the district of Mokuleia prior to 1900. The first embryonic whorl is avellaneous tinted with white, below the sutural line the last two embryonic whorls pale pinkish cinnamon, post-embryonic whorls white, first post-embryonic whorl and a half spirally lined with deep livid brown, last whorl and a half above the periphery tinted or faintly axially streaked with pale gull gray, below the warm sepia band at the edge of the periphery of the last whorl is a subperipheral band of pale pinkish buff faintly tinted with streaks of pinkish buff, on the last half whorl the band darkens to pinkish buff with a central band of cinnamon, base banded with warm sepia faintly flecked or streaked with cinnamon buff, lip and columella callus avellaneous. Many variations of this subperipheral banded color pattern occur. The last three whorls may be white above the periphery with the subperipheral band of figure 2c, plate 2. In locality W240-4, the extremes of form are shown in figures 2b, 3c, 3e, plate 2.

Figure 3c is an unusually thick spired form, length 22.4, greater diameter

12.4 mm., spire height 11.7 mm. Figure 2b is an elongate, narrow spired shell, length 21.4 mm., greater diameter 10.8 mm., spire height 12.6 mm.; the shell is dead and faded but the remnants of color on the post-embryonic whorls are pale mouse gray axially streaked or tinted with sayal brown, below the white sutural band a band of hair brown, on the last whorl above the periphery the ground shades to drab gray, below the peripheral edge of the last whorl one band of sayal brown, a band of white, and a basal band of clove brown. An extremely elongate, dextral shell has a length 22.7 mm., greater diameter 10.9 mm., spire height 14.2 mm., colored on the last two whorls with drab, tinted and axially streaked with warm sepia, banded above the periphery with a band of white, and on the base with two bands of pale pinkish buff (pl. 2, fig. 3e).

In the Gulick collection, the series of shells marked by Gulick "*A. sordida* Mokuleia" are all white shells. The entire shell is usually white lined below the periphery of the last whorl with lines and bands of vinaceous fawn (pl. 2, fig. 5). The form of this specimen is similar to Newcomb's figure of the type of *A. m. sordida* (pl. 2, fig. 1). The shell may be elongate and lined on the last whorl above the periphery with two faint lines of cinnamon, below the periphery with two lines of sayal brown and a band of bister in the umbilical region, ground of the entire shell white (pl. 2, fig. 5a). The form of the shells in this lot is not always elongate; some specimens are close to the form of figure 7, plate 2.

Table 7 shows that although little or no size differentiation occurs in the mean length of the shells when collected in different years in a definite locality, the Welch lot contains dextral shells while the Russ lots are entirely sinistral. It is difficult for two people to go to exactly the same place even when the locality is plotted on a map, for, in talking the matter over with Russ, it seems that I must have gone a few hundred yards lower in elevation than Russ did.

Table 7. Achatinella mustelina sordida Newcomb. Area 8.

Collector	Year	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ	1932	W240-4	18	5	21.0	18.5-22.5		31
Russ	1933	W240-4	27		21.5	19.5-24.5		38
Welch	1934	W240-4	23	17	21.5	19.5-23.5	7	56

Achatinella mustelina sordida var. (pl. 2, figs. 6-11).

Area 9: **Alaiheihe Gulch,** locality W230-3 el. 1,450-1,500 ft., Russ 1931, localities W230-4, el. 1,450 ft., W230-5, el. 1,500-1,600 ft., W230-6-8, el, 1,500-1,750 ft., W230-7, el. 1,650 ft., Russ 1932; W230-5-5a, el. 1,450-1,650 ft., W230-5c, el. 1,750 ft., Welch and Russ 1935, W230-5b, el. 1,650-1,900 ft., M. Langraff, W230-9, el. 1,850 ft., Russ 1935; **Alaiheihe-Kaimuhole Ridge,** locality W241-1, el. 1,650-1,750 ft., Lemke 1934 (maps 5, 5a, p. 32).

The usual form and color pattern of the shells in locality W230-3 is that shown in figure 6, plate 2, length 20.6 mm., greater diameter 11.8 mm., spire height 11.5 mm., embryonic whorls worn, retaining the white shell enamel on the last embryonic whorl, post-embryonic whorls below the impressed sutural and subsutural bands, which shade from white to pale pinkish buff, shade from light drab to buffy brown on the last whorl above the periphery; below the periphery a band of bister about 0.5 mm. wide, a band of light buff tinted with ochraceous buff about 1 mm., the remainder of the base bister, lip edged and tinted with fawn color, columella callus fawn color. The embryonic whorls when not worn are pale pinkish buff shading to white, first embryonic whorl banded on the lower half with sepia, post-embryonic whorls pale pinkish buff, spirally banded and lined with hair brown, below the periphery and just above the edge of the periphery the pale pinkish buff ground is finely spirally lined and faintly axially streaked with cinnamon, base banded with hair brown, sutural band white or pale pinkish buff (pl. 2, fig. 6a). The characteristic, light, subperipheral band may be absent, the post-embryonic whorls below the combined white sutural and subsutural bands, which shade from pale pinkish buff to pinkish buff, shade from light drab to buffy brown on the last whorl, below the periphery the ground is buffy brown banded with olive brown, the spire elongate, shell length 21.0 mm., greater diameter 11.2 mm., spire height 11.5 mm. (pl. 2, fig. 6b). The shell may be solid buffy brown without any dark bands. An obese form is figured in figure 6c, plate 2, length 20.7 mm., greater diameter 16.4 mm., spire height 10.9 mm., the color is unusually dark occurring on only one of two specimens, first post-embryonic whorls mouse gray banded with chocolate, penultimate whorl buffy brown axially streaked with fuscous, cinnamon buff almost completely covered over by spiral bands and lines and axial streaks of clove brown, impressed sutural band pale pinkish buff, lip and columella callus vinaceous fawn.

Above locality W230-3 dextral forms occur, the color pattern of figure 6, plate 2, becomes very rare being found on only one or two shells in the entire area, the color patterns while similar to those in locality W230-3 are usually banded with darker shades of brown such as figures 7, 7a, 11, plate 2. The typical form of the shell is that of figure 7, length 20.3 mm. greater diameter 12.0 mm., spire height 10.8 mm., embryonic whorls similar to figure 6, plate 2, last two and a half post-embryonic whorls below the pale pinkish buff sutural band and wide subsutural bands (1.5 mm.) buffy brown, at and below the periphery the shell is bister, lip and columella callus fawn color. The post-embryonic whorls can be pale pinkish buff, below the sutural and subsutural bands of pale pinkish buff, the first two post-embryonic whorls are bone brown, on the last whorl the ground is antimony yellow closely axially streaked with ochraceous orange, banded above the periphery with drab, and a band 1.5 mm. wide of sepia, below the periphery the base is banded with

sepia or black (pl. 2, fig. 7a). This is an example of the rare *sordida* pattern with the yellow subperipheral band similar to figure 6, plate 2. The shell may have a more elongate spire, length 20.7 mm., greater diameter 11.6 mm., spire height 11.5 mm., embryonic whorls white, post-embryonic whorls pale pinkish buff, spirally banded on the last whorl with a band of cinnamon buff above the periphery, below the periphery the ground is warm buff tinted with ochraceous orange, banded with ochraceous buff, dresden brown and black about the umbilical wall (pl. 2, fig. 7b). The post-embryonic whorls above the periphery of the last whorl light buff, below the periphery light buff spirally lined with ochraceous tawny and two bands of russet 1.5 mm. wide about the base, lip army brown (pl. 2, fig. 8). The ground of the post-embryonic whorls light buff finely axially streaked with ochraceous tawny, spirally banded and lined with bister below the periphery, sutural and subsutural band cinnamon (pl. 2, fig. 9). The ground color of the entire shell white, spirally lined on the last half whorl with sayal brown and bister (pl. 2, fig. 10). The usual color pattern in locality W230-7 is that of figure 11, plate 2, embryonic whorls white, post-embryonic whorls, below the impressed sutural and wide subsutural bands of cinnamon buff, olive buff, below the periphery of the last whorl clove brown.

In area 9 the shells decrease in size with increase in elevation. The lowest localities are dominantly sinistral above which occur pure dextral localities of shells. The localities at the upper edge of area 9 where the shells are border forms between an upper and lower race contain a mixture of dextral and sinistral shells. The shells from localities W230-6 and W230-8 were mixed together when collected because they contained dextral and sinistral shells. Locality W230-7, in between, was kept separate because the shells were all sinistral. Because of this mixture, the proportion of dextrality and sinistrality of the shells of W230-8 cannot be ascertained, nor can it be determined whether the color pattern is closer to the higher gray race of *A. m. brunibasis* var. until the localities have been recollected (table 8).

Table 8. Achatinella mustelina sordida var. Area 9.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ	W230-3	50		20.0	17.5-22.5	3	56
Russ	W230-4	34		20.0	18.5-22.5	18	25
Russ	W230-5	30		19.5	17.5-21.5	35	
Welch	W230-5a	36		20.0	18.5-21.5	50	
Welch	W230-5c	29	5	20.0	18.5-21.5	52	
Langraff	W230-5b	8		18.0	16.5-19.5	21	
Russ	W230-6 and 8	103		19.5	17.5-23.5	119	50
Russ	W230-7	45		19.5	18.5-21.5		50
Russ	W230-9		16	19.5	16.5-20.5	6	10

Achatinella mustelina sordida var. (pl. 2, fig. 12-12c).

Area 10: **Kaumokunui Gulch,** locality W200-6, el. 1,300 ft., Russ 1932, 31 live adults, mean length 20.0 mm., length range 18.5-23.5, 51 sinistrals (maps 5, 5a, p. 32).

The form of the shell is more obese than that of the Alaiheihe shells, and the shell patterns usually have more dark color forms than the Alaiheihe shells although the patterns in both places are very similar. The typical form of the shell and the usual color pattern occurring on 69 percent is that shown in figure 12, plate 2. Embryonic whorls white, post-embryonic whorls below the wide band of pale pinkish buff about the suture (2.5 mm. wide measured above the aperture) is bone brown axially streaked with buffy brown on the first two post-embryonic whorls and spirally lined with a line of sayal brown just above the periphery, lip and columella callus fawn color. This color pattern is similar to *A. m. bicolor* in form and color pattern. The form of an obese shell with a color pattern like that of figure 6b, plate 2, is shown in figure 12a, plate 2, only the impressed sutural band is white, length 18.3 mm., greater diameter 12.0 mm., spire height 13.2 mm. The usual light color pattern occurring with the pattern of figure 12 is shown in figure 12b, plate 2, post-embryonic whorls white finely axially streaked and spirally lined with ochraceous tawny and buckthorn brown, base banded with cinnamon brown, the shell an example of an elongate spired form, length 20.8 mm., greater diameter 12.8 mm., spire height 11.4 mm. The ground may be pinkish buff deepening to cinnamon on the last whorl spirally lined with snuff brown and bister (pl. 2, fig. 12c).

Achatinella mustelina sordida var. (pl. 2, figs. 13-13c, 14; pl. 1, figs. 19-19a).

Area 12: **Kaawa Gulch,** localities W190-5, el. 1,300 ft., 1 dextral, 7 sinistrals, W190-6, el. 1,350-1,500 ft., 2 dextrals, 13 sinistrals, Winne and Welch 1932, 13 adults in the combined lots, mean length 20.0 mm., length range 19.5-21.5 mm., all dead specimens (maps 5, 5a, p. 32).

In this area the buffy brown or drab gray patterns similar to those found in Alaiheihe Gulch are absent. The form of the shells is similar to that of the Kaumokunui shells differing in that the embryonic whorls are usually a shade of yellow instead of white, although white embryonic whorls occur. The typical form of the shell has a length of 20.7 mm., greater diameter 12.4 mm., spire height 11.0 mm., embryonic whorls a dirty shade of chamois, post-embryonic whorls warm blackish brown, wide sutural band (2.0 mm., side above the aperture) pale pinkish buff (pl. 2, fig. 13). The shell may be similar to figure 13, spirally banded and lined with pinkish buff, below the periphery a subperipheral band of pinkish buff axially streaked, and lined with a median line of ochraceous tawny, embryonic whorls a dirty shade of chamois (pl. 2, fig. 13a). The usual form of a dextral shell, length 21.0 mm., greater diameter 12.2 mm., spire height 11.7 mm., is shown in figure 13b,

plate 2. The shell is worn and faded. What remains of the color is similar to figure 13, except that the embryonic whorls are white and there are traces of spiral bands of pale gull gray on the last two whorls. The form of the shell may be narrower and the color pattern a light one, embryonic whorls light mouse gray banded on the upper fourth whorl with white, last embryonic whorl white tinted with light mouse gray, post-embryonic whorls white, faintly tinted with pale gull gray, first post-embryonic whorl banded with chocolate, first half of the penultimate whorl lined with a line of black below the white impressed sutural band and shading to sayal brown on the last two whorls, last half whorl lined with sayal brown, length 20.0 mm., greater diameter 11.7 mm., spire height 10.3 mm. (pl. 2, fig. 13c).

In the E. Lyman collection in Bishop Museum, the specimen shown in figure 14, plate 2, has on the original locality label merely "Waianae Mountains." From the similarity of this Lyman specimen to the dead shells of Kaawa Gulch, probably the shell is an example of a live one from lower Kaawa Gulch, either from area 12 or just below. Embryonic whorls and first post-embryonic whorls faintly lined with cinnamon, last two whorls and a half shade from mikado brown to dark livid brown on the last whorl, impressed sutural band cartridge buff, below the periphery of the last whorl a band of light buff axially streaked with ochraceous tawny, lip tinted with warm buff (pl. 2, fig. 14). The lip has probably faded to warm buff possibly having lost its pinkish color.

The length of the 31 live adult shells in locality W200-6 varies from 18.5-23.5 mm., with a mean length of 20.0 mm. The locality is dominantly sinistral, only one dextral occurring in the entire combined lot of 52 shells.

Higher in Kaawa Gulch in locality W190-7, in area 20 (p. 80), Russ found a mixture of *sordida* var. and the higher race of *griseitincta*. The characteristic *sordida* forms shown in figures 19 and 19a, plate 1 are similar to typical *A. m. mustelina* of area 1.

Achatinella mustelina sordida var. (pl. 2, figs. 15, 15a).

Area 11: **Kaumokuiki Gulch,** localities W210-2 and W210-4, el. 950 ft., Welch and Russ 1936 (located 1932 by Russ), fossils (maps 5, 5a, p. 32).

Fossil *Achatinella* are found in area 11 under large, flat rocks on the east slope of the gulch. The shells are faded and probably retain little of their original color. They are narrow and elongate. The typical form is shown in figure 15, plate 2, length 21.8 mm., greater diameter 11.8 mm., spire height 12.0 mm., embryonic whorls white, pointed, and not bicolored or as rounded as the embryonic whorls of the shells in areas 8, 9, 10 and 12. The post-embryonic whorls fawn color, impressed sutural band white, lip and columella callus white, lip edged with vinaceous buff, spire straight in outline, base flattened with the edge of the periphery slightly angled. The

typical form of a shell of the 20.5 mm. length class measures, length 20.5 mm., greater diameter 11.6 mm., spire height 10.8 mm. (pl. 2, fig. 15a).

The range of length of these fossil shells is 19.5-24.5 mm., with the mean, 21.5 mm. The total number of shells 53, one of which is dextral; 21 are adults.

Achatinella mustelina sordida var. (pl. 7, figs. 2-3*b*).

Area 14: **Palikea Gulch East Branch,** localities W250-9, el. 1,350 ft., W250-10, el. 1,450 ft., Welch and Blackman 1932, W250-11, el. 2,050 ft., Russ 1931; **Palikea West Branch,** locality W250-7, el. 1,400 ft., Russ 1932, W250-8, el. 1,600 ft., Russ 1931 (maps 5, 5a, p. 32).

The typical form and color pattern of a dextral shell in area 14 is shown in figure 2, plate 7, length 19.4 mm., greater diameter 11.4 mm., spire height 10.4 mm., embryonic whorls white, tinted on the first two whorls with pale pinkish buff, post-embryonic whorls bicolored, light drab, spirally banded and streaked with snuff brown just above and all below the periphery, white above including the impressed sutural band, lip fawn color. The impressed sutural band may be mikado brown shading to sayal brown on the penultimate, and cinnamon buff on the last whorl, last whorl a dull shade of drab gray spirally lined and banded with drab and no white subsutural band (pl. 7, fig. 2a).

While the sinistral shells in Palikea West Branch are similar to figure 1a, plate 7, more elongate forms are conspicuous in Palikea East Branch. The usual form of one of these elongate shells is shown in figure 3, plate 7; the last three whorls shade from drab axially streaked and tinted with benzo brown to drab tinted with snuff brown, length 19.9 mm., greater diameter 11.4 mm., spire height 10.9 mm. The extreme elongate specimens are typical *sordida*-like shells similar to the Kaimuhole forms. An example is shown in figure 3a, plate 7, length 21.2 mm., greater diameter 11.2 mm., spire height 12.1 mm., embryonic whorls white, first post-embryonic whorl pale drab gray axially streaked with ecru drab, shading to drab gray, axially streaked with saccardo's umber, last whorl tawny olive spirally lined with saccardo's umber, basal band warm sepia, lip fawn color. Three or four shells in area 11 have a drab gray color pattern similar to figure 3b, which is also an example of the more obese form, length 20.8 mm., greater diameter 12.7 mm., spire height 10.7 mm., first post-embryonic whorl chocolate, axially streaked with drab gray, penultimate whorl light drab, axially streaked with chocolate and lined and streaked with hair brown, last whorl drab, axially streaked with warm sepia and spirally banded with saccardo's umber, banded about the base with warm sepia.

Table 9. Achatinella mustelina sordida var. Area 14.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ	W250-7	11		20.0	18.5-21.5		14
Russ	W250-8	15		20.0	18.5-21.5	22	
Welch	W250-10	3	3	20.0	18.5-20.5		15
Russ	W250-11	3			17.5-19.5	8	

The lots of shells from area 14 are too small to be a criterion of the mean length value of the shells in this region. As erroneous as the figures may be, however, it is interesting to note that the mean length is constantly 20 + mm. and that all the localities are below 1,650 ft. Here also the sinistral localities are all the lower ones with the higher localities 100 percent dextral.

Lower down in Palikea Gulch, locality W250-4, elevation 900 feet., W250-5, elevation 1,000 feet, area 13, Welch and Blackman found a dead sinistral specimen of *Achatinella* in each locality (maps 5, 5a, p. 32). The form and color pattern of the shell in W250-4 is similar to figure 3a, plate 7, length 20.5 mm., greater diameter 12.0 mm., spire height 11.0 mm. The specimen from W250-5 is a broken fragment of a juvenile shell; the color of the base is intact, which is seen when the shell has been broken back a whorl, leaving the internal portion of the whorl exposed to view, white, finely, axially streaked with light gull gray, base banded with a line and a band of natal brown in the umbilical region. These two specimens indicate that the typical slender Kaimuhole forms of locality W240-4 existed in lower Palikea Gulch.

Achatinella mustelina sordida var. (pl. 7, figs. 1-1c).

Area 18: **Kihakapu Gulch,** locality W260-1, el. 1,750 ft., Russ 1932; **Puulu Gulch,** locality W270-8-8a, el. 1,650-1,750 ft., Welch and Hosaka 1932 (maps 5, 5a, p. 32).

The shells of locality W260-1 are brown color forms which are intermediate in form between *A. m. brunibasis* and an uncollected lower race of *A. m. sordida*. The usual form of a dextral shell (pl. 7, fig. 1) is very similar to the usual form of a dextral shell in Alaiheihe Gulch. Embryonic whorls white with the usual black or dark tip of the first half embryonic whorl, first post-embryonic whorl pale pinkish buff banded at the suture with tawny olive and pale snuff brown on the lower three fourths of the whorl, last two whorls below the suture and subsutural bands of pale pinkish buff, snuff brown, base bister axially streaked with snuff brown and lined with bister, lip army brown, length 20.4 mm., greater diameter 12.4 mm., spire height 10.5 mm. The usual form of a sinistral shell measures, length 20.9 mm., greater diameter

12.8 mm., spire height 10.6 mm., embryonic whorls white, post-embryonic whorls tawny olive above the periphery, banded with a band of white shading to pinkish buff, below the periphery banded with snuff brown, lip army brown (pl. 7, fig. 1a). This usual sinistral form is quite different from the Alaiheihe shells, being more obese and less elongate of spire (compare with pl. 2, fig. 6). The shell may be narrow and elongate, length 20.2 mm., greater diameter 10.9 mm., spire height 11.9 mm., color pattern similar to figure 1a, plate 7, but having the basal band warm sepia (pl. 7, fig. 1b). The entire last whorl may be warm sepia. A light lineate pattern (pl. 7, fig. 1c) figs. 7b, 8) but differs from the Alaiheihe shells in usually having the entire base below the periphery banded. The post-embryonic whorls are white, spirally lined with ochraceous tawny, and tinted on the last whorl with ochraceous tawny, basal band chocolate (pl. 7, fig. 1c). The basal band may be black.

Locality W260-1 is the only pure colony on hand of this particular form of *A. m. sordida*. Locality W270-8-8a is a mixed one containing two distinct forms, being the border region between *A. m. sordida* var. and *A. m. mailiensis*, and represented by dead shells which are useful merely to denote the presence of this form of *A. m. sordida* in Puulu Gulch. The division line between the two races is probably in the center of Puulu Gulch near the stream bed. The length range of the shells of locality W260-1 is 18.5-22.5 mm., with the mean at 20.4 mm. The shells are dominantly dextral, 30 out of 189 specimens sinistral, all live shells.

Achatinella mustelina mailiensis, new subspecies (pl. 7, figs. 4-6a).

The shell is intermediate in shape between *A. m. sordida* var. of area 18 and *A. m. brunibasis*, embryonic whorls white, post-embryonic whorls pinkish buff, spirally lined, finely axially streaked and tinted with light pinkish buff, the entire base below the edge of the periphery fuscous black, faintly lined at the edge of the periphery with pinkish buff, and below the periphery a line of ochraceous orange about the middle of the half whorl, lip fawn color, thin, not completely thickened, length 19.0 mm., greater diameter 11.8 mm., spire height 9.1 mm. (pl. 7, fig. 4).

Distribution, area 17: **Puulu Gulch**, type locality W270-8a, el. 1,750 ft., Russ 1932, mean length 19.5 mm., length range 18.5-21.5 mm., 41 live adults, 1 dextral, 66 sinistral, all live specimens. Also found in locality W270-9, el. 2,250 ft., Meinecke 1936, mean length 19.0 mm., length range 17.5-21.5 mm., 4 dextrals and 31 sinistrals, 8 live and 4 dead adults. This is an example of a size change in shells between a locality above and one below 1,900 feet (map 5, 5a, p. 32).

The holotype is not quite as usual a form as the shape of figure 5, plate 7, length 19.8 mm., greater diameter 11.5 mm., spire height 10.2 mm., embryonic whorls white, post-embryonic whorls white tinted and spirally lined with vinaceous buff, impressed sutural band shades from tilleul buff to vinaceous buff on the last whorl; below the periphery last whorl tinted with pale neutral gray at the edge of the periphery, shading at the base and on the last

fourth whorl to a ground tinted with ochraceous tawny, banded with clove brown. The shell may be pale gull gray above the periphery with a line of sayal brown below the white subsutural band, on the first half of the last whorl axially streaked and tinted with ochraceous tawny, last half spirally lined with drab, base banded with bone brown, with the *sordida*-like subperipheral band of pinkish buff (pl. 7, fig. 5a). An extreme, obese form measures, length 18.7 mm., greater diameter 12.0 mm., spire height 9.0 mm., post-embryonic whorls shade from light mouse gray to aniline black on the last whorl, with a subperipheral band of white, suture banded with a wide band of pinkish buff (2 mm. wide above the aperture) (pl. 7, fig. 5b). The elongate form does not vary much from the usual form, length 19.7 mm., greater diameter 11.2 mm., spire height 11.2 mm., embryonic whorls pale pinkish buff, first three post-embryonic whorls and impressed sutural band cinnamon buff, first half of the last whorl cinnamon buff immediately below the sutural band, above the periphery saccardo's umber, on the last whorl below the periphery and on the last half of the last whorl above the periphery burnt umber (pl. 7, fig. 5c). Figure 5d, plate 7, shows the form of a dextral specimen which resembles *A. m. brunibasis* in form; the color pattern is similar to figure 4, plate 7. The dark basal color pattern of figure 4 and the line color pattern of figure 5 occur on about 50 percent of the shells.

In locality W290-1 of *A. m. brunibasis,* Meinecke found two shells with the color pattern of *A. m. mailiensis* (pl. 7, figs. 6-6a). The shell of figure 6a is thin, embryonic whorls worn, the color shades from warm buff to light buff, post-embryonic whorls walnut brown darkening to light seal brown or black, last half whorl light buff axially streaked and tinted with clay color, sutural band walnut brown up to the last half whorl where it is the color of the ground, subsutural band pale pinkish buff or pinkish buff darkening to sayal brown and disappearing on the last whorl. The other shell (pl. 7, fig. 6) has the embryonic whorls antimony yellow, first post-embryonic whorl warm buff, banded and lined with mars brown; penultimate and first part of last whorl pale pinkish buff, banded just above the periphery with black, and faintly, axially streaked and faintly tinted on the penultimate with buffy brown, on last whorl banded with buffy brown, last half whorl buffy brown lined with black, below the periphery base black with a line of antimony yellow, just below peripheral edge, a band of buffy brown lined with black. Figure 6a is a diseased specimen and lacks the internal pale gull gray enamel usually found in forms of *brunibasis* and in the shell of figure 6.

Achatinella mustelina waianaeensis, new subspecies (pl. 3, figs. 4-6).

Shell obese with a rounded last whorl, spire concave differing from the closely related form of *A. m. altiformis* in color pattern and having a very characteristic, wide white band about the suture, composed of a composite, impressed sutural band and subsutural band, while *A. m. altiformis* has only a fringe of white at the upper edge of the

impressed sutural band. The embryonic whorls of *A. m. altiformis* are white while those of *A. m. waianaeensis* may be white or bicolored. The embryonic whorls of the holotype are bicolored, upper half white, lower half tawny, first half post-embryonic whorl white, last two whorls and a half buffy brown, axially streaked with natal brown, clove brown and olive brown; lip edge fawn color, shading to white or pale vinaceous fawn at the columella callus and on inner margin of the lip; length 18.7 mm., greater diameter 12.1 mm., spire height 9.7 mm., number of whorls 6½ (pl. 3, fig. 4).

Distribution, area 29: **Pahole-Kapuna Ridge,** type locality W160-4, el. 2,300-2,400 ft., Meinecke 1933, Russ 1932, W160-1a, el. 2,000 ft., W160-1b, el. 2,150 ft., W160-1c-2-3a, el. 2,250 ft. Lemke and Lemke, Jr. 1933, W160-1, el. 2,050-2,100 ft., W160-1c, el. 2,100-2,250 ft., W160-2, el. 2,250 ft., W160-6, el. 2,200 ft., W160-5, el. 2,100-2,250 ft., Russ 1932. Localities of larger extent were collected by Heine, Lemke, Lemke, Jr., Russ, and Meinecke, but only the most localized areas were used for plottings. **Kapuna Gulch,** localities W160A-3, el. 1,550 ft., W160A-4, el. 1,650-2,000 ft. Russ 1933, W160A-5, el. 1,650-2-000 ft., Russ 1932, W160A-5a, el. 2,000 ft., W160A-5b, el. 2,000 ft., W160A-5c, el. 2,050 ft., W160A-5d, el. 2,250 ft., Welch and Winne 1935; **Pahole-Makua Ridge,** locality W150B-10, el. 2,350-2,400 ft., Meinecke 1933; **Pahole Gulch,** localities W150B-2, el. 1,450-1,550 ft., Russ 1932, Welch and Yamaguchi 1935, on native trees and lantana, W150B-7a, el. 1,650-1,750 ft., Russ 1932, W150B-7, el. 1,550 ft., Lemke and Lemke, Jr. 1933 (maps 3, 3a, p. 18).

The range of form of the shell in the type locality is shown in figures 5, 5a, 5b, plate 3. The obese form measures, length 18.2 mm., greater diameter 12.5 mm., spire height 9.0 mm., post-embryonic whorls pale smoke gray axially streaked with drab, hair brown and benzo brown (pl. 3, fig. 5). The usual narrow form measures 18.7 mm., greater diameter 11.6 mm., spire height 9.6 mm., spire not as concave as holotype, last two post-embryonic whorls mouse gray axially streaked with clove brown, natal brown, buffy brown (pl. 3, fig. 5a). The typical form of a sinistral shell measures, length 18.3 mm., greater diameter 12.0 mm., spire height 8.3 mm., embryonic whorls white, penultimate whorl benzo brown axially streaked with pinkish buff, last whorl olive brown axially streaked with clove brown (pl. 3, fig. 5b). A rare color form found on only two specimens in the combined Russ and Meinecke lots from locality W160-4 has the embryonic whorls colored white, shading to cream buff on the last whorl, post-embryonic whorls brownish olive axially streaked with hair brown and benzo brown, the usual white sutural band is light buff (pl. 3, fig. 6).

Table 10. Achatinella mustelina waianaeensis Welch. Area 29.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W160-1	5	8	19.5	17.5-21.5	20	
Lemke	W160-1a	54		19.0	16.5-21.5	12	82
Lemke	W160-1b	24		19.0	17.5-20.5	6	31
Welch	W160-1c	28		19.0	16.5-20.5	5	42
Welch	W160-2		5	19.0	18.5-19.5	5	8
Lemke	W160-1c-2-3a	70		18.5	16.5-20.5	48	79
Meinecke	W160-3	45		20.0	16.5-21.5	88	
Meinecke	W160-4	51	11	18.5	16.5-20.5	52	41
Russ	W160-4	29		18.5	16.5-20.5	2	48
Welch	W160-5	16	2	19.5	17.5-21.5	32	2
Welch	W160-6		8	19.0	18.5-20.5	19	1
Russ	W160-7	8		19.0	17.5-19.5	16	
Russ	W160A-3	12		20.0	18.5-22.5	8	8
Russ	W160A-4	11		18.5	17.5-19.5	12	
Russ	W160A-5	8		19.5	18.5-21.5		12
Welch	W160A-5a-5b-5c-5d		26	19.0	17.5-21.5		
Welch	W160A-5a		3			14	
Welch	W160A-5b		9	18.5	17.5-21.5	4	14
Welch	W160A-5c		7	19.0	17.5-20.5	4	13
Welch	W160A-5d		6	19.0	17.5-20.5	4	5
Russ	W150B-2	45		19.0	17.5-21.5	7	70
Lemke	W150B-7	31		19.5	18.5-19.5	39	1
Russ	W150B-7a	62		20.0	18.5-22.5	90	3
Meinecke	W150B-10	21	13	19.0	17.5-21.5	1	40

Table 10 is puzzling as regards the size of the shells in area 29, for they do not show size gradation with altitude. Locality W160-3 with a mean length value of 20 + mm. occurs between localities W160-7 and W160-4 with mean length values of 19 + and 18 + mm. respectively. Locality W150B-10 on the Pahole-Makua Ridge, above but at the same elevation as locality W160-4, has larger shells than W160-4. Similarly the Cooke lot of shells from the approximate region of W160A-6 (see area 28, table 10a) are larger than those from W160-4. Localities W160A-9 and 9a also have larger shells than lower localities in the same gulch. Shell size in area 29 from these data appears to vary at random, dependent possibly on local conditions, and not correlated with altitude. It must be pointed out, however, that this area has not been checked, and that all localities except W160-4 have been collected but once as far as the data on hand are concerned. This region is also complex in the multiplicity of small gulches and should be carefully recollected in order to determine whether this random size variation actually exists without a doubt of error in the plotting of localities. All the localities with the excep-

tion of W160-3, W160-5 and W160-9a above 1,900 feet, have a mean length of 19 + or 18 + mm. and in this agree with size variation found in localities to the west in the district of Mokuleia.

Achatinella mustelina waianaeensis var. (pl. 3, figs. 1-3; pl. 4, fig. 20).

Area 28: **Kapuna-Keawapilau Ridge,** localities W161B-1, el. 2,250 ft., W161B-2, el. 2,300 ft., W161B-3, el. 2,350 ft., Meinecke 1933; **Kapuna-West Makaleha Ridge,** W160A-9, el. 2,450 ft.; **Kapuna Gulch,** W160A-9a, el. 2,350 ft., W160A-9b, el. 2,400 ft., Lemke and Lemke Jr. 1933; **Kapuna-Makua Ridge,** W160A-10, el. 2,500 ft., Meinecke 1935, general region of locality W160A-9-10 (?), Cooke 1908, general region of W160B-6 (?), approximate el. 2,350-2,400 ft., Cooke 1907; **Keawapilau Gulch,** W160B-6, el. 2,300 ft., W160B-7, el. 2,300 ft., Meinecke 1933; **Keawapilau-West Makaleha Ridge,** locality W160-7a, el. 2,325 ft., Meinecke 1933; **West Makaleha-Makua Ridge,** localities W171D-3, el. 2,250 ft., W171D-4, el. 2,200 ft., Meinecke 1933; **Makua Valley,** W501-8, el. 1,500-1,750 ft., Russ 1932 (maps 3, 3a, p. 18).

The outstanding difference between the shells of area 28 and typical *waianaeensis* is the presence of a narrow sutural band similar to *A. m. altiformis* or *brunicolor*. Locality W160-6 (map 3, p. 18) which may be plotted too far to the west on the Kapuna-Makua Ridge, is made of 57 percent of a narrow sutural banded form, and 43 percent typical *waianaeensis* pattern. The locality is undoubtedly a border one between the areas of two closely related forms. The usual color pattern is not axially streaked and resembles that of *A. m. altiformis* Welch (pl. 4, figs. 15a, 18a). The color may be lighter although that is less usual, the last two post-embryonic whorls mouse gray (pl. 3, fig. 1).

The form and usual color pattern in the remainder of the localities with the exception of W171D-3-4, is illustrated in figure 2, plate 3, embryonic whorls white, post-embryonic whorls shade from white to white axially streaked and spirally lined with army brown, last two whorls warm sepia, lip and columella callus white. The sinistral form of the shell is shown in figure 3, plate 3, the color pattern of this shell being slightly darker, the post-embryonic whorls warm sepia tinted with bone brown.

In locality W171D-3-4, the dark color pattern of figure 2, plate 3, does not occur. The usual pattern is that illustrated in figure 20, plate 4, length 19.7 mm., greater diameter 12.0 mm., spire height 9.5 mm., number of whorls 6½, first embryonic whorl and a half vinaceous fawn, last embryonic whorl and a half white, first half of first post-embryonic whorl white, last half natal brown lined and streaked with white and light mouse gray, last two whorls light mouse gray spirally lined and axially streaked with drab, lip and columella callus light buff, impressed sutural band narrow, white streaked with vinaceous fawn.

Table 10a. Achatinella mustelina waianaeensis var. Area 28.

Collector	Locality	Adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Meinecke	W161B-1	6	19.5	17.5-20.5	6	
Meinecke	W161B-2-3	8	18.5	17.5-19.5	18	2
Meinecke	W160B-6	34	18.5	17.5-19.5	39	14
Meinecke	W160B-7	10	19.0	19.5-21.5	16	
Meinecke	W160B-7a	5	19.0	16.5-20.5	13	
Meinecke	W160A-9	24	18.5	17.5-21.5		37
Lemke	W160A-9a	43	20.0	18.5-19.5	60	
Lemke	W160A-9b	6	19.5	18.5-20.5	5	11
Meinecke	W160A-10	37	19.0	16.5-21.5	28	29
Cooke	W160A-9-10(?)	37	19.5	16.5-20.5	15	29
Cooke	W160A-6(?)	243	19.5	16.5-22.5	290	86
Meinecke	W171D-3	7	20.0	18.5-21.5		8
Meinecke	W171D-4	7	20.0	18.5-21.5		12

In table 10a is shown the same random variation in length noted in area 29. Moreover no relation exists between altitude and the turn of coil of the shell.

Achatinella mustelina waianaeensis var. (pl. 3, figs. 8-8b).

Area 30: **Kapuna Gulch,** locality W160-2a, el. 1,950 ft., Russ 1933 (maps 3, 3a, p. 18).

Russ found here a large gray form of *A. m. waianaeensis*. The typical form of the shell is shown in figure 8, plate 3, length 21.2 mm., greater diameter 12.6 mm., spire height 11.7 mm., number of whorls 7; first embryonic whorl and a half faintly banded on the lower half of the whorl with pale vinaceous fawn, remaining embryonic whorls white, first post-embryonic whorl white, axially streaked with vinaceous brown, last two whorls and a half pale mouse gray axially streaked with pale neutral gray and natal brown; sutural band white, lip light pinkish cinnamon tinted with pinkish buff. A narrow shell is shown in figure 8a, plate 3, which also shows a straight spired shell, the color pattern is similar to figure 5a, plate 3, length 21.0 mm., greater diameter 12.0 mm., spire height 11.4 mm. An obese form with the color pattern similar to figure 8, plate 3, is shown in figure 8b, length 21.4 mm., greater diameter 13.5 mm., spire height 11.4 mm., the band about the suture is especially wide measuring .5 mm., more than that of the shell of figure 8. The embryonic whorls may be pure white or there may be a faint trace of a band on the first two embryonic whorls. No specimens have the colored tip of figure 4, plate 3.

The shells were collected on lantana, 158 adults in all, having a mean length of 21.5 mm., length range 18.5-23.5 mm., 205 dextrals. The extremely large shells in area 30 which are 100 percent dextral are exceedingly difficult

to account for when viewed on the map. In the field, however, the problem looks more simple. All the W160 localities are higher than W160-2a and the nearest localities W160-1 and W160-1d are separated from W160-2a by a high, steep, bare cliff so that the shells in W160-2a are set apart from the remainder of the smaller, higher Pahole-Kapuna Ridge shells. This race of *A. m. waianaeensis* may be an intermediate one between the lower subspecies of *A. m. griseipicta* and typical *waianaeensis*. The color pattern and general shape of the shells are closest to *waianaeensis*, the size closest to *griseipicta*.

Achatinella mustelina waianaeensis var. (pl. 3, figs. 7-7c).

Area 31: **Pahole Gulch,** localities W150B-1, el. 1,350-1,500 ft., on *Sapindus* trees, number of adults 162, mean length 19.0 mm., length range 16.5-21.5, 13 dextrals, 242 sinistrals, Russ 1932, all live shells, W150B-4, el. 1,300 ft., dead shells collected under a rock near the forest fence, 14 adults, mean length 20.0 mm., length range 18.5-20.5 mm., 40 dextrals, W150B-3, el. 1,300 ft., 1 dead dextral, W150B-3a, el. 1,250 ft., 2 dextrals and 3 sinistrals, Welch and Yamaguchi 1935 (maps 3, 3a, p. 18).

The shells in locality W150B-1 are a light gray race of *A. m. waianaeensis*, having a similar color pattern to the larger, light gray forms of area 30. The embryonic whorls are white and the post-embryonic whorls have a wide, white band about the suture about 1 mm. wider than that of the type of *A. m. waianaeensis*. The typical form of the shell was selected from the 18.5 mm. length class because it contained the largest number of specimens. The typical form of 50 percent of the shells of the 18.5 length class is elongate, length 18.0 mm., greater diameter 11.4 mm., spire height 9.2 mm., embryonic whorls white, first post-embryonic whorls pale pinkish cinnamon axially streaked with pinkish buff, last two whorls and a half drab gray, axially streaked with benzo brown, lip light pinkish cinnamon (pl. 3, fig. 7). The other 50 percent of the shells of the 18.5 length class resemble figure 7a, plate 3, length 18.7 mm., greater diameter 11.7 mm., spire height 9.4 mm., last two whorls and a half pale drab gray axially streaked with ecru drab. The obese form of the shell measures, length 18.4 mm., greater diameter 12.0 mm., spire height 8.7 mm., last two whorls pallid mouse gray axially streaked with ecru drab (pl. 3, fig. 7b). An extremely elongate specimen has a length of 18.2 mm., greater diameter 10.5 mm., spire height 9.8 mm., color pattern of figure 7c, plate 3, similar to figure 7, plate 3.

The dead shells in the lowest locality in Pahole Gulch, W150B-4, have a badly faded color pattern. The remains of the color appear to be the same as that found on the shells in W150B-1.

Locality W150B-2 is a border locality, a mixture of the darker, typical *waianaeensis* patterns and the light gray colors of locality W150B-1.

The two lowland localities, W150B-1 and W150B-2, all below 1,600 ft., are exceptions to what is found to the east in Mokuleia where the mean length at low elevations below 1,650 ft. is 20 or 21+ mm. Length size from

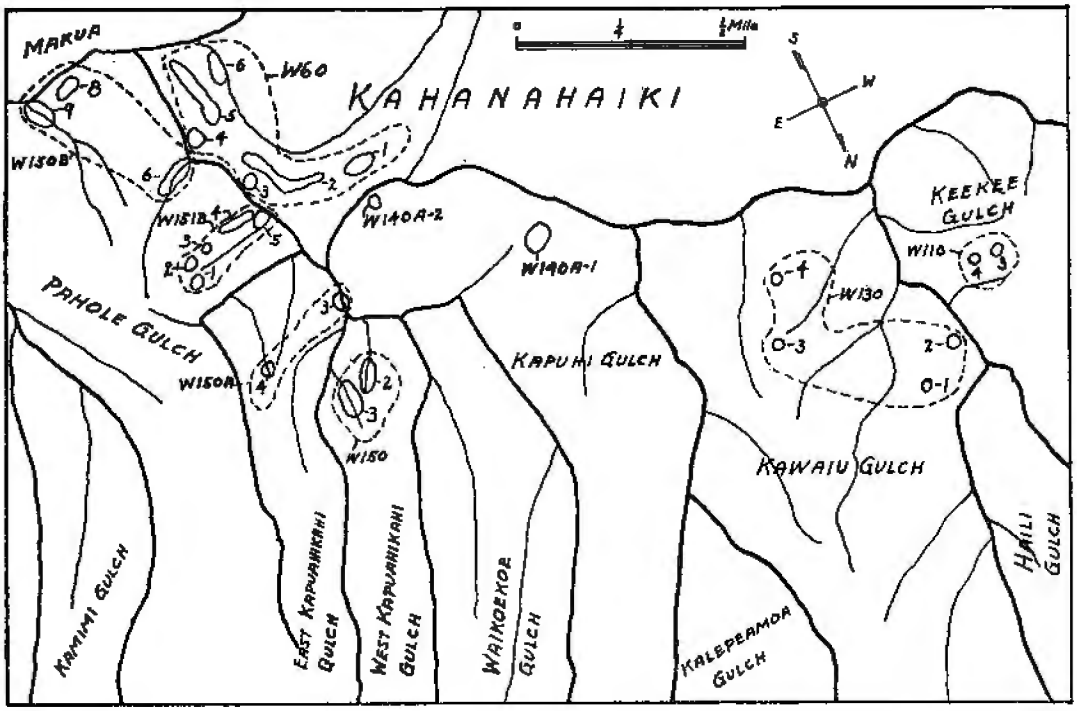
these data is not merely dependent on altitude but possibly other factors. To the east of locality W150B-1-2 and to the northwest of locality W160-2a in Kapuna Gulch, the intervening country is quite barren on the tops of the ridges and only a remnant, scattered forest exists in the gulch. In this barren region, a lowland light gray race of *A. m. waianaeensis* probably existed at one time of which only a trace remains today. At W160-2a, this lowland race graded into the larger, lowland *A. m. griseipicta* forms which could account for the size of the shells in this locality. But to the west, the gray shells graded into the smaller *waianaeensis* forms of Pahole Gulch. No intermediate or lowland localities are known to me. Possibly in the future, dead shells may be found at low elevations under rocks on rocky talus slopes.

The form and size of the shells in localities W150B-1 and 2 may be due to the fact that no barriers are present between the upland Pahole-Kapuna Ridge and the gulch bottom of Pahole, the two regions being joined by a continuous, thickly wooded slope. The small highland *A. m. waianaeensis* could easily migrate down from the upland localities to W150B-2 where the lower gray race is encountered. However, while the color pattern of the gray race is maintained, the size of the shells grade into the smaller race. If migration does occur between the higher and lower localities, why is not the small remnant gray race completely obliterated by cross breeding, so that no light gray forms exist? Why do they only go up to locality W150B-2 and there become mixed with the higher, darker forms? The shells in locality W150B-1 today are separated by a short distance of three or four hundred yards from locality W150B-2, and the intervening country is grassy, the forest scattered and not very propitious for the growth of land shells. Therefore, the shells in locality W150B-1 maintain themselves almost independent of the higher locality.

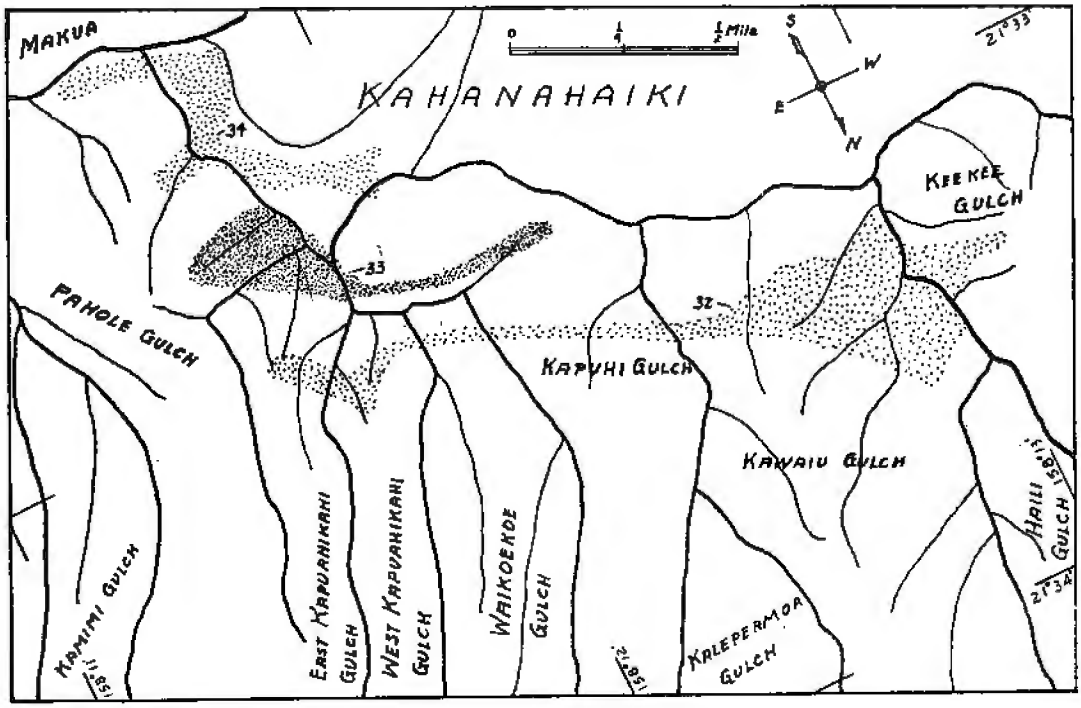
If a line is drawn from locality W150B-10 through localities W150B-7a and W150B-2, we have the western limit of the typical form of *A. m. waianaeensis*. To the west, races of shells occur which differ in color pattern, form, and size from typical *A. m. waianaeensis* but which nevertheless are so close to the shells of area 30 that individuals, selected specimens from these western localities cannot be separated from the typical form. The western forms are subdivided into areas 32, 33, 34.

Achatinella mustelina waianaeensis var. (pl. 3, figs. 9, 9a).

Area 34: **Pahole-Makua Ridge,** localities W150B-9, el. 2,150-2,250 ft., W150B-8, el. 2,050-2,250 ft., Meinecke 1933; **Pahole Gulch,** locality W150B-6, el. 2,000-2,200 ft., Meinecke 1930; **Pahole-Kahanahaiki Ridge,** localities W60-1, el. 1,550-1,700 ft., W60-2, el. 1,950-2,000 ft., Russ 1932; W60-3, el. 1,950-2,000 ft., W60-4, el. 2,100-2,150 ft., W60-5, el. 2,050-2,250 ft., Meinecke 1933; W60-6, el. 2,150-2,250 ft., Lemke and Lemke Jr. 1933; **Kapuhi-Kahanahaiki Ridge,** locality W140A-2, el. 1,850 ft., Meinecke, E. J. Meadows 1933 (maps 6, 6a, p. 50).


MAKUA
KAHANAHAIKI
W60
W150B
W151B
W140A-2
W140A-1
W150A
W150
W110
W130
KEEKEE GULCH
PAHOLE GULCH
KAPUHI GULCH
KAWAIU GULCH
HAILI GULCH
KAMIMI GULCH
EAST KAPUAHIKAHI GULCH
WEST KAPUAHIKAHI GULCH
WAIKOEKOE GULCH
KALEPEAMOA GULCH
0 1/4 1/2 Mile
S W E N

MAP 6.


MAKUA
KAHANAHAIKI
KEEKEE GULCH
PAHOLE GULCH
KAPUHI GULCH
KAWAIU GULCH
HAILI GULCH
KAMIMI GULCH
EAST KAPUAHIKAHI GULCH
WEST KAPUAHIKAHI GULCH
WAIKOEKOE GULCH
KALEPEAMOA GULCH
0 1/4 1/2 Mile
S W E N

MAP 6a.

Area 34 contains shells close in size and form to typical *A. m. waianaeensis* but the color patterns tend to be more brown and are similar to color shades found in area 32. On the limital western edge of area 34 is locality W140A-2 which has slightly different patterns from the other localities. Here the darkest color forms have on the last two and half whorls a ground of pinkish buff shading to cinnamon buff and sayal brown axially streaked with close set lines of sayal brown, snuff brown and warm sepia (pl. 3, fig. 9). A more usual pattern (pl. 3, fig. 9a) has a white spire and the last one and a half whorls pale pinkish buff, axially streaked and spirally lined with pinkish buff and cinnamon buff. This pattern is very similar to the lineate pattern found on the shells in the region of Keawapilau and Makaleha. The spire of the shells in area 34 becomes increasingly less concave the farther west the locality. In W140A-2 there is a mixture of shells with narrow, white sutural bands similar to figures 8 and 8a, plate 3, and shells with the usual, wide, white sutural band of *A. m. waianaeensis*.

Table 11. Achatinella mustelina waianaeensis var. Area 34.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Meinecke	W150B-8	20	11	19.0	17.5-21.5	48	
Meinecke	W150B-9	7		19.0	18.5-19.5	7	
Meinecke	W150B-6	22	1	18.5	16.5-20.5	47	32
Russ	W60-1	14		20.5	17.5-22.5	1	17
Russ	W60-2	15		19.5	17.5-21.5	24	
Meinecke	W60-3	37	4	20.0	17.5-21.5		
Meinecke	W60-4	28	1	20.0	17.5-22.5		
Meinecke	W60-5	95	32	19.5	17.5-21.5	7	158
Lemke	W60-6	12		19.0	18.5-21.5	2	21
Meinecke	W140A-2	113	24	19.5	17.5-22.5	189	

Elevation and size are not correlated in area 34. The shells in localities above 1,900 ft. have a mean length of 20+, 19+, or 18+ mm. Locality W60-2 is hard to understand, since the shells are smaller than in the localities above and below it. In the W60 localities, the lower localities tend to have sinistral shells, grading at higher localities to dominantly dextral localities, which in turn grade to dominantly sinistral localities.

Achatinella mustelina waianaeensis var. (pl. 3, figs. 10-12).

Area 33: **Pahole Gulch,** localities W151B-1, el. 1,650 ft., Lemke 1933, W151B-2, el. 1,650-1,700 ft., W151B-3, el. 1,700 ft., W151B-4, el. 1,750-1,950 ft., Russ 1932, W151B-5, el. 1,900-2,000 ft., Meinecke 1933; **Kapuhi-Kapuahikahi Ridge,** locality W150A-3, el. 2,050 ft., Russ 1932; **Kapuhi Gulch,** locality W140A-1, el. 1,500 ft., Russ 1932 (maps 6, 6a, p. 50). This form also collected by E. H. Bryan, Jr., and O. Swezey.

The shells are comprised mostly of forms with spires straight in outline, size greater than typical *waianaeensis,* color patterns dominantly browns mixed with gray or entirely grayish. The typical form of an elongate shell 12.5 mm. wide may have a long or a short spire. The short spired form measures, length 22.1 mm., greater diameter 12.6 mm., spire height 11.5 mm., embryonic whorls upper half white, lower half pale pinkish buff shading to white on the last embryonic whorl; post-embryonic whorls light drab axially streaked with smoke gray, lip pinkish buff, sutural band white (pl. 3, fig. 10). The other 55 percent of the 22.5 mm. class are narrower, length 22.5 mm., greater diameter 12.2 mm., spire height 12.1 mm., color pattern similar to figure 10 (pl. 3, fig. 10a). Forty-two percent of the shells of the 22.5 mm. class have an obese form, length 22.8 mm., spire height 11.3 mm., greater diameter 13.2 mm. (pl. 3, fig. 10b). This specimen shows a shell with a slightly convex spire. The form of a dextral shell is illustrated in figure 11, plate 3.

The shells in locality W140A-1 differ slightly from those described for area 33. The typical form of the shell measures 20.8 mm., greater diameter 12.7 mm., spire height 10.6 mm., post-embryonic whorls pallid mouse gray faintly axially streaked with fine streaks of ecru drab, lip pinkish buff (pl. 3, fig. 12). The embryonic whorls may be white or bicolored as figure 4, plate 3. This light gray color pattern is the usual one in W140A-1. The darkest color pattern is that of a shell colored on the last three whorls with a shade between buffy brown and light drab.

Table 12. Achatinella mustelina waianaeensis var. Area 33.

Collector	Locality	Live adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Lemke	W151B-1	7	21.0	18.5-23.5		13
Russ	W151B-2	19	21.0	18.5-23.5		27
Russ	W151B-3	2			5	2
Russ	W151B-4	13			23	
Russ	W151B-3-4	15	22.5	20.5-24.5		
Meinecke	W151B-5	4		20.5-22.5	10	
Russ	W150A-3	57	22.5	20.5-24.5	1	92
Russ	W140A-1	142	20.0	16.5-22.5	170	

The sudden increase in size between the shells of areas 33 and 29 from localities at similar elevations is striking, and a further proof that no correlation exists in this region between size and elevation. Locality W140A-1, moreover, at lower elevation than other localities in area 33, has the smallest shells. Thus where size decreases with increase in elevation in the district of Mokuleia to the west, here the shells decrease in size with decrease in elevation.

Achatinella mustelina waianaeensis var. (pl. 3, figs. 13-16).

Area 32: **East Kapuahikahi Gulch,** locality W150A-4, el. 1,550 ft., Welch and Yamaguchi 1935; **West Kapuahikahi Gulch,** W150-2, el. 1,550-1,650 ft., W150-3, el. 1,500-1,600 ft., Russ 1932, W150-2-3, Lemke and Lemke Jr. 1933; **Kawaiu Gulch,** localities W130-1, el. 1,500-1,650 ft., W130-2, el. 1,750 ft., W130-3, el. 1,450-1,500 ft., W130-4, el.1,550-1,650 ft., Russ 1932; **Keekee Gulch,** localities W110-3, el. 1,600-1,650 ft., W110-4, el. 1,600-1,650 ft., Russ and Welch 1935 (maps 6, 6a, p. 50).

Below the light grayish colonies and west of Pahole Gulch, all the shells are brown color forms. Taking locality W130-3 as typical the usual form of the shell measures, length 20.2 mm., greater diameter 12.4 mm., spire height 10.0 mm., embryonic whorls white, first half post-embryonic whorl white, last two whorls and a half snuff brown axially streaked with light drab and a light shade of snuff brown, lip and columella callus pale ochraceous buff, band about the suture white (pl. 3, fig. 13). An extreme, elongate shell is 20.4 mm. in length, greater diameter 11.8 mm., spire height 11.4 mm., the outline of the shell is straight, not convex as is the typical form (pl. 3, fig. 13a). An extreme obese form measures, length 20.6 mm., greater diameter 14.1 mm., spire height 9.8 mm., post-embryonic whorls prouts brown axially streaked with hair brown, lip vinaceous buff (pl. 3, fig. 13b). The typical form of a shell of the 19.5 mm. class with a color pattern similar to figure 25 measures, length 19.7 mm., greater diameter 12.2 mm., spire height 10.6 mm., embryonic whorls bicolored as in typical *A. m. waianaeensis* (pl. 3, fig. 13c). The typical form of a sinistral shell of the 19.5 mm. length class is shown in figure 14, plate 3, length 19.8 mm., greater diameter 12.6 mm., spire height 9.5 mm.

In locality W150-2, 6 shells in the Russ collection, no. 133157, have a line of white above the periphery similar to Gulick's specimen of *A. m. decolor* Welch from Mokuleia (pl. 1, fig. 23). The color pattern otherwise is the usual one of figure 13, plate 3 (pl. 3, fig. 15).

The forms in Keekee Gulch are drab axially streaked with warm sepia and verona brown, embryonic whorls similar to the typical *A. m. waianaeensis* (pl. 3, fig. 16).

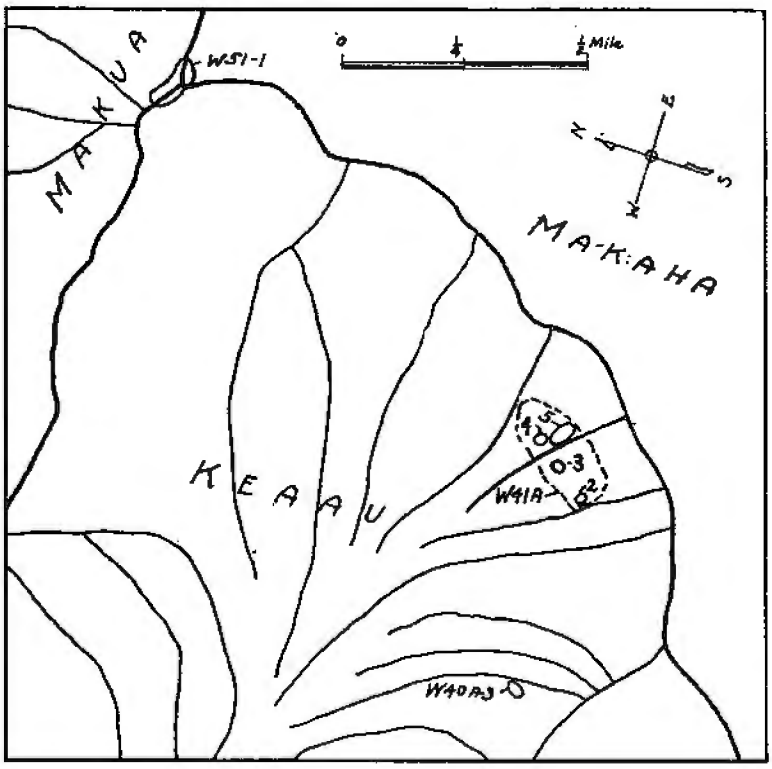
Table 12a. Achatinella mustelina waianaeensis var. Area 32.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W150A-4	10	3	21.0	19.5-21.5	20	
Russ	W150-2	41		21.0	18.5-23.5	55	4
Russ	W150-3	27		20.5	18.5-22.5	43	3
Lemke	W150-2-3	41		20.5		46	4
Russ	W130-1	21		20.0	18.5-22.5		25
Russ	W130-2	3			20.5-22.5	3	
Russ	W130-3	106		20.5	17.5-22.5	204	7
Russ	W130-4	35		20.5	18.5-22.5		44
Russ	W110-3	9	15	20.5	19.5-21.5	37	
Russ	W110-4	4	8	21.0	19.5-21.5		18

The size of the shells appears to be fairly uniform, 21+ or 20+ mm. The sequence of dextrality or sinistrality cannot be determined in this section, for only twelve scattered localities are known in this large section of the Waianae Mountains.

Achatinella mustelina maxima, new subspecies (pl. 5, figs. 1-4).

The shell is larger, with blunter or more rounded embryonic whorls, than *A. m. mustelina.* First two and a half embryonic whorls, upper half white, lower half a faded shade of chamois, last half of last embryonic whorl white, post-embryonic whorls shade from tilleul buff to vinaceous buff on the last whorl axially streaked with drab gray and light cinnamon drab, impressed sutural band white axially streaked with light grayish cinnamon, lip and columella callus light buff, length 23.9 mm., greater diameter 13.3 mm., spire height 12.6 mm., number of whorls 6½ (pl. 5, fig. 1).

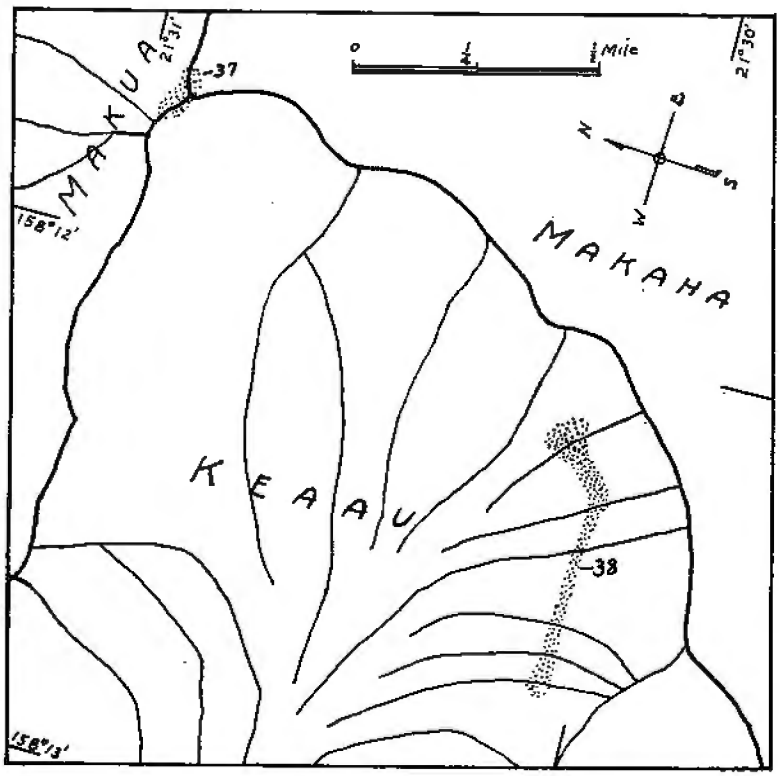


MAP 7.

Distribution, area 38: **South Keaau,** fossil locality W41A-2, el. 1,750 ft., Russ 1936, also found in localities W41A-3, el. 1,650 ft., W41A-4, el. 1,600 ft., W41A-5, el. 1,650-1,800 ft., Russ 1936, W40A-3, el. 1,500 ft., Welch and Russ 1936, all shells in fossil state (maps 7, 7a, pp. 54-55).

The holotype is slightly angled on the aperture side of the last whorl; this is not a usual character. Figure 2, plate 5, shows a specimen 24.0 mm.

long, greater diameter 13.2 mm., spire height 13.7 mm., with a more elongate and rounded last whorl, the spire and embryonic whorls are thicker than in the holotype. A more obese form is figured (pl. 5, fig. 3), length 24.1 mm., greater diameter 13.8 mm., spire height 11.1 mm. The form of a dextral shell is shown in figure 4, plate 5, the embryonic whorls are like the holotype, post-embryonic whorls much faded, pale pinkish buff or pinkish buff axially streaked with light drab, lip light pinkish cinnamon shading to white within, columella callus white.



MAP 7a.

The lip of the specimen shown in figure 2 has no inner ridge within the aperture as is found in the holotype. This raised ridge is not usual, the lips of the shells of figures 2, 3, and 4 being usual in all forms of *A. mustelina.* The form of the last whorls of figures 2 and 3 in common.

Only 18 shells are known to me from area 37, 1 dextral from locality W40A-3, and 17 sinistral from the other localities. Among these shells are 12 adults with a mean length of 23.5 mm., length range 21.5-25.5 mm. While the number of shells is relatively small, the size of the shells is markedly

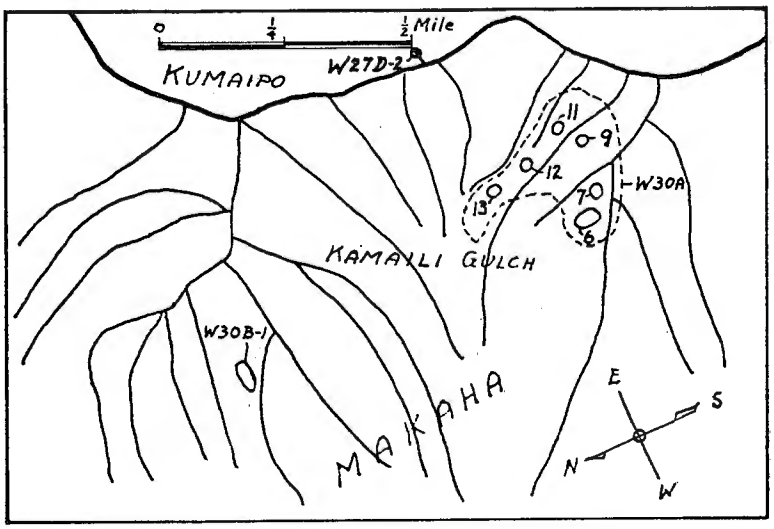
larger than anything known in the northern part of the Waianae Mountains. Undoubtedly if a larger number of shells were on hand, the mean length would still be exceptionally great. In other localities between 1,500 and 1,800 ft., the usual length range is from 17.5 or 18.5 mm. to 22.5 or 23.5 mm., and the usual mean length 20.0 mm. or 19.0 mm. Altitude then is not a factor in producing shells of any particular size, because shells collected at even lower altitudes in other places do not attain such size as the shells in Keaau Valley.

Achatinella mustelina maxima var. (pl. 4, figs. 5-8).

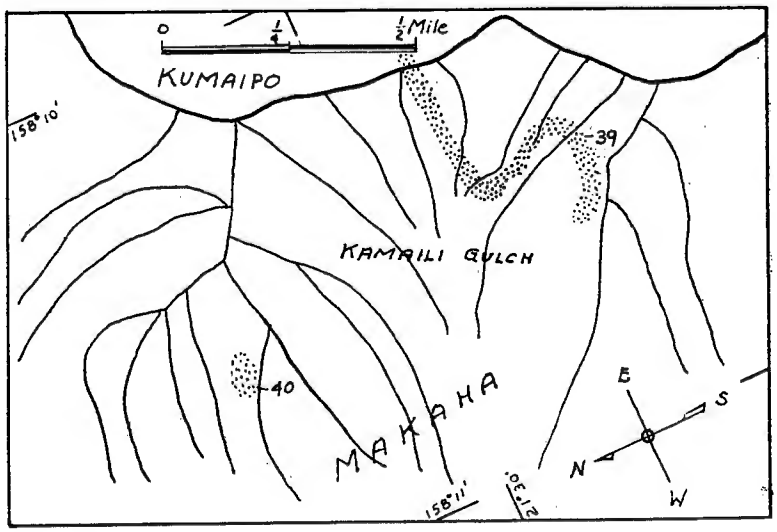
Area 39: **Kamaili, Makaha Valley,** localities W30A-6, el. 1,750-1,900 ft., 2 adult sinistrals, W30A-7, el. 1,900 ft., 1 dextral and 1 sinistral, one of which is adult, W30A-9, el. 2,000 ft., 1 adult out of 2 sinistrals, W30A-11, el. 2,000 ft., 1 adult out of 3 dextrals, W30A-12, el. 1,750 ft., 10 adults out of 14 dextrals, W30A-13, el. 1,650 ft., 6 adults out of 9 dextrals, all the shells found in fossil state under rocks, Russ and Welch 1933. The mean length of the 23 adults from area 40 is 21.0, length range 18.5-23.5 mm.; **Kumaipo, Waianae Kai,** locality W27D-2, Russ 1935, 3 dextrals, el. 2,050 ft. (maps 8, 8a, p. 57).

The fossil shells from area 39 are not typically *A. m. maxima,* but have a more elongate and pointed spire similar to the smaller, more pointed race of *A. m. brunicolor* var. (p. 69) which occurs in area 40 at a higher elevation in Makaha Valley. The color pattern of the shell, from the much faded, dead material, appears to be dominantly gray rather than the browner shades that occur higher in Makaha Valley. The typical form of the shell measures, length 20.9 mm., greater diameter 12.6 mm., spire height 11.2 mm. (pl. 5, fig. 5). Most of the shells lack color, but the shell of figure 6, plate 5, has the embryonic whorls pinkish buff on the first whorl shading to pale pinkish buff on the later whorls, post-embryonic whorls mouse gray faintly axially streaked and lined with pale olive gray, impressed sutural band pale pinkish buff, lip and columella callus pale pinkish buff. An obese shell, length 22.3 mm., greater diameter 13.6 mm., spire height 11.9 mm., retains a patch of the original color above the aperture, and is between a light shade of buffy brown and avellaneous, with two bands of cartridge buff below the periphery (pl. 5, fig. 6a). An elongate specimen with the base of the lip chipped measures, length 21 + mm., greater diameter 11.8 mm., spire height 12.7 mm. (pl. 5, fig. 6b). Figure 7, plate 5, shows the form of a sinistral specimen. Figure 8, plate 5, shows one of the Kumaipo specimens.

Although the shells of area 39 are not as large as the shells found in area 38, they are much larger than any found in the remainder of Makaha Valley even though localities farther up the valley are at similar elevations to those of area 39. Elevation then is not size determining. May not the distance of the locality from the main division ridge or Mount Kaala be the important factor in this regard, for the nearer the locality to Mount Kaala, the smaller the shells?


0
¼
½ Mile
KUMAIPO
W27D-2
11
9
12
13
7
6
W30A
KAMAILI GULCH
W30B-1
MAKAHA
E
S
N
W

MAP 8.


0
¼
½ Mile
KUMAIPO
158°10'
39
KAMAILI GULCH
40
MAKAHA
158°11'
21°30'
E
S
N
W

MAP 8a.

Achatinella mustelina makahaensis Pilsbry and Cooke (pl. 4, figs. 1-5).

Achatinella mustelina makahaensis Pilsbry and Cooke: Man. Conch. **22**: 345, pl. 62, figs. 3-4, 1912-14.

Further down, in Makaha, back of the home clearing of the manager of Makaha plantation, and on the edge of the coffee clearing there is a race in which the tint varies from nearly white with indistinct pale ochraceous salmon streaks, to vinaceous pink; sutural border white. As this is a pure race, it may be distinguished by the name *A. mustelina makahaensis* (Pilsbry and Cooke).

Figure 1, plate 4, is a photograph of the specimen which Pilsbry considers to be the holotype (pl. 62, fig. 3), which best matches the description. The embryonic whorls are pale pinkish buff or white shading to tilleul buff and vinaceous buff, the last whorl lightens again to tilleul buff faintly axially streaked and lined with a color slightly darker than the ground, suture cartridge buff or white, lip cartridge buff, columella callus white. Length 20.3 mm., greater diameter 12.5 mm., lesser diameter 12.1 mm., number of whorls 6⅝.

The type locality of this distinct race has not been located exactly in recent years. The Makaha Coffee Plantation has long been abandoned and the site of the manager's house is so overgrown with bushes that the landmark has been obliterated. The original label of the type, lot 2004, Spalding collection, states that the shells were collected by Spalding and Thurston, May 29, 1910, in Makaha Valley on a ridge behind the house of the manager of this company. There are 147 specimens in lot 2004, Spalding collection, all of which are dextral with the exception of one sinistral. All but three have the typical *makahaensis* pattern (pl. 4, fig. 1); these three shells are similar to the pattern of figure 2a, plate 4. The embryonic whorls shade from light pinkish buff to pinkish buff and pale pinkish buff, the post-embryonic whorls pinkish buff closely lined and axially streaked with verona brown (pl. 4, fig. 2a). In the Thurston collection, cat. no. 131255, Bishop Museum, is a lot of *Achatinella* of the *makahaensis* pattern from Makaha Valley, which are undoubtedly type material of *A. m. makahaensis*. The lot of shells is labeled:

Makaha, N of stream, 5 ridges N of old coffee mill, extending toward Kaala, 1600'-1700', Hab. lehua, kea, kukui, lantana, ti, & ieie, 130 specimens, all dextral. Note—unusually light colored, all dextral, while S. of stream abt. ½ are sinistral, Col. Dec. '08 & May '10 by M. C. T., L. P. T., and L. A. T. ac. by Spalding.

The Thurston collection was badly mixed, for the cabinet containing the collection was tipped when moved out of the house during a fire. Therefore, I do not know how much of this lot has been mixed. All the shells are dextral; the lot when prepared for cataloging by me contained 100 specimens, eight of which were of the verona brown pattern of figure 2a, plate 4, or the grayish pattern of figure 3b, plate 4, which is tilleul buff on the post-embryonic whorls, spirally lined and axially streaked with wood brown. This lot does not appear to have been badly mixed. It may have been sorted out

by Mr. Thurston afterwards. Nevertheless I believe that the lot is sufficiently pure to be considered material from the type locality.

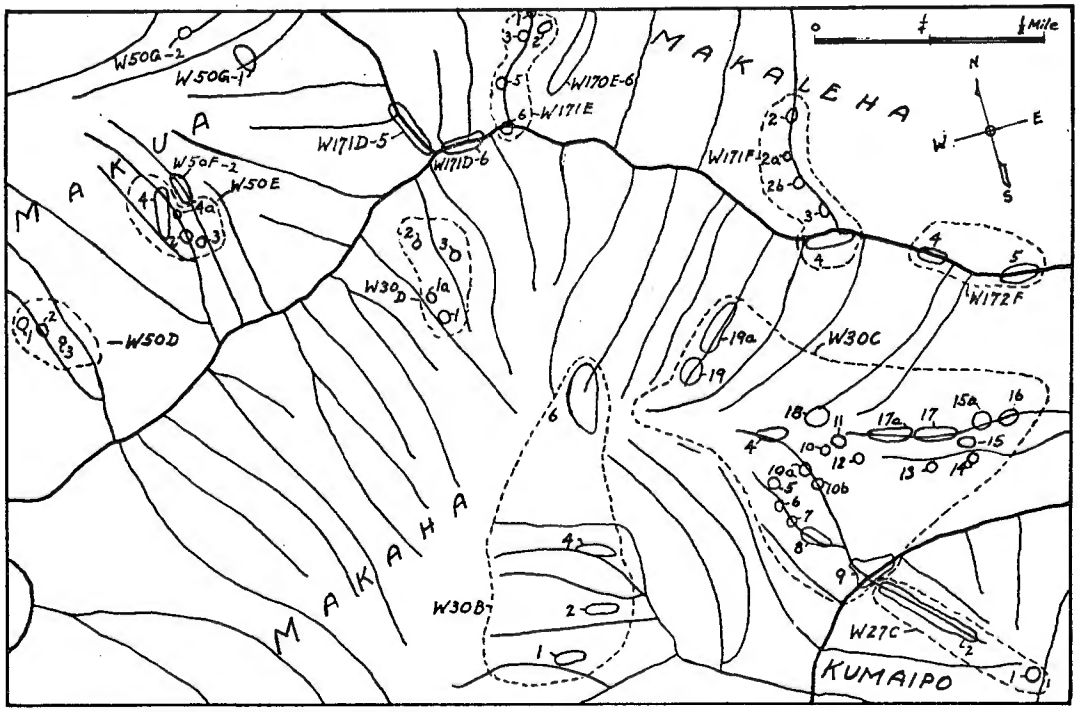
The typical form of a shell of the 19+ class and the usual color pattern of *A. m. makahaensis* chosen out of the Spalding type lot is shown in figure 2, plate 4, length 19.1 mm., greater diameter 11.5 mm., spire height 10.4 mm., has the first embryonic whorls worn, last embryonic whorl pale cinnamon pink, last three whorls light pinkish cinnamon, lip and columella callus cartridge buff tinted with cream buff, impressed sutural band pale pinkish buff. The modal length of both the Spalding and Thurston lots is 19 +. The embryonic whorls may be pale pinkish cinnamon or white, post-embryonic whorls and impressed sutural band light pinkish cinnamon (pl. 4, fig. 3). Figure 3a, plate 4, shows a narrow form with the color pattern of figure 3, length 20.0 mm., greater diameter 11.3 mm., spire height 11.6 mm., sutural band white. Usually the spire is not very concave but rather straight in outline (pl. 4, fig. 2), but the spire may be concave and tapering (pl. 4, fig. 2b), embryonic whorls white, post-embryonic whorls pale pinkish cinnamon, impressed sutural band white.

The outstanding difference between *A. m. makahaensis* and *A. m. mustelina* is the extremely narrow sutural band which may be the color of the ground (pl. 4, fig. 3) or have the upper half of the impressed sutural band white or a light color and the lower half the color of the whorl below.

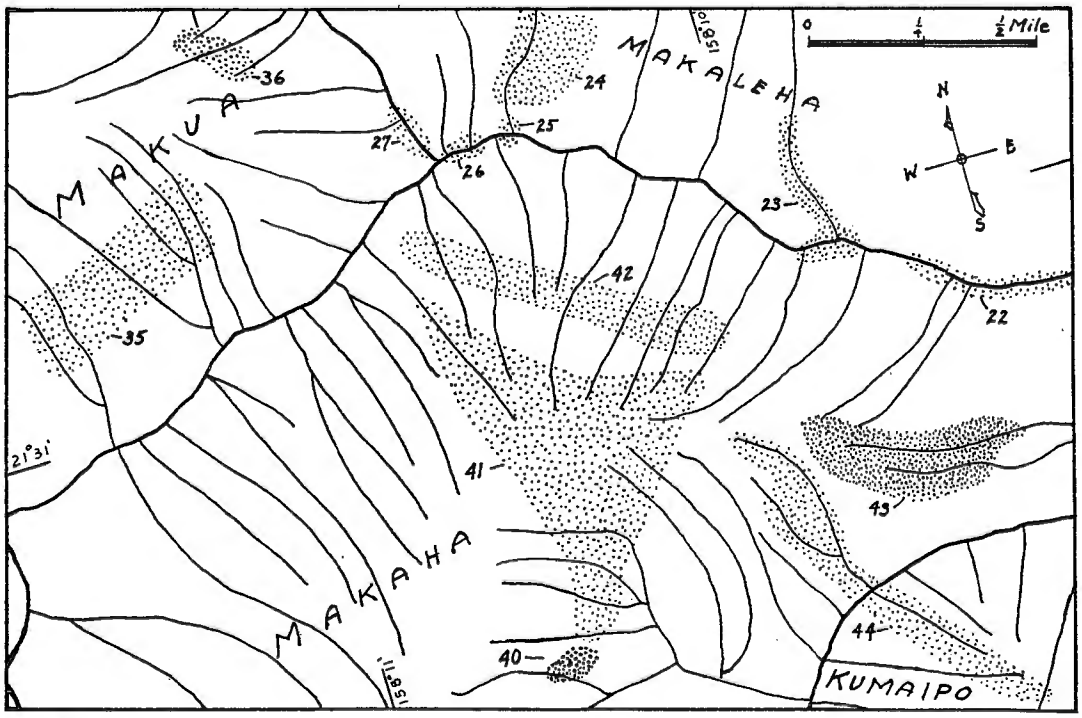
A. m. makahaensis is very close to the form of *A. m. altiformis* but the two forms have been separated out as distinct from each other, because the range of size of *A. m. makahaensis* is greater than that of *A. m. altiformis*. The color patterns of the two subspecies are also different. Many specimens of *A. m. makahaensis* have concave spires and are quite like *A. m. altiformis* but the usual forms shown in figures 2, 3 and 3a, plate 4, have not as concave spires as the usual forms of *A. m. altiformis*. *A. m. makahaensis* as far as form is concerned is an intermediate race existing in Makaha Valley between the lowland race of *A. m. brunicolor* (area 41) and the higher elevation form of *A. m. makahaensis* var. which occurs on the Makaleha-Makaha Division Ridge and has a color pattern close to *A. m. makahaensis*.

Distribution, area 42: **North Makaha Valley,** localities W30D-2, 1 dead shell, el. 2,250 ft., W30D-3, el. 2,000 ft., 7 dead and 5 live shells, Welch and Russ 1933, region of W30C-19-19a, approximate el. 1,750-1,950 ft., Lemke and Brother Flum 1931 (maps 9, 9a, p. 60).

The two localities of W30D-2 and 3 contain chiefly shells of typical *A. m. makahaensis* form. The color pattern is darker than that of the holotype, but is definitely the *makahaensis* pattern. Of the 12 sinistrals in locality W30D-3, one shell has the brown pattern of *A. m. brunicolor*. The form of a sinistral judged from the two adult dead specimens taken from that locality


MAKUA
MAKALEHA
MAKAHA
KUMAIPO
W50G-2
W50G-1
W50F-2
W50E
W50D
W171D-5
W171D-6
W170E-6
W171E
W171F
W172F
W30D
W30C
W30B
W27C
0 ¼ ½ Mile
N
E
S
W

MAP 9


MAKUA
MAKALEHA
MAKAHA
KUMAIPO
158°10'
158°11'
21°31'
0 ¼ ½ Mile
N
E
S
W

MAP 9a.

is figured (pl. 4, fig. 4). The base is more flattened than that of the holotype and the last whorl slightly more angled. The color pattern found on live juvenile specimens is closer to the high Makaleha-Makaha Ridge forms of area 23 than to the typical pattern. Embryonic whorls light buff, post-embryonic whorls ochraceous tawny deepening to sudan brown on the last whorl.

In the wide localities of W30C-19 and 19a, 28 percent of the shells have the *brunicolor* pattern and 72 percent a light *makahaensis* pattern with the ground color similar to figures 2 or 2b, plate 4, usually spirally lined with wood brown similar to figure 3b, plate 4, only less lineate. In the lower more limited locality of W30C-19, the *brunicolor* pattern occurs on 86 percent of the shells and the *makahaensis* on 14 percent. At a lower elevation in locality W30C-6, the *makahaensis* pattern is rare or lacking. From these data I assume that the probable locality of the holotype of *A. m. makahaensis* is somewhere in area 42, where it occurs as a pure race.

The mean length of the 119 adult shells in the Spalding type lot is 20.0 mm., length range 17.5-22.5 mm. The 86 adults in the Thurston lot, 131255, also have a mean length of 20.0 mm., the length range 16.5-22.5 mm.

In area 43, Makaha Valley, localities W30C-18, W30C-17a, W30C-16-17, W30C-15a (map 9a, p. 60), a few specimens with a *makahaensis* pattern are found mixed with *A. m. mixta* var., the dominant form of this area (p. 76). Although the typical *makahaensis* pattern is found, the more usual *makahaensis* pattern (pl. 4, fig. 5) is a shell with a wide, white sutural band similar to that of *A. m. mixta* var. with the color pattern of the holotype of *makahaensis*.

Achatinella mustelina makahaensis var. (pl. 4, figs. 6-10).

Area 23: **East-Central Makaleha Ridge,** localities W171F-2, el. 2,200 ft., W171F-2a-3, el. 2,650-2,800 ft., W171F-4, el. 2,968 ft., Russ 1932, W171F-3, el. 2,650-2,850 ft., W171F-2a, el. 2,300-2,350 ft., W171F-2b, el. 2,400 ft., Meinecke 1933; other collectors of this form of *A. m. makahaensis* are A. F. Judd and P. W. Frazer (maps 4, 4a, p. 25; 9, 9a, p. 60).

The typical *makahaensis* pattern is rare in area 23; the usual form and color pattern is similar to the dark *makahaensis* forms of locality W30D-3. Shells from area 23, Makaleha, have been separated from the lower Makaha forms by the presence of a distinct, dark brown color pattern (pl. 4, fig. 8a). Another distinction is that this pattern occurs in Makaleha but not in Makaha, and the Makaleha shells are smaller than the Makaha ones, having a smaller length range (table 13). The form of the shell is closest to *A. m. altiformis*.

The usual color pattern is illustrated in figure 6a, plate 4, first embryonic whorl worn, color vinaceous fawn, second embryonic whorl bicolored, upper half white, lower half pale vinaceous fawn, last embryonic whorl white, first half post-embryonic whorl white, last two and a half whorls ochraceous tawny

faintly axially streaked and spirally lined with pinkish buff, lip and columella callus white; length 19.6 mm., greater diameter 12.4 mm., spire height 10.3 mm., 6½ whorls, spire convex, last whorl rounded. The spire may be straight in outline, base flattened, edge of the periphery rounded, last whorl pinkish buff lined with ochraceous tawny (pl. 4, fig. 6); a marked lineate form, length 18.3 mm., greater diameter 12.0 mm., spire height 9.6 mm. A short spired, sinistral specimen, length 18.6 mm., greater diameter 11.5 mm., spire height 9.0 mm., has a similar color pattern to figure 6a with the last two post-embryonic whorls ochraceous tawny or tawny faintly lined with pinkish buff (pl. 4, fig. 7a). A darker color form (pl. 4, fig. 8), which shows an elongate spired, sinistral shell, length 20.2 mm., greater diameter 11.8 mm., spire height 10.4 mm., has the ground color of the last three whorls ochraceous buff deepening to ochraceous tawny on the last whorl, axially streaked with cinnamon brown and russet. An elongate dextral with the base of the lip chipped has a length of 19 + mm., greater diameter 11.6 mm., spire height 10.5 mm., has a darker pattern, post-embryonic whorls russet spirally lined with ochraceous tawny (pl. 4, fig. 9). The distinct, dark brown Makaleha pattern already alluded to has the embryonic whorls white, post-embryonic whorls axially streaked with black and mars brown, impressed sutural band or line ochraceous tawny axially streaked with russet (pl. 4, fig. 8a). A rare, light color pattern (pl. 4, fig. 7) has the last three whorls white or pale pinkish buff, lined with light pinkish cinnamon and a light shade of ochraceous tawny on the last fourth whorl. A few streaked forms are found in W171F-4, last two post-embryonic whorls tilleul buff, axially streaked with wood brown, and spirally lined with tilleul buff, impressed sutural band with upper half white, lower half streaked with wood brown (pl. 4, fig. 10).

Table 13. Achatinella mustelina makahaensis var. Area 23.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ	W171F-2	14		19.0	17.5-19.5	20	
Meinecke	W171F-2a	7		19.0	17.5-19.5		11
Meinecke	W171F-2b	30	1	19.0	17.5-20.5	19	28
Russ	W171F-2a-3	2	2		18.5-20.5	7	4
Meinecke	W171F-3	16		19.5	17.5-21.5	34	
Russ	W171F-4	9		18.5	17.5-21.5	34	

According to table 13, the mean length of the shells is constantly 19 + mm. with the exception of one lot with a mean length of 18.5 mm. which is at the highest elevation. The lowest shells are dextrals grading to sinistrals at high elevations and then to dextral again in the highest localities.

Specimens of *A. m. altiformis* var. with a *makahaensis* pattern have been found farther to the west along the Makaleha-Makaha Division Ridge in localities W171E-6 and W171D-6. They are very close to the typical light *makahaensis* pattern but occur only as rare patterns in these two localities. For further description see page 64 and figures 17a and 19, plate 4. No carefully localized material has been turned in to Bishop Museum from the section of the Makaleha-Makaha Division Ridge between locality W171E-6 and area 23. When this region is collected it will probably yield shells shading from the dark form of *makahaensis* var. to a lighter, more typical color form, and finally to light gray shades similar to those found in locality W171E-6, and intermediate between *makahaensis* var. and *altiformis*.

The *makahaensis* pattern is also found on a few specimens of *A. m. altiformis* in W172F-3 to the east of area 23 (p. 65). A juvenile specimen is figured in figure 13, plate 4.

Achatinella mustelina altiformis, new subspecies (pl. 4, figs. 14-16).

To the west of area 23, a small distinct race of *mustelina* occurs which is separable from typical *A. m. makahaensis* Pilsbry and Cooke, by color pattern, difference in length range, and mean length. This new race, however, is closely related to *A. m. makahaensis* having the characteristic, narrow, threadlike, impressed sutural band which usually has only the upper half tinted or colored white.

The shell is dextral, perforate, but may be imperforated, spire pointed, slightly concave, last whorl obese, base slightly flattened; embryonic whorls white, post-embryonic whorls shade from white on the first half whorl to roods brown, verona brown and on the last whorl snuff brown covered with close set lines and axial streaks of snuff brown and saccardo's umber. At a casual glance the color looks uniform. The upper half of the impressed sutural band is white, lower half the color of the whorl below, columella callus white, length 18.0 mm., greater diameter 11.8 mm., spire height 9.5 mm., number of whorls 6¼ (pl. 4, fig. 14).

Area 24: **West-Central Makaleha Ridge,** type locality W171E-2, el. 2,250-2,400 ft., also localities W171E-1, el. 2,350 ft., W171E-3, el. 2,400-2,450 ft., W171E-5, el. 2,600-2,650 ft., Meinecke 1933; **Central Makaleha Valley,** locality W170E-6, a wide locality, el. 1,750-2,800 ft., Russ 1931; other collectors of this subspecies are L. A. Thurston, E. Lyman (maps 4, 4a, p. 25; 9, 9a, p. 60).

The type locality W171E-2 has color patterns of two shades of brown. Fifty-nine percent of the shells have the snuff brown color of the holotype, or the last whorl may be darker, brussels brown (pl. 4, fig. 15). Figure 15 shows a specimen with the last whorl more rounded and the spire less pointed than the holotype. The other 41 percent are drab on the last two whorls, axially streaked with hair brown, lip edged with cream buff, columella callus white as in figure 15a, plate 4, which also shows an obese form of the shell, length 18.6 mm., greater diameter 12.6 mm., spire height 8.8 mm. The sinistral form of the shell figured in figure 16, plate 4, has the color pattern of figure 15a, plate 4, length 19.3 mm., greater diameter 11.8 mm., spire height 8.8 mm.

Approximately 51 percent of the shells in locality W171E-1 are diseased

or lack shell enamel over the entire shell or in patches. This locality contains the same color pattern as W171E-2. Localities W171E-1, W171E-3, W171E-5 have a greater proportion of shells similar to the pattern of figure 15a, plate 4. The higher the locality the grayer the pattern. Locality W170E-6 has a shell population mostly colored like the holotype.

Achatinella mustelina altiformis var. (pl. 4, figs. 17-17a).

Area 25: **West-Central Makaleha-Makaha Ridge,** locality W171E-6, el. 2,750-2,850 ft., Meinecke 1933 (maps 4, 4a, p. 25; 9, 9a, p. 60).

Here the shells are of a marked light gray color. The last two whorls may be pale smoke gray spirally lined with smoke gray (pl. 4, fig. 17). Other specimens have white embryonic and post-embryonic whorls except for the last whorl which is axially streaked with tilleul buff, edge of the lip white, tinted as usual with cream buff (pl. 4, fig. 17a). Intermediates occur between figures 17 and 17a, plate 4, which are of such delicate shades of gray that they are difficult to match in Ridgeway.

Achatinella mustelina altiformis var. (pl. 4, figs. 18-18a).

Area 27: **West Makaleha-Makua Ridge,** locality W171D-5, el. 2,650-2,850 ft., Meinecke 1933 (maps 4, 4a, p. 25; 9, 9a, p. 60).

Another distinct pattern of *A. m. altiformis* occurs in area 27 in which the embryonic whorls are pinkish buff shading to a faint shade of orange citrine, first post-embryonic whorls warm sepia axially streaked with zigzag lines of pale drab gray shading to brownish olive on the last whorl and a half, axially streaked and spirally lined with sepia, lip and columella callus white, impressed narrow sutural band white, length 18.2 mm., greater diameter 11.3 mm., spire height 8.8 mm. (pl. 4, fig. 18). The shells do not all have the squat appearance of figure 18, but may be more elongate in shape, length 18.2 mm., greater diameter 11.1 mm., spire height 10.0 mm., last 2½ post-embryonic whorls drab gray axially streaked with cinnamon drab, shading on the last whorl to buffy brown axially streaked with olive brown (pl. 4, fig. 18a).

Achatinella mustelina altiformis var. (pl. 4, fig. 19).

Area 26: **West Makaleha-Makaha Ridge,** locality W171D-6, el. 2,850 ft., Meinecke 1933 (maps 4, 4a, p. 25; 9, 9a, p. 60).

In area 26 shell patterns are intermediate between those of areas 25 and 27, with a mixture of the color forms of figures 17 and 18, plate 4. The usual color form, however, is that of figure 18. The light whitish forms of W171E-6, figure 17a, plate 4, are present but are much darker and tinted with brown, the last three whorls shade from white to tilleul buff, spirally lined and axially streaked with a faint shade of cinnamon buff (pl. 4, fig. 19). This pattern resembles light forms of *A. m. makahaensis.*

Table 14. Achatinella mustelina altiformis Welch, and varieties. Areas 24, 25, 26, and 27.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Meinecke	W171E-1	23		18.5	16.5-19.5	2	37
Meinecke	W171E-2	36		19.5	17.5-20.5	40	1
Meinecke	W171E-3	38		18.5	16.5-20.5	11	30
Meinecke	W171E-5	8		18.5	16.5-19.5	11	
Meinecke	W171E-6	8		18.0	16.5-18.5	12	
Meinecke	W171D-6	6		18.0	16.5-21.5	12	13
Meinecke	W171D-5	46	2	18.5	16.5-21.5	69	5

Since the type locality has larger shells than those found in all other localities, the holotype was chosen from the usual mean length class of area 24 rather than from the mean length class of W171E-2. The larger mean length of shells of the type locality can be ascribed either to the small number of shells, which may not give a true picture to size variation or to the lower range of elevation than the remainder of the localities in area 24. Comparing the sizes, given in tables 13 and 14, *A. m. altiformis* and its varieties proves to be smaller in size than the shells of area 23 in all localities except W171E-2, even though area 23 has a similar range of elevations. This indicates that within certain limits, size may vary at random regardless of altitude or proximity to Mount Kaala. The change from dextrality to sinistrality is present in definite, circumscribed regions, but no definite rule as to where the change will occur can be discovered.

Achatinella mustelina altiformis var. (pl. 4, fig. 11).

Area 22: **East Makaleha-Makaha Ridge,** localities W172F-3, el. 3,550-3,600 ft., W172F-4, el. 3,100-3,250 ft., W172F-5, el. 2,989-3,000 ft., Meinecke 1934 (maps, 4, 4a, p. 25).

This region contains a series of gray shells with narrow sutural bands unseparable from forms of the gray race of *A. m. altiformis* var. occurring in locality W171E-5. With these light gray forms in area 22 are other characteristic color patterns which do not occur in areas 24 or 25. Lots of shells from widely separated regions of areas 22 and 25 are easily identifiable by these peculiar patterns. Since so many shells from the two areas have analogous patterns, the shells of area 22 will be considered a form of *altiformis* and not a distinct subspecies.

The characteristic dark color form of area 22 resembles the dark *makahaensis* color form found in area 23 (pl. 4, fig. 8a). An obese shell, length 17.7 mm., greater diameter 12.0 mm., spire height 9.1 mm. is colored on the last two post-embryonic whorls dark livid brown shading to warm sepia or black on the last whorl, spirally banded, lined and axially streaked with pallid mouse gray (pl. 4, fig. 11a). The color pattern may be warm sepia

on the last two whorls axially streaked with zigzag lines of pinkish buff (pl. 4, fig. 12). This rare color pattern also shows an obese, squat form of the shell, length 17.0 mm., greater diameter 11.0 mm., spire height 8.3 mm. The darkest color pattern (pl. 4, fig. 12a) is an elongate shell, length 19.4 mm., greater diameter 12.2 mm., spire height 10.1 mm., embryonic whorls pale pinkish buff shading to light buff, post-embryonic whorls chocolate deepening to black on the last whorl, last whorl faintly lined and streaked with pinkish buff, below the periphery a line of light buff. These dark color forms are more usual in locality W172F-5, and become rarer to the east in locality W172F-4 where light color forms are dominant.

The light color forms may be white on the embryonic whorls, post-embryonic whorls pale smoke gray axially streaked with drab, impressed suture, lip and columella callus white (pl. 4, fig. 12b). Another shell has the last two whorls pale smoke gray axially streaked with hays brown (pl. 4, fig. 11). The post-embryonic whorls may be drab gray spirally lined with tawny olive (pl. 4, fig. 12c), a color pattern which is very close to that of figure 16, plate 4. Figure 12d has a color pattern similar to figure 11, but has a wider, white sutural band than the remainder of the shells in area 22. The color pattern is similar to that of *A. m. griseitincta,* new subspecies. In locality W172F-3 a few shells with the *makahaensis* pattern are found; figure 13, plate 4, shows one of these specimens with a color pattern resembling that of figure 17a, plate 4.

Table 14. Achatinella mustelina altiformis var. Area 22.

Collector	Locality	Live Adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Meinecke	W172F-3	17	18.0	17.5-19.5		20
Meinecke	W172F-4	13	18.5	17.5-19.5	19	1
Meinecke	W172F-5	34	18.5	16.5-20.5	29	14

East of area 23 the shells decrease in size, and dextrals and sinistrals are found in definite areas.

Further collecting should be done on the Makaleha-Makaha Ridge to discover what occurs between localities W171F-4 and W171E-6, and also more localities should be collected in Makaleha and Makaha below areas 22 and 23. Then possibly the extraordinary occurrence of the *makahaensis* pattern between two regions of gray *altiformis* patterns can be accounted for. Is the *makahaensis* pattern in area 23 due to migration from Makaha Valley, or did this light pattern originate on the Makaleha-Makaha Ridge and migrate into Makaha? I do not believe the Makaha shells ever migrated up onto the Makaleha-Makaha Ridge because shells in other Waianae Mountain localities appear to be circumscribed in distribution to a definite region even though

the terrain is favorable to migration. It is probable that Makaleha shells with the *makahaensis* pattern migrated or fell over the precipitous Makaleha-Makaha Ridge and populated the lower localities collectable in Makaha. But this does not account for the presence of the *makahaensis* pattern in Makaleha. This question will have to be worked out by future workers.

Achatinella mustelina brunicolor, new subspecies (pl. 5, figs. 14-16).

The shell is closely related to *A. m. makahaensis,* but differs in having an elongate form, definite, white sutural band, and a different color pattern. The color pattern is similar to that of the holotype of *A. m. altiformis* Welch but differs in the width and color of the sutural bands and size of the shell. The first embryonic whorl and a half bicolored, upper half white, lower half pale vinaceous fawn, last embryonic whorl white, first post-embryonic whorl shading from white to benzo brown streaked with white, darkening on the last two whorls to dresden brown faintly axially streaked and lined with raw umber, about the umbilicus a patch of white, 1.5 mm. wide, 4.6 mm. long, impressed sutural band white, about 7 mm. wide at the edge of the lip, lip and columella callus white, length 19.6 mm., greater diameter 11.8 mm., spire height 10.5 mm., number of whorls 6¼ (pl. 5, fig. 14).

Distribution, area 35: **Makua Valley,** type locality W50E-4, el. 1,250-1,550 ft., Lemke 1935; also W50E-4a, el. 1,500 ft., Russ 1935, W50E-2 el. 1,550-1,600 ft., 1 dead dextral, W50E-3, el. 1,600-1,650 ft., 4 dextrals, 1 sinistral, all dead, Pilsbry and Welch 1933, W50F-2, el. 1,300-1,450 ft., 3 live dextrals, Russ 1935, W50D-1, el. 1,500 ft., 3 dead dextrals, W50D-2, el. 1,600 ft., 3 dextrals, 4 sinistrals, all dead, W50D-3, 1,050 ft., 5 dead sinistrals, S. Record, Welch and Russ 1933, W50D-2-3, 7 sinistrals and 1 dextral dead, 1 live sinistral, Russ 1933 (maps 9, 9a, p. 60).

The Pilsbry and Welch localities are possibly plotted too high and their localities should be checked; also collected in Makua by Cooke and Spalding 1913, and W. D. Wilder.

The shell may be very narrow, length 19.2 mm., greater diameter 10.5 mm., spire height 11.2 mm., color pattern similar to the holotype (pl. 5, fig. 15). In some specimens the color pattern is darker and the shell more obese than in the type, length 19.5 mm., greater diameter 12.0 mm., spire height 10.2 mm., post-embryonic whorls saccardo's umber faintly spirally lined and axially streaked with sepia (pl. 5, fig. 15a). The embryonic whorls may be cartridge buff shading to honey yellow and cartridge buff again on the last embryonic whorl, post-embryonic whorls similar to those of the holotype (pl. 5, fig. 15b). Figure 16, plate 5, illustrates a sinistral shell.

Achatinella mustelina brunicolor var. (pl. 4, fig. 21).

Area 36: **Makua,** localities W50G-1, el. 1,550-1,600 ft., W50G-2, el. 1,350 ft., Lemke and Lemke, Jr. 1935 (maps 9, 9a, p. 60).

The shells in this region are intermediate in form between *A. m. waianaeensis* var. of area 28 and typical *brunicolor.* The color pattern is as a rule grayer than *A. m. brunicolor.* Narrow, sutural banded specimens occur similar to figure 21, plate 4, which are like *A. m. altiformis.* But on the whole the race is definitely closer to *A. m. brunicolor* than anything else.

Achatinella mustelina brunicolor var. (pl. 5, figs. 10-12).

Area 41: **Makaha Valley,** south side of Kamaile, localities W30B-2, el. 1,550-1,900 ft., 4 dextrals, 1 sinistral, W30B-4, el. 1,500-1,650 ft., 1 dextral, Russ 1932, W30B-6, el. 1,450-1,600 ft., Russ 1929; **North Makaha,** W30C-19, el. 1,550-1,600 ft., Brother Steven and Welch 1931, W30D-1, el. 1,800 ft., W30D-1a, el. 1,850-1,900 ft., Welch and Russ 1933 (maps 9, 9a, p. 60).

The shells of area 41 are a mixture of the shells of areas 40, 42, and 44. The dominant form and color pattern is that of the shells of area 44 or *A. m. brunicolor*. The usual form and color pattern of the shell is shown in figure 10, plate 5, length 19.6 mm., greater diameter 11.6 mm., spire height 11.0, first embryonic whorl vinaceous fawn, second embryonic whorl pinkish cinnamon, last embryonic whorl cinnamon buff, post-embryonic whorls light cinnamon drab shading to drab on the penultimate and hair brown on the last whorl axially streaked with vinaceous buff, impressed sutural band white, lip white tinted with tilleul buff. The shell may be more obese, length 19.9 mm., greater diameter 12.5 mm., spire height 10.8 mm., last two post-embryonic whorls drab, below the periphery of the last half whorl the ground darkens to benzo brown (pl. 5, fig. 10a). The *makahaensis* pattern occurs in this area, and is usually a lined form similar to figure 10b, plate 5, first embryonic whorl vinaceous fawn, last two embryonic whorls white tinted with cream buff on the lower half of the whorl, post-embryonic whorls pale pinkish cinnamon spirally lined with vinaceous buff.

The shells from locality W30D-1 were dead but some specimens still retain some color. Of 10 shells, eight have the *brunicolor* pattern and two, the typical *makahaensis* pattern of figure 2, plate 4. One brown, dead specimen in fairly fresh state is snuff brown on the last three post-embryonic whorls, impressed sutural band, upper half white, lower half snuff brown, first embryonic whorl snuff brown with a band of white at the edge of the suture, second embryonic whorl and a half clay color, banded with white at the edge of the suture, last embryonic whorl and a half pinkish buff (pl. 5, fig. 11). The shell may be grayer, last three whorls shade from drab gray to buffy brown on the last whorl, last whorl lined with white and with lines slightly darker than the ground (pl. 5, fig. 12).

Achatinella mustelina brunicolor var. (pl. 5, figs. 17-18).

Area 44: **Makaha Valley,** localities W30C-5, el. 1,800 ft., 4 sinistrals, W30C-6, el. 2,000 ft., W30C-8, el. 2,200-2,300 ft., W30C-9, el. 2,450-2,500 ft., Welch and C. S. Judd 1931, W30C-7, el. 2,050 ft., W30C-8-9, Russ, region of W30C-9-W27C-2 (?), Gregory 1925, W30C-4, el. 1,750 ft., W30C-10a, el. 1,850 ft., W30C-10b, el. 1,800 ft., W30C-9, W30C-7-8, Lemke 1933, 1934; **Kumaipo, Waianae Kai,** W27C-1, el. 1,750 ft., 25 dextrals, W27C-2, el. 1,800-2,500 ft., 1 dextral and 3 sinistrals, Welch and C. S. Judd 1931, probable region of W27C-1-2 (?), C. M. Cooke, Jr., and R. A. Cooke 1911 (maps 9, 9a, p. 60).

The forms in area 44 while usually not as elongate as typical *brunicolor* may have specimens which are analogous in form and color pattern. The Makaha shells in this region tend more to drab and grayish shades than those in Makua. The usual form in area 44 is figured in figure 18, plate 5, embryonic whorls white, post-embryonic whorls buffy brown spirally lined with bister, impressed sutural band white, lip and columella callus tilleul buff. A sinistral shell (pl. 5, fig. 17) has a grayer pattern, post-embryonic whorls drab spirally lined on the last whorl with olive brown.

Since *A. m. brunicolor* var. occurs as a pure race in area 44, and area 41 is a mixture of brown, grayish brown, and pinkish buff lined patterns, I believe that *A. m. brunicolor* is a brown race extending from Makua across Makaha into Kumaipo in a definite band. Although *brunicolor* is not a pure race in area 41, as far as the Museum collections show, I believe it might prove to be one if some central localities were collected. All plotted localities are from points where *A. m. brunicolor* is mixed with another form. To the north *A. m. makahaensis* borders localities W30C-5 and W30D-1. To the south the localities are bordered by the gray races of areas 39 and 40.

Achatinella mustelina brunicolor var. (pl. 5, figs. 9-9d).

Area 40: **South Makaha,** in the first subvalley north of Kamaile, locality W30B-1, el. 1,500 ft., Russ 1933 (maps 9, 9a, p. 60).

A large race of *A. m. brunicolor* occurs here with gray and grayish brown color patterns. The shells in this locality are intermediate between the large lowland Makaha *maxima* forms of area 39 and the upland *brunicolor* forms of area 41. The shells, while close to *brunicolor* var. in color and form, are larger and therefore appear to be more elongate. The shells of area 40 are similar to the form and color pattern of the shells in Central Makaleha Valley, locality W170E-3-4 (p. 26).

The dark color pattern and typical form of the shell is that of figure 9, plate 5, length 20.7 mm., greater diameter 12.5 mm., spire height 10.5 mm., embryonic whorls cartridge buff shading to cream buff, post-embryonic whorls sayal brown axially streaked with verona brown and warm sepia, spirally banded with bister, last whorl almost solidly warm sepia, impressed sutural band, lip and columella callus white, lip edged with cream buff. A light form is a gray streaked *makahaensis* pattern, last two whorls pale cinnamon pink, spirally banded and axially streaked with vinaceous buff, last half whorl closely finely axially streaked with drab gray (pl. 5, fig. 9a). The most common color pattern has white embryonic whorls tinted with cartridge buff, first post-embryonic whorl white shading to pale pinkish cinnamon on the last two whorls, last two whorls spirally lined and banded with light drab above the periphery and benzo brown below (pl. 5, fig. 9b). The last two whorls may be smoke gray spirally lined with white (pl. 5, fig. 9c), or deep

mouse gray spirally lined with white and axially streaked with pale olive buff (pl. 5, fig. 9d).

Achatinella mustelina brunicolor var. (pl. 5, figs. 13-13b).

Area 37: **Makua-Keaau Ridge,** locality W51-1, el. 2,750-2,900 ft., Russ 1928, also collected by Emerson, C. S. Judd, H. P. Judd, and Dranga (maps 7, 7a, pp. 54, 55).

This gray race of *A. m. brunicolor* is quite distinct from other gray forms of *A. m. brunicolor* when seen in bulk lots, but when individual specimens are mixed with gray varieties of *A. m. waianaeensis* var. from area 28 or specimens of *A. m. brunicolor* var. from areas 41 and 35, the distinctions are not as evident and the shells cannot be sorted completely. The usual form of the shell is elongate; figure 13, plate 5, shows a typical specimen, length 19.5 mm., greater diameter 11.5 mm., spire height 10.3 mm., embryonic whorls pale pinkish buff shading to pinkish buff on the last embryonic whorl, post-embryonic whorls pale olive gray, finely axially streaked with light grayish olive, last half whorl tinted and streaked with buffy brown, lip and columella callus white, outer margin of the lip edged with tilleul buff, impressed sutural band pinkish buff More usually the impressed sutural band is white, as in figure 13a, plate 5, first two embryonic whorls worn, last embryonic whorl white, first half of first post-embryonic whorl white, last half pale neutral gray, axially streaked with dark vinaceous drab, first half of penultimate mouse gray axially streaked with snuff brown, last whorl and a half olive brown shading to saccardo's umber faintly axially streaked and lined with sepia. A characteristic but not common pattern in this area is shown in figure 13b, plate 5, embryonic whorls white, first post-embryonic whorl pale pinkish buff, penultimate pale pinkish buff darkening to pallid mouse gray finely streaked with light vinaceous drab, and dark vinaceous drab, last whorl ground color pale pinkish buff shading to tawny olive on the last fourth whorl, axially streaked with zigzag lines of warm sepia. Zigzag streaked shells may have straighter or more wavy, less pronounced streaks than shells shown in figure 13b, plate 5, which is an extreme example of the zigzag streaked form. Usually the streaking is on the penultimate whorl which tends to have a gray ground while the last whorl is not streaked and is some shade of brown.

Table 15. Achatinella mustelina brunicolor Welch, and varieties, Area 35, 41, 44, 37.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ and Welch	W50D-1-3		17	20.5	18.5-22.5		
Lemke	W50E-4	40		19.5	18.5-20.5	52	
Russ	W50E-4a	6		19.5	19.5-21.5	19	
Russ	W30B-6	80		19.5	17.5-21.5	107	
Welch	W30D-1	7		20.0	18.5-21.5	10	
Lemke	W30C-4			19.5	17.5-20.5	3	16
Welch	W30C-6	12	3	18.5	15.5-20.5	4	17
Lemke	W30C-10a-10b	38		19.5	17.5-21.5		47
Welch	W30C-8	9	4	18.5	16.5-19.5	3	24
Welch	W30C-9	12	1	18.5	16.5-19.5	40	
Russ	W30C-7-9	13		19.0	17.5-20.5	5	4
Gregory	W30C-9-W27C-2	40		18.5	16.5-19.5	61	2
Welch	W27C-1-2	26		19.5	18.5-20.5	45	3
Russ	W27C-1-2	35		19.0	16.5-20.5	23	8
Cooke	W27C-1-2(?)	51		18.5	16.5-21.5	42	23
Russ	W51-1	54		20.0	16.5-22.5	54	43

Table 15 shows a decrease in shell size the farther the locality in the interior of Makaha Valley, or the nearer the locality to Mount Kaala. The Makua shells also increase in size farther southwest, or with increase of distance from the head of the valley. In Kumaipo, the difference in size between the mean lengths of the Cooke and Welch lots is undoubtedly due to difference in the places where the shells were collected. Welch obtained only dextrals in W27C-1, and sinistrals and dextrals in W27C-2, while Cooke obtained nearly equal numbers of dextrals and sinistrals.

Achatinella mustelina nocturna, new subspecies (pl. 8, figs. 8-11).

The shell is solid, spire concave, shape of the shell similar to *A. m. altiformis* Welch, but differs in having a strikingly different color pattern and a characteristic, wide white sutural band. Embryonic whorls white, tip of the first embryonic whorl chaetura drab, post-embryonic whorls dark grayish brown faintly axially streaked and spirally lined with mouse gray, lip and columella callus white, length 18.6 mm., greater diameter 11.6 mm., spire height 9.3 mm., number of whorls 6¼ (pl. 8, fig. 8).

Distribution, area 48: **South Kalalua Gulch,** type locality W25-6, el. 1,900-2,000 ft., 14 adults, mean length 18.5 mm., length range 17.5-20.5 mm., 18 dextrals, 5 live, 13 dead; also W25-5, el. 1,800-1,850 ft., 17 adults, mean length 19.0 mm., length range 17.5-19.5 mm., 28 dextrals, 1 sinistral, all dead, W25-7, el. 1,900-1,950 ft., 18 adults, mean length 19.0 mm., length range 17.5-19.5 mm., 7 dextrals, 18 sinistrals, all dead, W25-8, el. 2,000 ft., 3 adults, 3 dextrals, 9 sinistrals, 1 live, 11 dead, W25-9, el. 2,000 ft., 5 live dextrals, Russ and Welch 1933. Collected on native trees (maps 10, 10a, p. 73).

The outline of the spire may be straight, and the shell narrow, length 18.4 mm., greater diameter 10.1 mm., spire height 8.8 mm., color pattern that

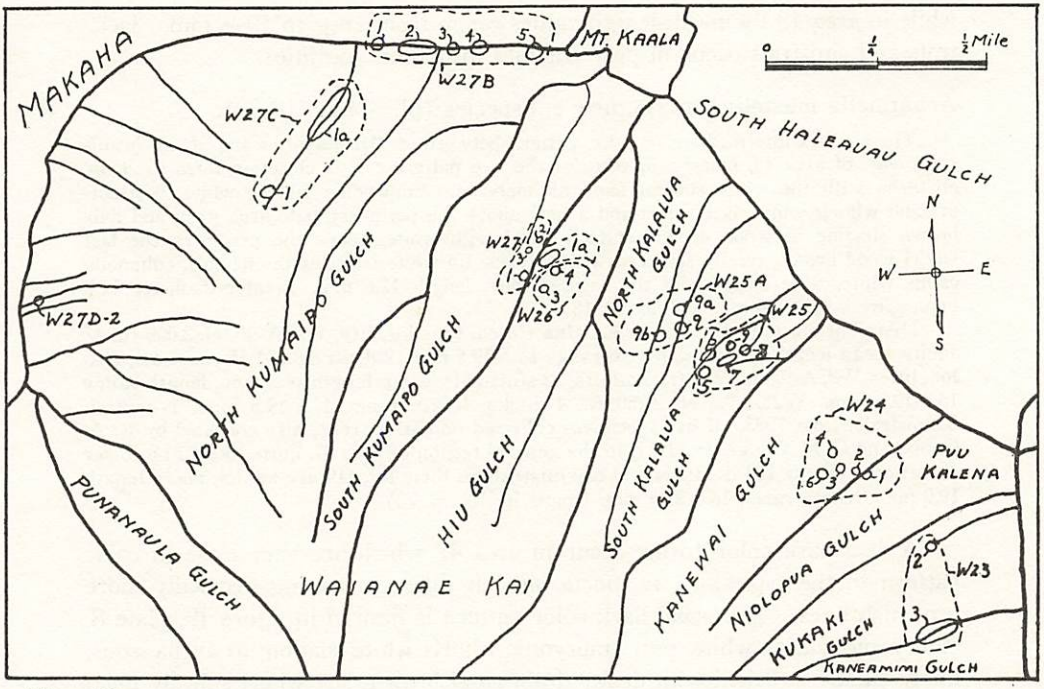
of the holotype (pl. 8, fig. 9). The shell may be obese, length 18.6 mm., greater diameter 12+ mm., lip edge chipped, spire height 8.8 mm., a dead specimen but color intact, last two whorls almost solid, dull purplish black, lip and columella callus pale vinaceous fawn (pl. 8, fig. 10). A rare color pattern has embryonic whorls ochraceous buff, post-embryonic whorls banded with black and mouse gray streaked with black, sutural and subsutural bands ochraceous buff (pl. 8, fig. 11). Figure 10a, plate 8, exhibits a typical sinistral form, length 19.6 mm., greater diameter 11.4 mm., spire height 9.5 mm. A freshly dead albino is found which is entirely white except that the lip and columella callus are tinted with cream color (pl. 8, fig. 10b). This albino shows a more obese form, length 19.8 mm., greater diameter 12.1 mm, spire height 9.3 mm.

Achatinella mustelina nocturna var. (pl. 8, figs. 12-13b).

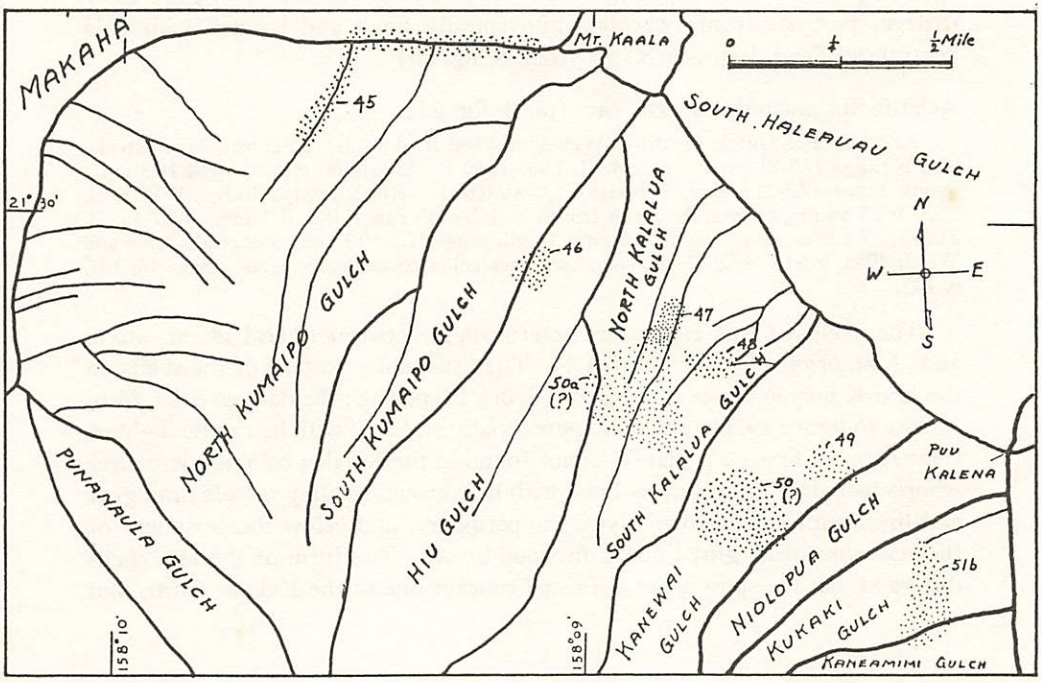
Area 49: **Kanewai Gulch,** localities W24-1, el. 1,850-1,900 ft., W24-2, el. 1,850 ft., total number of adults 9 in W24-1 and 2, mean length 18.5 mm., length range 16.5-19.5 mm., 11 dextrals, W24-3, el. 1,800 ft., 8 adults, mean length 18.0 mm., length range 16.5-18.5 mm., 11 dextrals, 4 sinistrals, W24-4, el. 1,800 ft., W24-6, el. 1,700-1,750 ft., combined lots of W24-4 and 6, 18 adults, mean length 18.5 mm., length range 17.5-19.5 mm., 39 sinistrals collected by Welch and Anderson 1933, all dead specimens. These elevations may be plotted too low and should be checked in the field (maps 10, 10a, p. 73).

The race has a much narrower and smaller appearance than typical *nocturna.* Sinistral forms similar to figures 10b and 11, plate 8, do not occur, the common shape being a narrower shell as figure 12, plate 8, which is a little shorter than the usual form. The length is 17.5 mm., greater diameter 10.4 mm., spire height 8.9 mm., the color pattern similar to figure 10a but faded. Figure 13, plate 8, shows a light color pattern and narrow, usual form of a dextral shell, last three whorls light mouse gray axially streaked with quaker drab, behind the edge of the lip an axial streak of white, lip edge honey yellow, wide sutural band white, length 18.1 mm., greater diameter 10.1 mm., spire height 9.3 mm. The shell may be more obese, have a concave spire and a light gray color pattern, first two embryonic whorls cartridge buff shading to chamois, last embryonic whorl chamois fading to white on the last fourth of the whorl, and banded below the suture with a band of white, post-embryonic whorls white shading to pale mouse gray on the last two whorls, axially streaked with light mouse gray and deep mouse gray, last whorl spirally lined with white (pl. 8, fig. 13a). The lightest color pattern (pl. 8, fig. 13b) is a dead specimen, faded and discolored by weathering. The color of the post-embryonic whorls is cartridge buff, probably once white, last whorl lined with cinnamon lines, which darken on the last half whorl to mikado brown. Light white color forms are rare in area 48, only one or two specimens recorded. They are more usual in area 50.

The mean length of the shells in area 49 is less being constantly 18 + mm.,



MAP 10.



MAP 10a.

while in area 48 the mean length values range from 18+ to 19+ mm. Dextrals and sinistrals occur in pure colonies in definite localities.

Achatinella mustelina mixta, new subspecies (pl. 8, figs. 18-20).

The shell is intermediate in color pattern between *A. M. nocturna* and *A. m. brunicolor* var. of area 44, being a mixture of the two patterns; it is closer in form to *A. m. nocturna* with the white sutural band of *nocturna*. Embryonic whorls white, post-embryonic whorls white, last whorl and a half above the periphery pale drab gray and hair brown shading to wood brown, spirally lined with white, below the periphery the last whorl wood brown axially streaked with fuscous, lip white edged with chamois, columella callus white, wide band about the suture white, length 17.6 mm., greater diameter 11.0 mm., spire height 8.4 mm. (pl. 8, fig. 18).

Distribution, area 47: **North Kalalua Gulch**, type locality, W25A-9b, el. 2,000 ft., 37 adults, mean length 17.5 mm., length range 15.5-19.5 mm., 2 dextrals and 35 sinistrals, also localities W25A-9, el. 2,200 ft., 5 adults, 12 sinistrals, mean length 17.5 mm., length range 16.5-19.5 mm., W25A-9a, el. 2,250 ft., 4 adults, length range 17.5-19.5 mm., 1 dextral, 5 sinistrals, Russ 1933, all live specimens collected on native trees; also collected by R. A. Cooke and C. M. Cooke, Jr., 1911, in the general region of area 47, quite likely at a lower elevation. Of the 124 dextrals and 85 sinistrals in their lot, 119 are adults, mean length 19.0 mm., length range 16.5-21.5 mm. (maps 10, 10a, p. 73).

A few dark color forms occur in area 47 which are very close in color pattern to the typical *A. m. nocturna*, but differ in having decidedly more brownish hues. The usual dark color pattern is figured in figure 19, plate 8, embryonic whorls white, post-embryonic whorls white shading to avellaneous, finely axially streaked with dusky drab, natal brown, last whorl spirally lined and axially streaked with natal brown and bone brown, wide sutural band white, lip and columella callus white. A few shells have a light gray color pattern, post-embryonic whorls white spirally lined and banded with pale neutral gray and deep neutral gray (pl. 8, fig. 20).

Achatinella mustelina mixta var. (pl. 8, fig. 21).

Area 46: **Hiu Gulch**, localities W26-3, el. 1,800 ft., 4 adults, 1 dextral, 20 sinistrals, length range 17.5-21.5 mm., W26-4, el. 1,900-1,950 ft., 15 adults, mean length 19.5 mm., length range 17.5-21.5 mm., 9 dextrals, 23 sinistrals; **Hiu-Kumaipo Ridge**, W27-1, el. 1,950 ft., 5 adults, 6 dextrals, mean length 19.0, length range 18.5-19.5 mm., W27-1a, el. 2,000 ft., 7 adults, mean length 18.5 mm., length range 17.5-19.5 mm., 8 dextrals, Russ and Welch 1933, mostly dead shells, some live ones collected on native trees (maps 10, 10a, p. 73).

The shells of this region are intermediate between typical *A. m. mixta* and *A. m. brunicolor* var. of area 44. The usual color pattern of the shells on the Hiu-Kumaipo Ridge is similar to figure 18, plate 8; the darkest color form is close to figure 19, plate 8, only more axially streaked with black; the lightest color form of figure 21, plate 8, is not found in the Kalalua colonies, last three whorls pale drab gray spirally lined with hair brown shading to pale drab gray and lined with wood brown above the periphery, and below the periphery of the last whorl drab gray lined with wood brown. The form of the Hiu shells differs in that the spire is not the usual concave one of the Kalalua forms, but

more straight in outline (pl. 8, fig. 21). Three dead and worn specimens of *Achatinella* were found in Kumaipo, locality W27-2-3, and from what remains of the color and from the close proximity to locality W27-1, it is probable that the form of *mustelina* found in this valley is of the same color pattern as that found on the Hiu-Kumaipo Ridge, locality W27-1.

Achatinella mustelina mixta var. (pl. 8, figs. 22-23).

Area 45: **Kumaipo Gulch,** locality W27C-1a, el. 2,050-2,400 ft.; **Kumaipo-Makaha Ridge,** localities W27B-1, el. 2,800 ft., W27B-2, el. 2,850-3,100 ft., W27B-3, el. 3,150-3,200 ft., W27B-4, el. 3,250-3,350 ft., W27B-5, el. 3,500 ft., Russ 1934, shells collected on native trees (maps 10, 10a, p. 73).

This variety of *A. m. mixta* is a small gray race of shells, conspicuously, finely, axially streaked. The spiral lineation is weak or wanting. In the lower localities, the shells have the same form as the shells of Hiu and Kalalua Gulches. Figure 22, plate 8, shows one of these specimens with the usual light color pattern of the shell, length 18.8 mm., greater diameter 11.7 mm., spire height 9.0 mm., post-embryonic whorls drab gray finely axially streaked on the last two whorls with light drab and hair brown, sutural band white. At higher elevations, localities W27B-3-4-5, mixed with this form occurs an obese shell, length 18.1 mm., greater diameter 12.8 mm., spire height 8.2 mm. (pl. 8, fig. 23). This obese shell shows the usual dark color pattern in area 46 which is especially common in the localities above W27B-3. Post-embryonic whorls shade from white to pale drab on the last two whorls axially streaked with close set axial streaks of hair brown and chaetura drab. These obese forms are very similar to *A. m. kaalaensis,* found across the ridge in Haleauau. But since these squat shells occur mixed with narrower forms, have the color pattern and look like extreme forms of *A. m. mixta,* they have been considered a *mixta* variety rather than a variety of *kaalaensis.*

On the Makaleha-Makaha Division Ridge, localities W172F-3, W172F-4, W172F-5 (maps 4, 4a, p. 25), some color patterns of *A. m. altiformis* occur which are very close to figure 23, plate 8, but the two groups of shells can be separated from each other by the fact that the Makaleha-Makaha shells have a narrower, white sutural band (pl. 4, fig. 11a) or if the sutural band is broader it does not extend below the impressed sutural band (pl. 4, fig. 12d). Some of the light gray patterns found in localities W27B-3 and W27B-2 bear a striking resemblance to forms of *A. m. waianaeensis* (pl. 3, fig. 7a). Also specimens from W27B-5 can be matched up with shells from locality W161B-1 on the Kapuna-Keawapilau Ridge. In spite of the difficulty in separating these shells from those found in other localities, however, the shells have such close affinities to *A. m. mixta* that they should be considered an offshoot of this subspecies which under a certain set of conditions has produced a form similar to other varieties of *A. mustelina.*

Table 15a. Achatinella mustelina mixta var. Area 45.

Locality	Live adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
W27C-1a	18	18.0	16.5-19.5	20	
W27B-1	8	18.0	17.5-20.5	4	5
W27B-2	7	18.0	17.5-18.5		8
W27B-3	7	18.5	17.5-19.5		8
W27B-4	5	18.0	17.5-19.5	5	
W27B-5	7	18.0	16.5-19.5	6	1

Table 15a shows that the shells have a fairly constant mean length value throughout area 45.

Achatinella mustelina mixta var. (pl. 5, figs. 19-21).

Area 43: **Makaha Valley,** localities W30C-13, el. 2,100 ft., W30C-14, el. 2,200 ft., W30C-15, el. 2,200 ft., W30C-17a, el. 2,050 ft., W30C-18, el. 1,750-1,800 ft., Russ and Welch 1933, W30C-15a, el. 2,200 ft., W30C-12, el. 1,900 ft., W30C-10, el. 1,800 ft., Meinecke 1933, W30C-11, el. 1,850 ft., W30C-16-17, el. 2,100-2,350 ft., Lemke and Lemke, Jr. 1933 (maps 9, 9a, p. 60).

All these localities are represented by so few shells that they are not of statistical value though important from a distributional standpoint.

The usual color form in area 43 is colored on the last three post-embryonic whorls drab gray, strongly axially streaked with mars brown and hair brown, lip and umbilical callus white, first whorl worn, showing the light pinkish cinnamon embryonic callus, next two whorls shade from white to pale pinkish cinnamon, sutural band wide and white (pl. 5, fig. 20). Some shells are lighter in color, avellaneous on the last two whorls, sparsely axially streaked with verona brown, russet, and less conspicuously streaked with wood brown, the first three whorls shade from cinnamon buff to pale pinkish buff (pl. 5, fig. 21). Other shells are more spirally lined and have narrower axial streaks, the color of the lines and streaking being similar to figure 20, plate 5 (pl. 5, fig. 19). The embryonic whorls in figure 19, plate 5, are white. An unusual color form is that of figure 20a, plate 5, which might be considered a grayish form of *makahaensis,* last two whorls pale drab gray, axially streaked with drab gray, embryonic whorls and sutural band white. These Makaha forms may be distinguished from the Kalalua forms of Waianae Kai by usually being more obese and having stronger or wider axial streaks. The center of distribution of this race is considered to be the long central ridge running from Mount Kaala down into the northeast head of Makaha. On the northeastern edge of area 43, *makahaensis* occurs in certain colonies so that the *mixta* form occurs only in pure colonies in Makaha Valley, in localities W30C-13, W30C-14, as far as material in Bishop Museum is concerned. In localities W30C-11 and W30C-12, the shells are more brownish,

these colonies being border colonies between *A. m. mixta* var. and *A. m. brunicolor* var. to the southeast. Other collectors of this Makaha variety of *A. mixta* are I. Spalding and L. A. Thurston, W. D. Wilder, and W. Meinceke. Most of their collecting was done somewhere in the region of areas 43 and 44. Area 43 was a favorite collecting ground and very productive at one time, but today this ridge is so overgrown with blackberry bushes that much of the country is barren, the forest has died out, and the shells have become increasingly difficult to find.

Achatinella mustelina mixta var. (pl. 5, figs. 22, 23; pl. 8, fig. 24).

Division ridge between Makaha and Makaleha, locality W172F-2, el. 3,600 ft. and **East-West Branch Ridge of East Makaleha,** localities W171G-5, el. 3,250-3,400 ft. and W171G-6, el. 3,500-3,600 ft., Meinecke 1934 (maps 4, 4a, p. 25).

Meinecke found here a light color form of *A. mustelina* occurring with *A. m. griseitincta* (p. 81). At first glance, the shells look like dark color forms of *A. m. makahaensis* Pilsbry and Cooke, but the shade of color is more brownish and the shells have a wide white sutural band. When these Makaleha shells are matched up with the Makaha forms of *A. m. mixta* var. of area 43, the shells from both localities are found to agree closely in form and color pattern. Localities W172F-2, 171G-5-6 are possibly border localities where *mixta* var. becomes mixed with *griseitincta.*

The usual color pattern of this Makaleha form is shown in figure 22, plate 5. Embryonic whorls worn, but what remains of the shell enamel is white, first post-embryonic whorl white faintly tinted or streaked, and lined with fawn color, impressed sutural band tinted with clay color, last two whorls army brown axially streaked with white, impressed sutural band white. More commonly the entire sutural band is white as in figure 23, plate 5, first embryonic whorl slightly worn, the remaining embryonic whorls pale vinaceous fawn, post-embryonic whorls similar to the color of figure 22, plate 5. Two specimens were found in locality W172F-2 lacking white sutural bands. The shell is closely axially streaked on the last two and a half post-embryonic whorls with pale pinkish buff, verona brown, warm sepia, suture same color as the remainder of the shell (pl. 8, fig. 24).

Achatinella mustelina obesiformis, new subspecies (pl. 8, figs. 4-5a).

The shell is short, last whorl inflated, spire straight in outline, entire ground white, except first embryonic whorl of benzo brown, last whorl spirally lined below and at the edge of the periphery with mikado brown, above the periphery above the aperture banded with a faint band of pale brownish drab for half a whorl, lip and columella callus white, length 17.0 mm., greater diameter 11.4 mm., spire height 12.3 mm. (pl. 8, fig. 4).

Distribution, area: **Kanewai Gulch,** probably somewhere in the vicinity of area 50 (?), C. M. Cooke, Jr. and R. A. Cooke 1911, 7 sinistrals, 1 dextral (maps 10, 10a, p. 73). Also collected by Spalding and now in his private collection, cat. no. 4072.

A more common form of the shell than that of the holotype, but with a rare color pattern is shown in figure 5a, plate 8, embryonic whorls similar

to the holotype, post-embryonic whorls below the wide white sutural and subsutural bands seal brown faintly spirally banded and axially streaked with white or pale gull gray, length 18.4 mm., greater diameter 11.7 mm., spire height 8.1 mm. The combined Spalding and Cooke lots have a mean length of 18.0 mm., length range 17.5-20.5 mm. The entire shell may be white except for five faint lines of cinnamon and faint streaks of cream color 6 mm. behind the edge of the lip (pl. 8, fig. 5).

This squat race of *mustelina* has similar color patterns to *A. m. nocturna* into which it undoubtedly grades, or at least once did. I could not find any locality containing this race in Kanewai Gulch. Either the exact place was not found or the race has become extinct. The light banded white color forms are very similar to Makaleha white *griseitincta* var. forms (pl. 3, fig. 19) but the usual shape and color patterns of the shells of Kanewai and Makaleha are quite distinct.

Achatinella mustelina obesiformis var. (pl. 8, figs. 6-7a).

In Kalalua Gulch, R. A. Cooke and C. M. Cooke, Jr. collected a series of light color forms with *A. m. mixta*. Russ in North Kalalua Gulch, W25A-9, obtained a single specimen with the light color pattern which is a form of *A. m. obesiformis* (pl. 8, fig. 6). The shell is white with the last whorl spirally lined with snuff brown, sayal brown and cinnamon, the spire more elongate and tapering than typical *A. m. obesiformis*. From this shell collected by Russ and from the fact that the Russ localities of *A. m. mixta* in North Kalalua Gulch do not contain this color pattern, I believe that the white shells of the Cooke lot, 22953, which are separated from the specimens of *A. m. mixta* because of color pattern, occur at a low elevation in Kalalua Gulch below *mixta* and that they exist or existed as a pure race, a variant of *A. m. obesiformis*. The probable location of this race is area 50a (?) (maps 10, 10a, p. 73). Some shells in lot 22953 are obese in form similar to figure 5a, plate 8. The usual shape of the shell measures, length 18.7 mm., greater diameter 11.4 mm., spire height 9.4 mm., the color is white ornamented on the last two post-embryonic whorls with cinnamon buff (pl. 8, fig. 7). A few specimens are mixed with the darker color pattern of the higher *mixta* shells. The last post-embryonic whorl and a half cinnamon buff above the periphery, below the periphery pale drab spirally lined with drab gray and a band of warm sepia in the umbilical region (pl. 8, fig. 7a). The mean length of the 11 adult specimens is 20.0 mm., length range 18.5-21.5 mm., 10 dextrals and 6 sinistrals. A comparison of the mean length values of this lot with the length size of the upper shells in area 47 shows a length increase with decrease in elevation.

Achatinella mustelina griseitincta, new subspecies (pl. 8, figs. 14-17).

The shell is obese, whorls convex, spire slightly convex or nearly straight in outline, first embryonic whorl and a half cartridge buff shading to white on the last embryonic whorl, post-embryonic whorl pale gull gray spirally lined with black and pale neutral gray, faintly axially streaked with pale neutral gray on the first post-embryonic whorl, subsutural band pale pinkish buff, on the last two whorls sutural and subsutural bands white lined with light pinkish cinnamon, lip and columella callus tilleul buff, length 18.7 mm., greater diameter 11.6 mm., spire height 8.2 mm., number of whorls 5¾ (pl. 8, fig. 14).

Distribution, area 20: **East Makaleha-Kaawa Ridge,** type locality W191-1, el. 2,500 ft., on lantana and native trees, Russ 1933, 37 adults, mean length 18.5 mm., length range 16.5-20.5 mm., 64 sinistrals, all live specimens, also W191-2, el. 2,400-2,600 ft., 17 dextrals, 14 sinistrals, 19 adults, mean length 18.0 mm., length range 16.5-20.5 mm., Russ 1933; **Kaawa-Kaumokumui Ridge,** W201-1, el. 2,250-2,500 ft., Welch and Grant 1935, 4 adults, 12 dextrals, length range 17.5-20.5 mm.; **Kaawa Gulch,** W190-7, el. 1,750 ft., Russ 1932, 22 adults, 36 dextrals, 8 sinistrals, mean length 19.5 mm., length range 18.5-21.5 mm. (maps 4, 4a, p. 25).

This race of shells is close to *A. m. nocturna* Welch, but differs from the Kalalua race in being more obese and having a gray color pattern which is the dominant color form in the type locality. While light gray similar color patterns occur in Waianae Kai (pl. 8, figs. 13a, 20), they are extremely rare exceptions only found here and there on single specimens in regions where the color pattern is dominantly darker.

A more usual color pattern characteristic of the race found on 41 percent of the shells in the type locality is shown in figure 15a, plate 8. Embryonic whorls white, first post-embryonic whorl white lined on the lower last half of the whorl with mars brown, impressed sutural band cinnamon buff, last two whorls pale gull gray finely lined with pale neutral gray and axially streaked with pale neutral gray and deep neutral gray, impressed sutural band white faintly tinted with cinnamon buff on the last half whorl, subsutural white band narrows to a line of olive brown, lip and columella callus white. The color of the shell may be darker resembling a light color form of *A. m. nocturna* Welch, streaked with light gray (pl. 8, fig. 15b). The post-embryonic whorls are pale gull gray finely axially streaked and spirally lined with pale purplish gray, and deep purplish gray; about the umbilical pore there is a band of pinkish buff, suture and subsutural bands white (pl. 8, fig. 15b). The color pattern may be very light, post-embryonic whorls white tinted and lined with pale gull gray, impressed sutural band pinkish buff (pl. 8, fig. 15); although a pure light gray race in the type locality, *A. m. griseitincta,* usually occurs mixed with various color patterns in the other localities of area 20.

On the Makaleha-Kaawa Ridge, W191-2, the color of the shells is dominantly 48 percent that of figures 15a and 15b, plate 8; 29 percent have the color pattern of figures 14 and 15, plate 8; while 23 percent have the dark typical *nocturna* pattern of figure 10, plate 8. Other collectors in the general region of this locality are W. Meinecke and C. Davis.

Locality W190-7 in Kaawa Valley is a border locality between *A. m. sordida* var. and *A. m. griseitincta* which is the dominant form. Seventeen percent of the shells are dark forms with the shape and color pattern of *A. m. mustelina* because the *sordida* form found in Kaawa is on the border line between typical *mustelina* and *sordida*. The embryonic whorls are white, last three post-embryonic whorls shade from seal brown to black, the white band about the suture extends below the impressed sutural band (pl. 1, fig. 19). The shell may have a band below the edge of the periphery of the last whorl of tawny lined with ochraceous buff (pl. 1, fig. 19a). This subperipheral band is a character found only on shells east of Makaleha. The remainder of the color patterns are *griseitincta* forms. Forty-four percent are like figure 15a, plate 8, the remainder resemble figures 14 and 15, plate 8.

Achatinella mustelina griseitincta var. (pl. 1, figs. 16, 18, 18a; pl. 3, fig. 19; pl. 8. fig. 17).

Area 19: **East-West Branch Ridge of East Makaleha,** localities W171G-2, el. 2,450-2,550 ft., 63 adults, mean length 19.5 mm., length range 17.5-21.5 mm., 59 dextrals, 18 sinistrals, W171G-3, el. 2,650-2,750 ft., 9 adults, mean length 19.0 mm., length range 18.5-20.5 mm., 1 dextral, 13 sinistrals, W171G-4, el. 2,850-3,000 ft., 3 adults, length range 18.5-20.5 mm., 3 dextrals, Meinecke 1934, all live specimens; **East Branch of East Makaleha,** locality W170G-6, el. 1,500 ft., Russ and Welch 1932, 6 live and 6 dead adults, mean length 20.0 mm., length range 18.5-22.5 mm., 47 sinistrals, live specimens found on native trees, 1 dead collected on the ground (maps 4, 4a, p. 25).

In area 19 a mixture of color patterns are found which are closest to *A. m. griseitincta* but differ in some of the color patterns present in different localities from those of the type locality of *griseitincta*.

The dominant color pattern on 47 percent of the shells in W171G-2 is the *griseitincta* pattern of figure 17, plate 8, which has a similar pattern to figure 15a, plate 8, nine percent have a dark *nocturna*-like color pattern (pl. 8, fig. 8) (see description, p. 71). Thirty-five percent have a linear pattern shown on the shell of figure 18, plate 1. Post-embryonic whorls pale gull gray profusely lined with chaetura drab and black, and sparsely axially streaked with chaetura drab, impressed sutural band white, subsutural band cinnamon. In other shells the subsutural band is white and not cinnamon. The remaining nine percent have color patterns similar to figures 17c and 18a, plate 1, and 19, plate 3. Figure 18a, plate 1, is a darker color form of figure 17c, plate 1, first post-embryonic whorl and a half below the impressed white sutural band burnt umber faintly axially streaked with sayal brown, last whorl and a half cinnamon buff shading to pinkish buff below the periphery, axially streaked with russet and tawny. An albinistic form of this pattern resembles the light lineate patterns of Kalalua Gulch, or *A. m. obesiformis* var., is entirely white, lined on the last whorl with a line of cinnamon above the periphery and a line of cinnamon buff below the periphery (pl. 3, fig. 19).

Forty-three percent of the 14 shells of locality W171G-3 have the dark

griseitincta pattern of figure 15b, plate 8, seven percent, light forms, as figure 15, plate 8, but with a white sutural band, and 28 percent the yellowish color pattern of figure 17c, plate 1. In W171G-4, two shells have the pattern of figure 15b, plate 8, and one is similar to figure 17, plate 8.

In East Makaleha Valley, locality W170G-6, 27 percent of the shells have the typical *griseitincta* pattern of figure 15a, plate 8, 26 percent are like figure 18, plate 1, and 29 percent have the light yellowish pattern of figure 17c, plate 1. A variant of the *griseitincta* pattern occurs on 18 percent of the specimens, post-embryonic whorls axially streaked with pale mouse gray and deep livid brown, faintly spirally lined with white, last half whorl tinted with mikado brown (pl. 1, fig. 16).

Achatinella mustelina griseitincta var. (pl. 8, fig. 16).

Area 21: **Makaleha-Makaha Division Ridge,** localities W172F-1, el. 3,600-3,700 ft., 4 adults, length range 17.5-18.5 mm., 4 dextrals, 1 sinistral, W172F-2, el. 3,600 ft., 2 adults, length range 17.5-19.5 mm., 5 dextrals; **East-West Branch of East Makaleha,** localities W171G-5, el. 3,250-3,400 ft., 8 adults, mean length 19.5 mm., length range 18.5-21.5 mm., 17 dextrals, 2 sinistrals, W171G-6, el. 3,500-3,600 ft., 7 adults, 1 dextral, 6 sinistrals, Meinecke 1934, all live shells; **Kaawa-Kaumokunui Ridge,** Thurston 1910 (maps 4, 4a, p. 25).

The dominant color patterns in area 21 are dark blackish forms much like typical *A. m. nocturna* (pl. 8, fig. 10) or dark *griseitincta* forms (pl. 8, fig. 15b). So few shells have been taken from the Makaleha localities of area 21 that very little can be said of form, although the shells tend to be obese. The usual color pattern in this region up to Kaawa-Kaumokunui Ridge is that of figure 10, plate 8, although no narrow, typical *nocturna*-like shells are known from this region in the Bishop Museum collections. The presence in area 21 of dark blackish shells is perplexing. All the intervening localities between Kalalua and area 21 contain, as far as I know, only brownish shells, and no connecting link exists between the widely separate areas. I have therefore considered the shells of area 21 to be dark color patterns of *A. m. griseitincta,* which have probably developed independently of the Kalalua forms and produced a color pattern similar to *A. m. nocturna* due to some set of factors as yet unknown. The other alternative explanation of the relationship of these shells is that possibly a young specimen was transported on a bird's foot in some way from Kalalua to Makaleha. But a study of the *Achatinella* fauna of the Waianae Mountains does not have to postulate such faunistic mixtures, because again and again similar color patterns are produced quite independently of each other in widely separated areas. Usually the color pattern is not so striking, being gray or brown.

The wood brown *mixta* pattern of figures 22, 23, plate 5, occurring in localities W172F-2, W171G-5, W171G-6, does not occur with these blackish shells to the east on the Makaleha-Kaawa Ridge, where typical *A. m. griseitincta* is a pure race. In locality W191-2, Russ collected a few of these dark

forms of *griseitincta*. C. Davis, collecting along the same ridge, obtained a greater number of these dark specimens than Russ. Therefore Davis probably collected most of his shells above W191-2 where the dark form is possibly quite distinct from the lower forms in W191-2.

In the Thurston collection, lots 131303, 131304, 131305, we have a series of shells all similar in form and color pattern to typical *nocturna*, only a bit lighter in color and tending towards the gray form. When received, they were mixed in a tray with shells from Manuwai Gulch region which are all drab gray color forms, while the shells from the Makaleha-Kaawa region are all bluish gray or mouse gray shells. The two lots were easily separable and linked up with their respective labels. The two original labels for lots 131303, 131304, 131305, read "Box 4 Waianae Mts., Waialua, 1st ridge E. of main ridge from Waialua direct to top of Kaala, . . . This ridge [Kaawa-Kaumokunui] curves to S. near top, and has an old trail to top, el. 1900′-3800′. Hab. lehua etc. Shells scarce, 66 specimens dextral 50, sinistral 16. . . . Col. Jan'y 1910 by L. A. T. acd by Spalding and Emory." "Box 5, Waialua main ridge from Waialua to top of Kaala [Makaleha-Kaawa Ridge], el. 1900′. Habitat Pua . . ." Mr. Thurston collected only one *Achatinella* on this ridge. The series of shells in the three lots represent the shells occurring on the Kaawa-Kaumokunui Ridge. The shells from box 4 are so like the forms on the Makaleha-Kaawa Ridge that it is impossible to separate the single shell of box 5 from the shells of box 4. The majority of the shells in the Thurston lots came most probably from somewhere above locality W201-1 in the possible region of locality W201-2 (?). The number of adults in the Thurston lots is 35, mean length 18.5 mm., length range 17.5-20.5 mm., 45 dextrals and 18 sinistrals. The usual form of the shell measures, length 19.3 mm., greater diameter 12.2 mm., spire height 9.5 mm., embryonic whorls worn, warm buff shading to white, post-embryonic whorls seal brown axially streaked with white, sutural band on first post embryonic whorl cinnamon buff, shading to white on the later whorls, wide subsutural band white (pl. 8, fig. 16).

The mean length of the shells in areas 19, 20, and 21 decreases with increase of altitude. In East Makaleha, the lowest locality, W170G-6, has a mean length of 20+ mm., while all the higher localities have mean lengths of 19+. On the Makaleha-Kaawa Ridge, localities W191-1 and W191-2 have definitely smaller shells with mean lengths of 18+ even though the localities are at similar or lower elevations than the Makaleha ones. Therefore increased elevation and size decrease are not correlated in this region.

Achatinella mustelina brunibasis, new subspecies (pl. 6, figs. 1-4c).

The shell is an elongate form similar to *A. m. kaalaensis* being intermediate between the *A. m. sordida* var. of areas 18 and 14 and *A. m kaalaensis*. The spire is slightly concave, embryonic whorls tinted with pale pinkish buff, shading to white on the last em-

bryonic whorl, first post-embryonic whorl white banded on the lower half of the whorl with bister, last two whorls a light shade of pale neutral gray below the white impressed sutural and subsutural bands, faintly lined with white, base banded with bister, lip and columella callus vinaceous fawn, length 18.4 mm., greater diameter 10.7 mm., spire height 10.3 mm., number of whorls 6½ (pl. 6, fig. 1).

Area 15: **South Maili-East Pulee West Branch Ridge,** type locality W300A-3, el. 2,400 ft., Meinecke 1936; **South Maili,** locality W290-1, el. 2,250 ft., **Puulu Gulch,** locality W270-10, el. 2,250 ft., **Puulu-East Pulee West Branch Ridge,** locality W300A-4, el. 2,450 ft.; **Palikea-East Pulee West Branch,** localities W300A-5, el. 2,450 ft., W300A-6, el. 2,500 ft., Meinecke 1936, locality W300A-5-4-3, Russ 1932; **West Pulee Gulch Central Branch,** locality W300B-2, el. 1,750-2,000 ft., Welch and Winne 1934; **Palikea-Puulu Ridge,** locality W270-11, el. 2,350-2,450 ft., Heine 1932 (maps 5, 5a, p. 32).

The form of the shell in the type locality ranges from narrow shells with almost straight spires, length 18.4 mm., greater diameter 10.7 mm., spire height 10.8 mm. (pl. 6, fig. 2) to obese forms with a very concave spire, length 18.3 mm., greater diameter 12.2 mm., spire height 9.3 mm. (pl. 6, fig. 2b). Figure 2a shows a specimen with the outline of the spire straight or slightly convex. The typical form of a shell of the length class 19.5 mm. measures, length 19.6 mm., greater diameter 11.6 mm., spire height 11.1 mm. (pl. 6, fig. 3). The color pattern varies; the shell may be light in color, first embryonic whorl mars brown shading to white tinted with light buff on the last half of the whorl, last two embryonic whorls shade from white tinted with light buff to white, post-embryonic whorls below the white subsutural band pallid mouse gray, base buckthorn brown, impressed sutural band ochraceous tawny on the first half of the first post-embryonic whorl, shading to avellaneous on last half of the whorl, on the last two whorls impressed sutural band tilleul buff (pl. 6, fig. 2b). The gray banding on the post-embryonic whorls may be smoke gray; the impressed sutural band white except for the first post-embryonic whorl where it is cinnamon brown shading to white (pl. 6, fig. 3).

While the shells in the type locality are 99 percent dextral, localities occur where the shells are dominantly sinistral. Locality W270-10 is 76 percent sinistral. The typical sinistral form of the shell measures, length 19.6 mm., greater diameter 12.2 mm., spire height 9.6 mm., spire concave on left hand side of aperture, straight on right hand side of aperture; last two whorls drab gray tinted with ochraceous tawny on the last whorl (pl. 6, fig. 4). A more obese sinistral (pl. 6, fig. 4a) has a length of 19.5 mm., greater diameter 12.8 mm., spire height 9.3 mm., and exhibits the variation of the spire usual on about 33 1/3 percent of the shells; the spire is slightly convex on the left hand side, and slightly concave on the right hand side when viewed from the aperture side of the shell. The spire may be almost straight in outline, slightly concave on the left side, base flattened so that the last whorl is very slightly angled (pl. 6, fig. 4b). Twelve percent of the shells in W270-10 have a brown pattern similar to figure 4c, plate 6, embryonic whorls light buff,

first post-embryonic whorl light buff shading to white, banded with cinnamon brown shading to smoke gray, penultimate whorl drab shading to buffy brown, finely closely axially streaked and spirally lined with tawny olive, base banded with bister. This brown pattern of figure 4c is common throughout area 15, anywhere from one to a dozen specimens being found in a locality. The type locality does not contain this pattern. As a general rule higher localities contain dominantly gray forms, while lower localities on the Mokuleia side of the range have dominantly brown patterns the nearer the locality to areas 14 and 17a.

Table 16. Achatinella mustelina brunibasis Welch. Area 15.

Collector	Locality	Live Adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Meinecke	W270-10	71	19.0	17.5-21.5	25	80
Heine	W270-11	156	19.0	17.5-21.5	148	8
Meinecke	W290-1	44	18.5	16.5-21.5	2	76
Meinecke	W300A-3	52	18.0	16.5-20.5	60	1
Meinecke	W300A-4	74	19.0	16.5-21.5	101	2
Meinecke	W300A-5	41	19.0	17.5-22.5	44	
Meinecke	W300A-6	4	19.0	17.5-20.5	17	8
Russ	W300A-3-5	185	18.5	16.5-22.5	267	

Comparing the length value of area 15 (table 16) and areas 14, 17 and 18 (pp. 41-42) a marked decrease in size is seen in the upper area. The change in size is somewhere above 1,800 feet.

Achatinella mustelina brunibasis var. (pl. 6, figs. 5-10).

Area 16: **Alaiheihe Gulch,** localities W230-10, el. 1,850-1,900 ft., 2 adults, 2 dextrals, 7 sinistrals, W230-11, el. 1,850 ft., 3 adults, 9 sinistrals, Russ 1935; **Manuwai-Alaiheihe Ridge,** localities W231-2, el. 1,850-1,950 ft., W231-3, el. 1,950 ft., W231-4, el. 1,950-2,000 ft., Russ and Welch 1935, W231-5, el. 2,200-2,300 ft., 1 dextral, 7 sinistrals, W231-6, el. 2,300-2,400 ft., 3 adults, 9 dextrals, 1 sinistral, Welch 1935; **Alaiheihe-Pulee Ridge,** locality W232-1, el. 2,550-2,600 ft., Russ 1931; **Manuwai Gulch,** localities W220-7a, el. 1,400 ft., 4 adults, 5 sinistrals, Russ 1931, W220-7, el. 1,450 ft., 2 dextrals, 7 sinistrals, dead, Welch 1932, 1 dextral and 2 sinistrals, dead, Anderson 1932, W220-10, el. 1,650-1,850 ft., Welch and Anderson 1932, combined lots, 2 dextrals, region of W220-11, approximate el. 1,600-1,650 ft. (?) region of W220-12, approximate el. 1,900 ft., (?), Lemke 1932; **Manuwai-Pulee Ridge,** locality W222-1, el. 2,700 ft., 3 adults, 8 sinistrals, Welch 1935; **Kaumokiki-Manuwai Ridge;** locality W211-1, el. 1,900 ft., 1932 (maps 5, 5a, p. 32).

Area 16 contains a form of *A. m. brunibasis* which lacks the dark, basal brown band. The only place shells are found having dark basal brown bands in any of the localities is on the lower or northern edge of area 16. All shells of the highland localities are 100 percent pure without a dark basal band. The typical form of the shell measures, length 18.4 mm., greater diameter 12.2 mm., spire height 9.1 mm., embryonic whorls shade from white tinted with cream buff to white; post-embryonic whorls buffy brown spirally

lined with lines slightly darker than the ground, impressed sutural band white, lip light vinaceous fawn (pl. 6, fig. 5). The spire may not be concave as in figure 5, plate 6, but straight in outline, or slightly convex; length 18.7 mm., greater diameter 11.5 mm., spire height 10.0 mm., embryonic whorls worn lacking enamel, first two post-embryonic whorls drab gray, last whorl drab gray faintly tinted with buckthorn brown, banded at the edge of the periphery with dresden brown, sutural and subsutural bands white (pl. 6, fig. 5a). The form of dextral shells varies a great deal. The form at the top of the range between Pulee and Alaiheihe Gulches is shown in figure 6, plate 6. The typical form cannot be determined for lack of specimens; the usual color forms occur here. The specimen of figure 6, plate 6, is an extreme light color form occurring on three or four specimens in W232-1, post-embryonic whorls white banded just above the periphery and all below the periphery with tilleul buff or vinaceous buff lined with white. The usual color form in W231-2 is that of figure 5, plate 6. In Manuwai Gulch, W220-11 and W220-12, the usual form and color pattern of the shell is that of figure 7, plate 6, length 18.6 mm., greater diameter 11.4 mm., spire height 9.7 mm., embryonic whorls white, post-embryonic whorls tilleul buff and vinaceous buff, impressed sutural band white. In locality W220-7a, gray sinistral forms similar in shape to figure 4, plate 6, are found. Russ also discovered a shell with a yellow color pattern, embryonic whorls white, first two post-embryonic whorls snuff brown; last whorl light buff finely axially streaked or tinted with ochraceous tawny, impressed sutural and subsutural bands white, wide white subsutural band darkens to the ground color on the last whorl below which is a band of buffy brown (pl. 6, fig. 8).

The shell of figure 8 is undoubtedly a shell of the lower form of *A. m. mustelina,* intermediate between *A. m. sordida* var. and *A. m. brunibasis* var. but having the lower *sordida*-like pattern. A similar color pattern is found in locality W220-12.

High on the backbone ridge in localities W222-1 and W231-6, gray obese shells with very concave spires occur (pl. 6, figs. 9-10). Whether these forms in these localities are usually similar to figures 9 and 10 cannot be determined because of the small number of shells on hand; post-embryonic whorls drab, impressed sutural band white (pl. 6, fig. 9) or the last two whorls shade from mouse gray to pale mouse gray on the first half of the last whorl, last half pale mouse gray tinted with buff brown (pl. 6, fig. 10). The shells from locality W211-2 are two juveniles and are closer to the typical *A. m. brunibasis* color pattern and form than the *A. m. sordida* intermediate forms. The shells are probably from the extreme lower limit of the area occupied by *A. m. brunibasis* because the black or dark basal brown band occurs on the shells.

Table 17. Achatinella mustelina brunibasis var. Area 16.

Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
W231-2	20	9	18.5	15.5-20.5	2	74
W231-3	4	40	18.5	17.5-20.5	14	34
W231-4	7		18.0	17.5-18.5		20
W232-1	8		18.5	17.5-19.5	12	23
W220-11	9		18.5	17.5-19.0	10	
W220-12	19		18.0	16.5-19.5	32	

When the statistics of areas 9 and 16 are compared (tables 17 and 8, p. 37), the higher shells are found to be decidedly smaller.

Achatinella mustelina diffusa, new subspecies (pl. 7, figs. 7-9b).

The shell is more obese than *A. m. brunibasis,* last whorl rounded, spire concave, first half embryonic whorl clove brown shading to cartridge buff on the next whorl, last embryonic whorl white, post-embryonic whorls up to the last whorl and a half, white including the impressed sutural band, just above the suture there is a line of clove brown beginning at the fourth whorl, last whorl and a half above the periphery below the wide white sutural band pale drab gray lined, lightly banded and lightly axially streaked with olive brown, below the periphery and extending just above the edge of the periphery, the ground is isabella color closely finely axially streaked and lined with indistinct threadlike lines of black, lip edge and columella callus light grayish vinaceous. Length 18.8 mm., greater diameter 12.2 mm., lesser diameter 12.1 mm., height of spire 9.4 mm. (pl. 7, fig. 7).

Distribution, area 58: **West Pulee-North Haleauau Ridge,** type locality W311-1, el. 2,000-2,200 ft., Welch and R. Emory 1935, 32 adults, mean length 18.5 mm., length range 17.5-20.5 mm., 41 dextrals, 31 sinistrals, also Heine, 77 adults, mean length 18.5 mm., length range 16.5-20.5 mm., dextrals 36, sinistrals 71; W311-2, el. 2,300-2,350 ft., 14 adults, mean length 18.0 mm., length range 16.5-20.5 mm., 8 dextrals, 41 sinistrals, Welch and R. Emory 1935; **North Haleauau Gulch,** W310-1, el. 2,000-2,100 ft., Meinecke 1918, 1925, 27 adults, mean length 18.5 mm., length range 16.5-21.5 mm., 9 dextrals, 39 sinistrals (maps 11, 11a, p. 88). The form was also collected by C. M. Cooke, Jr., A. F. Judd, W. D. Wilder, J. S. Emerson. On the **Pulee-Haleauau Ridge** in locality W311-3, el. 2,400-2,500 ft., Welch and R. Emory 1935, the shells were found to be intermediate in color and form between the shells of areas 58 and 57, 10 adults, mean length 18.0 mm., length range 17.5-19.5 mm., 32 dextrals, 6 sinistrals. The shells in W311-3 tend more toward the form of *diffusa* than to the upper race of *A. m. kaalaensis* var. (p. 90).

The shell may be narrower than the typical form, length 18.2 mm., greater diameter 11.7 mm., spire height 9.4 mm., post-embryonic whorls light buff finely lined and axially streaked with ochraceous tawny, penultimate and last whorl banded just above the periphery with buffy brown, below the periphery solid bone brown (pl. 7, fig. 9). The spire may be almost straight in outline and slightly convex in about 10 percent or less of the shells (pl. 7, fig. 9a). The color can be very light (pl. 7, fig. 9a), post-embryonic whorls white; color just above the periphery and all below the periphery snuff brown faintly spirally lined with white. A single, unusually narrow specimen (pl. 7, fig. 8) is found resembling certain forms of *A. m. brunibasis,* length 18.9 mm., greater diameter 10.9 mm., spire height 10.2 mm., the color pattern is quite

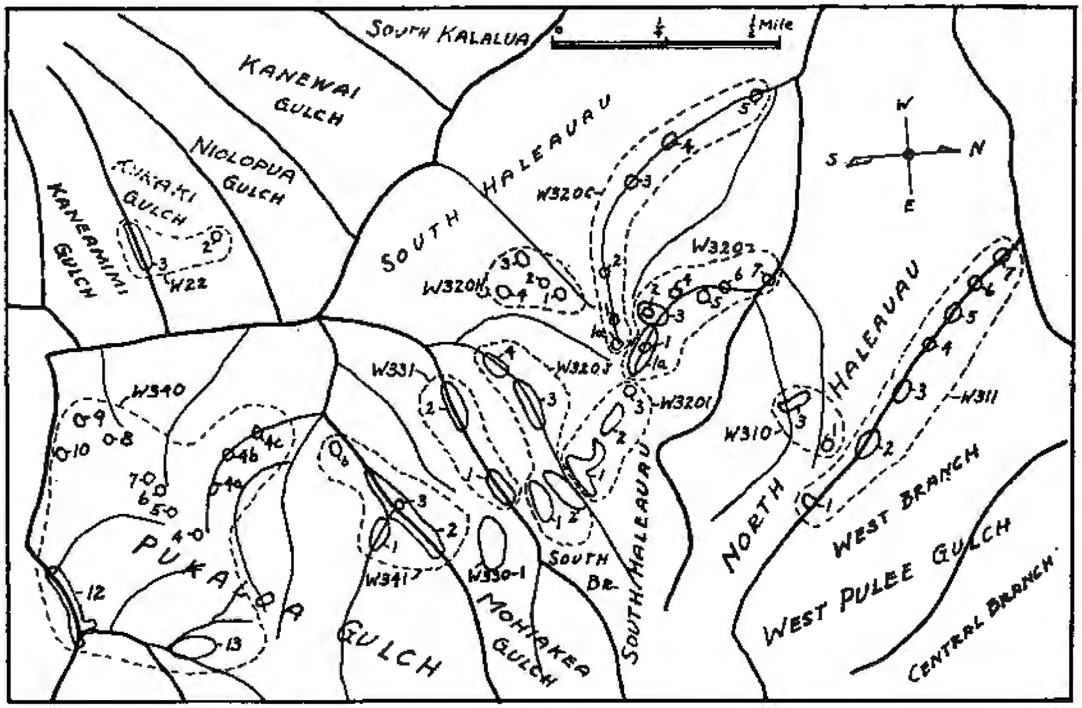
distinct, however, being similar to figure 9b, plate 7. Figure 9b shows the typical form of the sinistral specimen which is usually slightly narrower and shorter than the usual dextral form, length 18.5 mm., greater diameter 11.5 mm., spire height 8.6 mm., post-embryonic whorls below the white impressed sutural band mouse gray axially streaked and tinted with clove brown, just above the periphery and below the periphery the entire base is clove brown. In the Heine lot from the type locality, 63 percent have the typical color pattern; the Welch lot contains 73 percent of the typical pattern. The remainder of the shells is similar to figure 9a, plate 7.

Achatinella mustelina kaalaensis, new subspecies (pl. 6, figs. 11-12e).

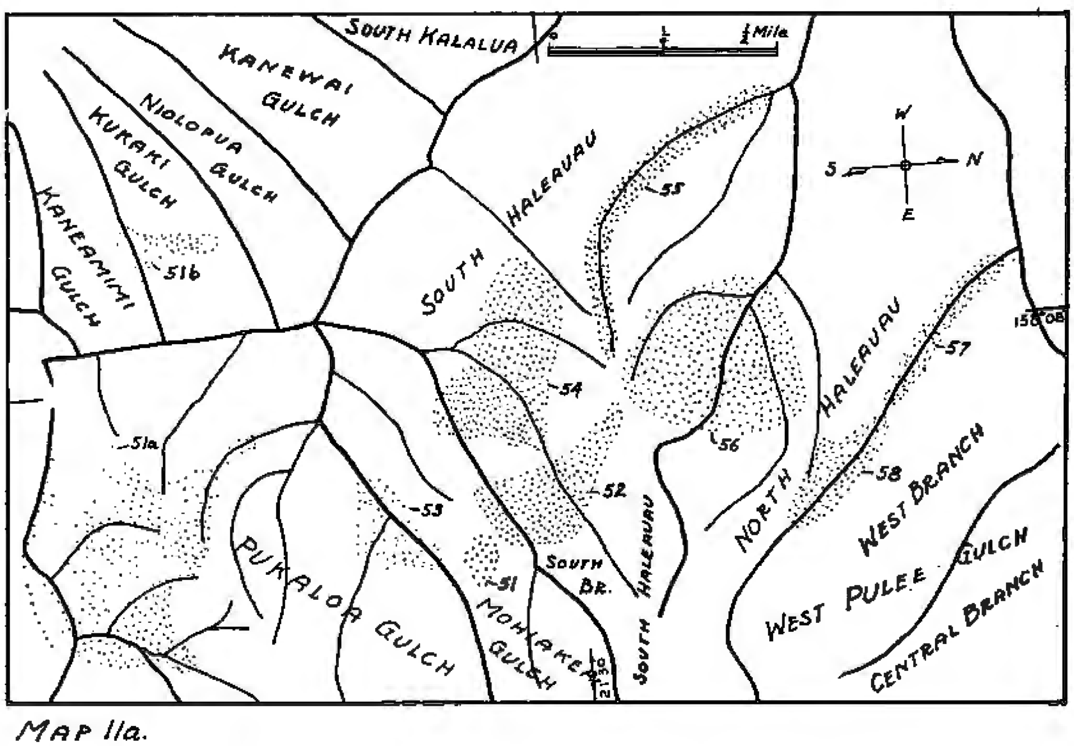
Shell dextral, spire straight in outline, whorls slightly convex, form of the embryonic whorls, or pointedness of the apex, similar to the closely related form of *A. m. nocturna*. The two forms differ in color pattern, shape of the spire; last whorl more obese and slightly flattened below the periphery in *kaalaensis*, so that the shell has a triangular appearance, while *nocturna* has a rounded last whorl and the typical form narrower. The embryonic whorls shade from pinkish buff on the first whorl to pale pinkish buff on the third, the first fourth of the first post-embryonic whorl pale pinkish buff axially streaked with mars brown, last two whorls and a half, below the white subsutural band, drab gray lined with snuff brown, below the periphery of the last whorl drab, lined and banded with snuff brown, upper half of the impressed sutural band edged with verona brown, lower portion white, outer margin of the lip fawn color, inner margin and columella callus white, length 17.3 mm., greater diameter 11.3 mm., lesser diameter 11.2 mm., height of the spire 8.9 mm. (pl. 6, fig. 11).

Distribution, area 56: **South Haleauau Gulch**, type locality W320-3, el. 2,350-2,500 ft., Meinecke 1921, lot 123067, also collected 1920, 1926, by Meinecke, and in locality W320-1-2-3, el. 2,250-2,500 ft., Meinecke 1918, 1922, region of W320-1-7, 1918, 1920, W320-1a, el. 2,250-2,450 ft., Meinecke 1920, W320-5, el. 2,700-2,750 ft., W320-6, el. 2,750 ft., 1 dextral, W320-7, el. 3,000 ft., 1 sinistral, Grant 1934, W320-4-5, F. R. Fosberg 1935; **North Haleauau Gulch**, locality W310-3, el. 2,300-2,400 ft., Meinecke 1918, 1925. Locality W320-1a is an intermediate one between the shells of areas 56 and 52 (maps 11, 11a, p. 88).

The usual dark color form may have the first two and three fourths embryonic whorls bicolored, white at the upper edge of the whorl and honey yellow on the lower three fourths of the whorl, the last half embryonic whorl being almost unicolored the honey yellow shading to white, post-embryonic whorls snuff brown spirally lined with pinkish buff and cinnamon buff, with a patch of russet on the first half post-embryonic whorl, impressed sutural band white, lip light pinkish cinnamon (pl. 6, fig. 12d). Figure 12e, plate 6, is a variation of figure 12d, embryonic whorls warm buff, first post-embryonic whorls burnt umber for a fourth a whorl, remaining whorls banded with white, snuff brown, sayal brown and bister, suture sayal brown; the form is an obese sinistral one. Light color forms have the embryonic whorls warm buff shading to white, sutural and subsutural band white, last three whorls pale drab gray finely axially streaked and lined with drab gray, banded with sayal brown about the umbilical pore, last fourth whorl below the periphery tinted with clay color. This shell (pl. 6, fig. 12) also exhibits an obese form



MAP II.



MAP IIa.

having a length of 17.4 mm., greater diameter 12.2 mm., lesser diameter 11.7 mm., height of spire 8.3 mm. An unusually slender shell having the color pattern of figure 11, plate 6, is shown in figure 12a. Figure 12b has the last three whorls banded with drab gray and light drab, lip tinted with cream buff. In figure 12c the shell is white banded on the last three whorls with light drab and drab above the periphery, below the periphery lined with snuff brown and bister. The patterns of figures 12b, 12c, 12e, are rare patterns in area 56.

Table 18. Achatinella mustelina kaalaensis Welch. Area 56.

Year	Locality	Live adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
	W310-3	15	18.0	16.5-19.5	5	17
	W320-1a	182	18.0	15.5-20.5	206	73
1920	W320-3	47	17.5	15.5-20.5	56	11
1921	W320-3	175	17.5	15.5-20.5	202	31
1926	W320-3	146	17.0	15.5-19.5	197	37
1918	W320-1-2-3	66	17.0	15.5-19.5	111	46
1922	W320-1-2-3	76	17.5	15.5-20.5	91	34
1922	W320-1-2-3	209	17.5	15.5-21.5	290	99
1918	W320-1-7	241	17.0	15.5-19.5	397	29
1920	W320-1-7	153	17.0	15.5-19.5	246	28
1934	W320-5	12	18.0	16.5-19.5	5	11

Since all the localities in table 18 are collected by Meinecke, except W320-5 which is collected by Grant, the name of the collector has been omitted. Locality W320-5, higher than the other W320- localities, has shells of larger mean length than the shells in the lower localities. This may be due to the small number of shells collected. The mean length of the shells of W320- localities is constantly 17+ even when collected over a period of eight years, giving an idea of the constancy of size and color pattern of a form in a definite region. The shells of area 56 and the adjacent region are much smaller than any other *Achatinella* in the Waianae Mountains, even though collected at similar elevations in Mokuleia, with the exception of locality W191-2 on the Makaleha-Kaawa Ridge. Therefore, altitude is not the determining factor for size, although the shells at the lower elevations in Haleauau are larger than the shells of area 56; and proximity to the top of Mount Kaala is not the deciding factor, for areas 21 and 22 (map 4a, p. 25), and 45 (map 10a, p. 73) have larger shells than area 56. Of course, the lots of shells from areas 21, 22, and 45 are smaller than those from area 56 and here may be a discrepancy. However, assuming the available data to be correct, altitude and proximity to Mount Kaala do not seem to be the deciding size factors.

Achatinella mustelina kaalaensis var. (pl. 6, figs. 13-16).

Area 55: **South Haleauau Gulch,** localities W320C-1, el. 2,300 ft., 1 dextral, W320C-1a, el. 2,200 ft., 22 sinistrals, Grant 1935, W320C-2, el. 2,400 ft., Maj. and Mrs. C.

Steel 1934, W320C-1-2, C. W. Isle 1935, 14 dextrals, 35 sinistrals, also Steel 1934, W320C-2-4, Isle, 7 dextrals, 32 sinistrals, W320C-3, el. 2,600-2,700 ft., 10 dextrals, W320C-4, el. 2,800-2,850 ft., 9 dextrals, 5 sinistrals, W320C-5, el. 3,150-3,250 ft., 1 dextral, 6 sinistrals, Grant 1935, W320C-5-4, 15 dextrals, 11 sinistrals, Isle 1935, 1 dextral, 7 sinistrals, Hosaka 1935. Combining the lots from W320C-1-2, the 25 adults have a mean length of 18.0 mm., length range 16.5-19.5 mm., of the W320C-2-4 lots, 7 adults, mean length 17.5 mm., length range 15.5-18.5 mm., of combined lot from W320-4-5, 15 adults, mean length 17.5 mm., length range 15.5-19.5 mm. (maps 11, 11a, p. 88).

The material from the above localities in area 55 is composed of small lots of shells, mostly juvenile specimens, so that it is not possible to say whether one pattern is dominant over another, although all the patterns seem to be fairly uniform. Even the dextral and sinistral localities need to be worked out more carefully in order to determine the exact limits of dextral and sinistral areas. In general the color patterns are darker than those in area 56. The form of some of the shells are very similar to the shape of the shells of *A. m. mixta* var. in localities W27B-4-5 on the Kumaipo-Makaha Division Ridge; but the bulk are closest to the shells in area 56. A typical pattern is a shell with the upper half of the first two embryonic whorls white, lower half cinnamon buff, lower band shades to white on the last embryonic whorl, first post-embryonic whorl axially streaked with benzo brown, last two whorls pallid mouse gray lined and axially streaked with olive brown (pl. 6, fig. 13). The last two whorls pale drab gray finely, closely, axially streaked with drab, behind the edge of the lip the color is mars brown, lip pale grayish vinaceous (pl. 6, fig. 14). Embryonic whorls tawny shading to light buff on the last half embryonic whorl, first half post-embryonic whorl mars brown lightening on the upper fourth of the whorl to russet, impressed sutural band mars brown, last two whorls light drab finely axially streaked with saccardo's umber, impressed sutural band shades from verona brown to snuff brown, subsutural band cinnamon buff (pl. 6, fig. 15). Embryonic whorls cinnamon buff, first fourth of first post-embryonic whorl warm sepia, last two whorls buffy brown, axially streaked and banded with bister (pl. 6, fig. 16).

Not much can be said about the size of the shells in area 55 because of the small lots of shells. From the material there seems to be an increase in size the lower the locality, similar to area 56, but this is not an altitudinal factor entirely as already discussed on page 89.

Achatinella mustelina kaalaensis var.

Area 57: **Pulee-North Haleauau Ridge,** localities W311-4, el. 2,500-2,600 ft., 14 adults, mean length 18.5 mm., length range 17.5-19.5 mm., 19 dextrals, 2 sinistrals, W311-5, el. 2,600-2,700 ft., 41 adults, mean length 18.0 mm., length range 16.5-19.5 mm., 17 dextrals, 77 sinistrals, W311-6, el. 2,700-2,850 ft., W311-7, el. 2,850-2,900 ft. Combined lots of W311-6-7, 18 adults, mean length 17.5 mm., length range 15.5-19.5 mm., 3 dextrals, 42 sinistrals, collected by Welch and R. Emory 1935 (maps 11, 11a, p. 88).

The representatives of area 57 are dominantly gray color forms similar in form and color pattern to figures 12b, 12c, 13, plate 6. The shells are all

small with mean lengths of 17 + or 18 + mm., except in W311-4 which has larger shells. This size discrepancy may be due to the small number of shells collected.

Achatinella mustelina collaris, new subspecies (pl. 7, figs. 10-11c).

The shell is similar to *A. m. diffusa* in form, differing in having a less concave and more elongate spire, and having a different color pattern, embryonic whorls bicolored, upper half white, lower half chamois, first two post-embryonic whorls just above the edge of the periphery seal brown, last whorl and a half cinnamon buff, ground almost completely covered over with spiral lines, band and axial streaks of seal brown, lip light vinaceous fawn, columella callus white, length 19.5 mm., greater diameter 12.5 mm., spire height 10.2 mm., number of whorls 6½ (pl. 7, fig. 10).

Distribution, area 51: **Mohiakea Gulch,** type locality W330-1, el. 2,000-2,200 ft., Meinecke 1936, 51 adults, mean length 19.5 mm., length range 16.5-21.5 mm., 55 dextrals, 7 sinistrals, all live specimens; also collected by Heine 1933 (maps 11, 11a, p. 88).

The shell may be narrower than the holotype and have a lighter color pattern, length 20.0 mm., greater diameter 11.7 mm., spire height 10.8 mm., embryonic whorls worn, upper half white, lower half very faintly tinted with cream buff, post-embryonic whorls white, just above the periphery and all below the periphery the ground color is drab, axially streaked with sepia and snuff brown with a single line of white below the periphery, lip and columella callus cartridge buff tinted at the edge of the lip with cream buff (pl. 7, fig. 11). The usual obese form of the shell measures 19.0 mm., greater diameter 12.8 mm., spire height 9.3 mm. (pl. 7, fig. 11a). The form of a sinistral shell may be more elongate, length 19.2 mm., greater diameter 11.7 mm., spire height 10.0 mm. (pl. 7, fig. 11b); or more obese, length 19.0 mm., greater diameter 12.4 mm., spire height 8.8 mm. (pl. 7, fig. 11c). The color patterns of figures 11a and 11b, plate 7, are similar to figure 10, plate 7. Figure 11c is a very light color form, last two whorls pale smoke gray, spirally banded with drab and natal brown, lip tinted with cream buff.

Achatinella mustelina collaris var. (pl. 7, figs. 12-13).

Area 51a: **Pukaloa,** localities W340-4, el. 2,100 ft., W340-5, el. 2,150 ft., W340-6, el. 2,200 ft., W340-7, el. 2,250 ft., 5 dextrals, 1 sinistral, W340-8, el. 2,300 ft., 3 sinistrals, W340-9, el. 2,400 ft., 2 dextrals, W340-10, el. 2,550 ft., 1 sinistral, W340-4a, el. 2,500 ft., W340-4b, el. 2,650 ft., W340-4c, el. 2,800-2,850 ft., Welch and Winne 1933, region of W340-4-5-6-7, Meinecke 1927, 1925, Heine 1933, W340-12, el. 2,750 ft., Steel 1933, W340-13, approximate el. 2,000-2,250 ft., O. Degener 1936. Other collectors in area 51a are L. A. Thurston, C. M. Cooke, Jr., W. D. Wilder, E. D. Baldwin, O. H. Emerson, J. S. Emerson, A. F. Judd, W. A. Bryan, and A. Seale (maps 11, 11a, p. 88).

While dark forms similar to figure 10, plate 7, are found in area 51a, the dominant color patterns on 93 percent of the shells are lighter colors varying from browns to drabs or grays. The usual forms of the shells of the 19+ mm. length class are either 50 percent elongate forms similar to figure 12, plate 7, or 50 percent obese shells similar to figure 12a, plate 7. The large Meinecke lot (no. 123213) of 325 shells from the region of localities W340-

4-5-6-7-8 was used as a basis of study. The elongate shell measures, length 19.4 mm., greater diameter 11.2 mm., spire height 10.4 mm., post-embryonic whorls pallid mouse gray axially streaked on the first two post-embryonic whorls with light mouse gray, last whorl spirally lined with buffy brown (pl. 7, fig. 12). The obese form has the post-embryonic whorls colored drab gray, darkening to light drab on the last whorl, finely spirally lined on the last whorl with pale drab gray, lip tilleul buff, length 19.4 mm., greater diameter 12.1 mm., spire height 9.2 mm. (pl. 7, fig. 12a). An unusual pattern is shown in figure 12b, plate 7, first two post-embryonic whorls pale mouse gray banded with benzo brown, last whorl light drab, spirally banded, lined, and streaked with bister, lip cartridge buff. The lip is also unusual in that it is strongly corrugate similar to *A. m. kapuensis*. In locality W340-7, Welch located dextral shells similar to figures 12c and 12d, plate 7. The shell of figure 12c, plate 7, measures, length 19.1 mm., greater diameter 11.0 mm., spire height 10.5 mm., post-embryonic whorls pale gull gray, almost completely covered over with spiral lines of pale smoke gray, impressed sutural band white, subsutural band light drab. The lightest color pattern is shown in figure 12d, plate 7, post-embryonic whorls pale gull gray with a band of drab gray above the periphery and five faint lines of drab gray below the periphery. In locality W340-4c, the form of the dextral shells is usually more obese similar to figure 13, plate 7, length 20.0 mm., greater diameter 12.4 mm., spire height 10.0 mm., post-embryonic whorls snuff brown spirally streaked with tawny olive; impressed sutural band white (pl. 7, fig. 13.) This brown color pattern is a common one throughout the area and specimens of this pattern are impossible to separate from the Makaha forms of *A. m. brunicolor*. The pattern of figure 12a, plate 7, is another difficult one to separate from the shells occurring on the Kapuna-Makua Ridge, locality W160A-6. The shells from W160A-6 are usually slightly darker and more gray but this fact is of little help in mixed lots. The embryonic whorls of the shells in area 51a are usually white or have a faint trace of a cream buff band on the lower half of the whorl. A few shells have the embryonic whorls similar to figure 10, plate 7.

Table 19. Achatinella mustelina collaris var. Area 51a.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W340-4	33	2	18.5	17.5-20.5		83
Welch	W340-5	7	9	19.0	17.5-21.5		24
Welch	W340-6	8		18.0	16.5-21.5	5	8
Meinecke	W340-4-7	311		19.0	16.5-22.5	57	786
Meinecke	W340-4-7	212		20.0	16.5-23.5	39	286
Welch	W340-4a	13	20	18.5	16.5-20.5	1	63
Welch	W340-4b	11		19.5	17.5-20.5	1	22
Welch	W340-4c	15	2	19.0	17.5-20.5	31	9

Table 19 points out that the shells vary in mean length values from 18+ to 19 + mm., with the larger shells (19 +) at higher elevations than the smaller shells, and that locality W340-5 is made up of large shells surrounded by localities of smaller ones. Therefore no regional size decrease with altitude is shown in area 51a by the present material. The Meinecke lot of 311 shells was collected in 1927, while the lot of 212 shells was procured in 1925. From these two lots it would be possible to postulate that from 1925 to 1927 there was an evolutionary change or a seasonal change causing the size decrease in the 1927 lot. A glance at the table indicates that if the majority of the shells were collected in W340-5 at one time, the shells would probably be larger than if collected in locality W340-4. The shells in localities W340-6-7 appear, from the small lots collected, to be smaller than the shells in the lower localities. If this could be statistically verified by additional material, the difference in the mean values in the Meinecke lots could be explained on a basis of differences in the exact locality from which the majority of the shells were collected in different years.

Achatinella mustelina collaris var. (pl. 7, figs. 14-16; pl. 6, figs. 17-18).

Area 52: **South Haleauau Gulch South Branch,** localities W320J-1, el. 2,000 ft., Welch 1935, 51 dead adults, 2 live adults, mean length 19.0 mm., length range 17.5-21.5 mm., 17 dextrals, 112 sinistrals, also Meinecke 1936, Steel 1934, Isle 1935, W320J-2, el. 2,000 ft., Steel 1934, Isle 1935; **South Haleauau Gulch,** localities W320I-1, el. 2,000-2,100 ft., W320I-2, el. 2,000-2,100 ft., Steel 1934, W320I-3, el. 2,000 ft., 91 live adults, mean length 19.5 mm., length range 17.5-22.5 mm., 5 dextrals, 142 sinistrals, Meinecke 1920; **South Haleauau South Branch-Mohiakea Ridge,** locality W331-1, el. 2,450-2,500 ft., Heine 1933, 11 live adults, mean length 19.5 mm., length range 18.5-20.5 mm., 23 dextrals, 2 sinistrals. Shells in area 52 collected on native trees and lantana (maps 11, 11a, p. 88).

A. m. collaris var. shells in area 52 are similar in form to *A. m. diffusa*. The typical form and color pattern of the shells is shown in figure 14, plate 7, length 18.7 mm., greater diameter 12.7 mm., spire height 8.5 mm., embryonic whorls similar to figure 10, plate 7, post-embryonic whorls white, colored just above the edge of the periphery with light seal brown, last whorl cinnamon buff axially streaked and spirally lined with seal brown so that the color is almost solid seal brown, lip and columella callus pale vinaceous fawn. The form may be narrower (pl. 7, fig. 15) with a more elongate spire, length 18.7 mm., greater diameter 11.9 mm., spire height 9.6 mm., post-embryonic whorls similar to figure 10, plate 7. Figure 16, plate 7, shows a dextral specimen; the color of the last whorl chocolate, below the periphery banded with two bands of seal brown axially streaked with seal brown and faintly lined and streaked with buffy brown and pinkish buff. Light color forms occur mixed with the dark typical color form. The shell can be colored on the last two whorls below the white sutural band with spiral lines and bands of olive brown over a ground of pinkish buff or white (pl. 6, fig. 17) or the penultimate whorl

may be banded with pale drab gray, last whorl closely axially streaked with drab gray and spirally lined with drab gray, white and natal brown, last fourth whorl tinted with clay color (pl. 6, fig. 18).

Achatinella mustelina collaris var. (pl. 6, figs. 19-19d).

Area 53: **Mohiakea-Pukaloa Ridge,** region of locality W341-2, el. 2,200-2,550 ft., Heine 1933, locality W341-3, el. 2,550 ft., Usinger 1936, 9 dextrals; **Pukaloa Gulch,** W341-6, el. 2,200 ft., Fosberg 1936, region of W341-1, el. 2,250-2,500 ft., Heine 1933 (maps 11, 11a, p. 88).

The shells of area 53 are a small variety of *A. m. collaris.* A typical sinistral shell measures 17.5 mm., greater diameter 11.5 mm., spire height 8.3 mm., post-embryonic whorls bister finely axially streaked with sayal brown, impressed sutural band white tinted with light buff, subsutural band white, lip light vinaceous fawn (pl. 6, fig. 19). The typical form of a dextral shell measures, length 17.2 mm., greater diameter 11.2 mm., spire height 8.6 mm., post-embryonic whorls below the white sutural band pale smoke gray spirally lined, banded and streaked with drab and hair brown, last quarter of last whorl tinted with tawny olive (pl. 6, fig. 19a). An obese specimen with a white spire, resembling the color pattern of the spire of *A. m. bicolor,* measures, length 17.6 mm., greater diameter 12.2 mm., spire height 7.6 mm. It is entirely white above the periphery; on the penultimate whorl a line of snuff brown occurs just above the suture of the whorl below, entire base below and just above the periphery of the last whorl snuff brown (pl. 6, fig. 19b). A slender specimen has a length of 17.5 mm., greater diameter 11.0 mm., spire height 8.5 mm.; just above the periphery and all below the periphery the color is tawny olive almost completely covered over by axial streaks and spiral bands of sepia and warm sepia, sutural band white (pl. 6, fig. 19c). The embryonic whorls of the shells of area 53 are usually white or with a faint trace of banding of cream buff on the lower half of the whorl. An unusually narrow form of a dextral shell represented by three or four specimens in locality W341-2 is shown in figure 19d, plate 6, length 17.3 mm., greater diameter 10.6 mm., spire height 9.0 mm., color pattern similar to figure 19c, plate 6.

Achatinella mustelina collaris var. (pl. 6, figs. 20-20a).

Area 54: **South Haleauau Gulch South Central Branch,** localities W320H-1, el. 2,400-2,450 ft., W320H-2, el. 2,450 ft., W320H-3, el. 2,600-2,650 ft., 1 dextral, 2 sinistrals, W320H-4, el. 2,500-2,600 ft., Meinecke 1936; **South Haleauau South-Central Branch Ridge,** locality W320J-3, el. 2,500-2,700 ft., Meinecke 1936, region of W320J-3, Heine 1933, region of W320J-4, el. 2,700-2,750 ft., Heine 1933; **Haleauau-Mohiakea Ridge,** region of locality W33I-2, el. 2,500-2,800 ft., Heine 1933 (maps 11, 11a, p. 88).

The shells of area 54 have the usual forms of figures 19, 19a, plate 6, of area 53, but occurring with the usual color patterns of area 53 are light colored and lined forms lined with white or gray (pl. 6, figs. 20, 20a). The nearer the locality is to the South Haleauau South Central Branch, the more

numerous are the shells having bicolored embryonic whorls similar to figure 20, plate 6, while to the south the embryonic whorls are usually white or only faintly banded with yellow. The embryonic whorls have the upper half white, lower half buckthorn brown, post-embryonic whorls shade from light drab to buffy brown or olive brown, spirally lined with white, lip light vinaceous fawn (pl. 6, fig. 20). Embryonic whorls upper half white, lower half sudan brown, first half whorl chocolate shading to pale smoke gray on the last half of the first whorl, last two whorls pale smoke gray axially streaked with hair brown spirally lined with sepia and buffy brown (pl. 6, fig. 20a).

Table 20. Achatinella mustelina collaris var. Areas 53 and 54.

Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
W320H-1	1	18	18.0	16.5-19.5	32	
W320H-2	20		17.5	14.5-18.5	37	3
W320H-2	2	24	18.0	15.5-22.5	35	
W320H-4	2	7	17.0	16.5-18.5	12	
W320J-3 Meinecke	27		17.5	15.5-19.5	19	18
W320J-3 (?) Heine	24		17.5	16.5-19.5	46	3
W320J-4 (?)	25		18.0	15.5-19.5	5	57
W331-2 (?)	61		18.0	16.5-20.5	5	139
W341-2 (?)	88		18.0	15.5-19.5	53	133
W341-1 (?)	15		17.5	15.5-19.5	22	4
W341-6	7		18.0	17.5-18.5	9	

In areas 53 and 54 the mean length of the shells ranges from 18 + to 17 + mm. Altitude again does not seem to play a part in size differentiation, because larger shells occur above smaller ones. The farther the locality is from Mount Kaala the more usual is a mean length of 18 + mm. The only thing that appears to be constant is that no shells with a mean length larger than 18 + mm. occur in this region, and in areas 51 and 52, below areas 53 and 54, the shells are definitely larger. Therefore, there does seem to be a kind of altitudinal difference. The Meinecke lots from W320H-2 are of interest. The first time he visited the locality in March he obtained dead dextral shells. The second time all the shells were alive and three sinistrals were included in the lot. Quite possibly Mr. Meinecke collected in slightly different places on separate occasions. If not, this is one of the only records of a size difference between live and dead shells of *A. mustelina* from a single locality.

Achatinella mustelina collaris var. (pl. 8, figs. 3-3d).

Area 51b: **Kukaki Gulch,** localities W22-3, el, 1,600-1,750 ft., 1 sinistral, W22-2, el. 1,700 ft., Russ 1933, 40 adults, mean length 19.5 mm., length range 17.5-21.5 mm., 49 sinistrals (maps 10, 10a, p. 73).

The shells are very similar to the Pukaloa shells in area 51a. The form differences are slight. About 50 percent of the Kukaki shells have bicolored tips and two light colored shells similar to figure 3c, plate 8, occur in Kukaki but not in Pukaloa. In general the Kukaki shells are strongly axially streaked while the Pukaloa shells are made up of more solid colors broken by spiral ornamentation, but there are exceptions to the rule, for shells occur which are similar to forms found in both areas. The usual form and color pattern of the shell measures, length 19.4 mm., greater diameter 12.1 mm., spire height 8.6 mm., embryonic whorls upper half white, lower half buckthorn brown, first post-embryonic whorl pallid mouse gray axially streaked with mouse gray, last whorl and a half drab faintly spirally lined above the periphery with white, axially streaked with pale pinkish buff and snuff brown, lip and columella callus white edged with cartridge buff (pl. 8, fig. 3). Thirty-five percent of the shells of the 19.5 mm. length class are more elongate, length 19.7 mm., greater diameter 11.8 mm., spire height 10.0 mm., first post-embryonic whorl white spirally lined with vinaceous brown, last whorl and a half white axially streaked with snuff brown, and sayal brown, faintly spirally lined with snuff brown so that the color appears to be entirely snuff brown or sayal brown (pl. 8, fig. 3a). The post-embryonic whorls are pallid mouse gray shading to pale vinaceous fawn axially streaked with light mouse gray and fawn color, spirally lined with white, lip white tinted with cartridge buff (pl. 8, fig. 3b). A rare pattern found on only two specimens is shown in figure 3c, plate 8. Post-embryonic whorls white spirally lined with vinaceous brown broken with axial streaks of white or pale gull gray on the first two post-embryonic whorls, last whorl spirally lined with snuff brown. The dextral form of the shell is shown in figure 3d, plate 8, post-embryonic whorls snuff brown axially streaked with white and faintly spirally lined with white.

2. *Achatinella mustelina* subspecies of the central section of the Waianae Mountains (map 2).

Achatinella mustelina bicolor (Gulick) Pfeiffer (pl. 9, figs. 1-4).

Achatinella bicolor (Gulick) Pfeiffer: Monogr. **4**: 529, 1859.

Achatinella mustelina bicolor (Gulick) Pfeiffer: Pilsbry and Cooke, Man. Conch. 22: 348, 1912-1914.

Shell subperforate, globose-conic, solid, lightly striate, glossy; whitish, obliquely streaked with brownish; spire conic, with rather acute apex, white; suture broadly impressed-marginate; whorls 5½, the upper ones flat, penultimate more convex, the last nearly equal to the spire, globose, black-chestnut below the periphery. Aperture oblique, subauriform; columella fold high, nodiform; peristome labiate within, brown bordered, the right margin narrowly expanded; columella margin dilated, subadnate. Length 16½, diam. 11 mm., aperture 8½ mm. long, 5 wide. Inhabits Lehui [Lihue], Island of Oahu (Pfeiffer) (translated by Pilsbry).

Distribution, area 65: **Maunauna Gulch**, locality W380B-1, el. 2,050 ft., Welch 1936,

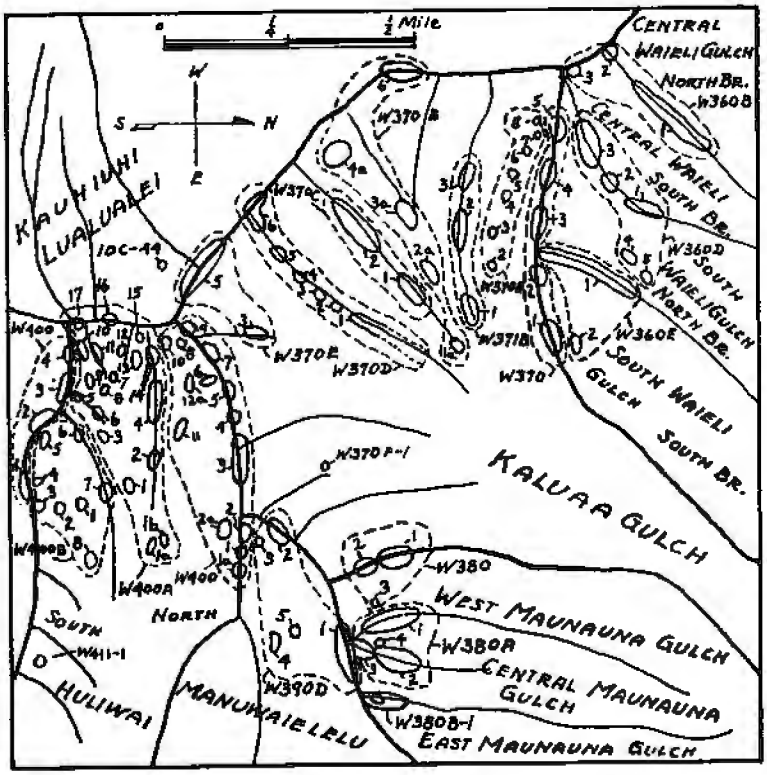
region of W380B-1, Mr. and Mrs. Heine 1932, W380A-1, approximate el. 1,850-2,150 ft., W380A-2, approximate el. 1,850-2,000 ft., W380A-3, approximate el. 2,000-2,100 ft., Mr. and Mrs. Heine 1932, W380A-4, el. 2,000 ft., W380A-3, el. 2,000 ft., Welch 1936; **Maunauna-Manuwaielelu Ridge,** region of locality W390D-1, Isle 1935, Mr. and Mrs. Heine 1932, St. John 1933; **Maunauna-Kaluaa Ridge,** localities W380-1, el. 2,100-2,150 ft., W380-2, el. 2,150-2,200 ft., Lemke, Lemke, Jr., and Welch 1932, Mr. and Mrs. Heine 1932.

In Kaluaa Gulch, area 65a, locality W370F-1, elevation 1,850 feet, Welch 1936, *A. m. bicolor* occurs mixed with Kaluaa form of *A. m. lathropae* of area 61. In localities W370A-2, W371B-1, W370B-1a, and W370D-1, odd specimens are found similar to *A. m. bicolor* mixed with *A. m. popouwelensis,* (map 12, p. 98). Undoubtedly *A. m. bicolor* in Gulick's day was a lowland race existing in Kaluaa and Maunauna Gulches below the upper brown races of *A. m. popouwelensis* and *A. m. lathropae* var. The lower Kaluaa forms have been wiped out due to the dying back of the forest so that only a mere trace of the lower *bicolor* form now exists in Kaluaa Gulch. Other collectors of *A. m. bicolor* are J. S. Emerson, T. McGuire, L. A. Thurston, Manly Hopkins (Myrtle Crozier, donor), W. D. Wilder, E. W. Thwing, and W. Meinecke. The shells live on native trees, *Bidens* and lantana (maps 12, 12a, p. 98).

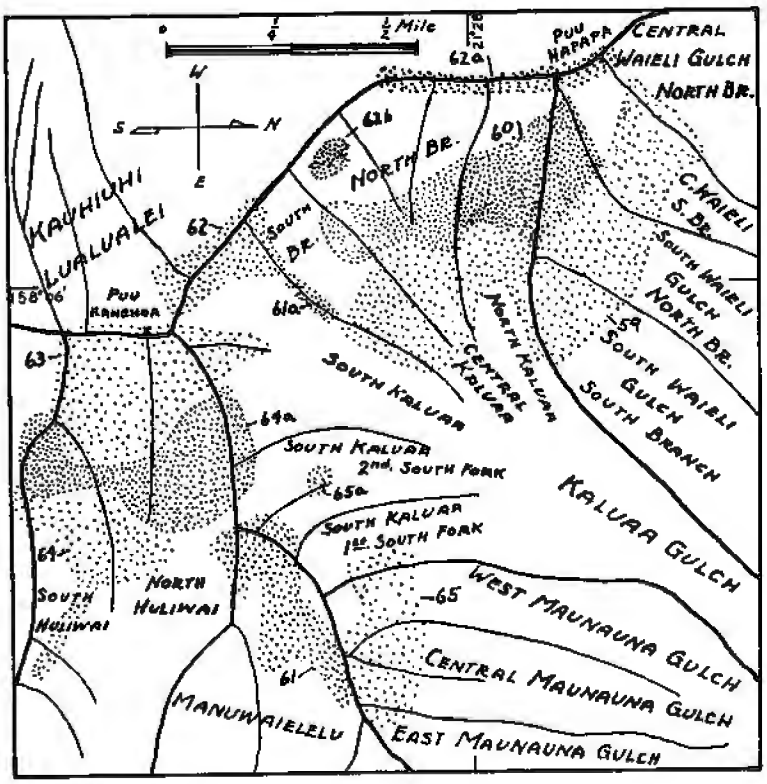
Through the courtesy of Colonel Peile at the British Museum, the type of *A. m. bicolor* in the Museum Cuming was located and photographed (pl. 9, fig. 1). The color pattern of the shell on the post-embryonic whorls is undoubtedly similar to that shown in figure 2a, plate 9, from an analysis of Pfeiffer's description and comparing it to figures 1 and 2a. The color pattern of figure 2a has the first embryonic whorl pinkish buff shading to white on the next two whorls, post-embryonic whorls including the impressed sutural band tilleul buff obliquely streaked with avellaneous; below the periphery of the last whorl walnut brown shading to liver brown on the last fourth whorl, lip cream buff. The color of this basal band of figure 2a is probably somewhat faded, and the chocolate band on the shell shown in figure 2, plate 9, is probably more typical. The post-embryonic whorls may be white above the periphery except for a few axial streaks of cinnamon on the suture of the first post-embryonic whorl, below the periphery dark chocolate (pl. 9, fig. 2b).

The typical color pattern shown in figures 1 and 2a is uncommon in the Gulick lots in Bishop Museum. Of the 209 specimens with the usual chocolate base, 51 show the typical pattern. The usual pattern in the Gulick lots is shown in figure 2, plate 9, embryonic whorls pale pinkish buff shading to cream buff, post-embryonic whorls white, impressed sutural band cinnamon; below the periphery and just above the edge of the periphery chocolate, so that a thin line of chocolate is on the lower portion of all the post-embryonic whorls.

The typical color pattern has not been collected to my knowledge in recent years. The usual form and color pattern is that of the shell in figure 3, plate



MAP 12.



MAP 12a.

9, length 19.4 mm., greater diameter 12.1 mm., spire height 10.3 mm., number of whorls 6½, first two embryonic whorls cartridge buff, last embryonic whorl white banded below the suture with pinkish buff, lower half of the first post-embryonic whorl light quaker drab, finely axially streaked with burnt umber, upper half white, impressed sutural band rood's brown, last two and a half whorls warm blackish brown below the sutural band of wood brown shading to tilleul buff on the last whorl, and the broad white subsutural band (1.5-1.8 mm. wide); lip army brown. The shell may be narrower, length 19.3 mm., greater diameter 11.4 mm., spire height 10.1 mm., embryonic whorls isabella color, post-embryonic whorls seal brown or black, sutural band warm sepia shading to sayal brown, subsutural band white, at the lower edge of the subsutural band is a band of cinnamon, lip fawn color (pl. 9, fig. 3a). An obese specimen measures, length 19.6 mm., greater diameter 12.7 mm., spire height 9.9 mm., color pattern similar to figure 3a, but the subsutural band is cinnamon buff axially streaked and spirally lined with tawny (pl. 9, fig. 3b). The form of a dextral specimen is shown in figure 4, plate 9.

Table 21. Achatinella mustelina bicolor Pfeiffer. Area 65 and 65a.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Lemke and Heine	W380-1-2 (?)	118		19.5	16.5-21.5	6	198
Welch	W380-1-2	53		19.5	17.5-21.5	12	173
Heine	W380A-1 (?)	158		19.5	17.5-21.5	48	479
Heine	W380A-2 (?)	138		19.0	17.5-21.5	1	266
Heine	W380A-3(?)	23		20.0	17.5-21.5	44	51
Heine	W380B-1 (?)	305		19.0	16.5-21.5	10	680
Welch	W370F-1	12	73	20.0	17.5-22.5		122

The size of *A. m. bicolor* is constant throughout area 65. Locality W380A-3 is the one exception, which may be due to the small number of shells collected. Five of the 53 adults in area W380-1-2 are dead specimens.

Achatinella mustelina popouwelensis, new subspecies (pl. 9, figs. 5-7).

The shell is closely related to *A. m. bicolor,* differing only in color pattern. The first half embryonic whorl slightly worn showing the dark embryonic callus of bone brown, remaining embryonic whorls pale pinkish buff on the upper half of three fourths of the whorl shading to white on the lower portion; post-embryonic whorls below the white sutural and subsutural bands dresden brown, shading to ochraceous tawny on the last whorl, spirally lined and axially streaked on the last two whorls with russet and mars brown, lip avellaneous, slightly corrugate on the inner margin, length 19.2 mm., greater diameter 12.6 mm., spire height 9.3 mm., number of whorls 6½ (pl. 9, fig. 5).

Distribution, area 59: **South Waieli Gulch North Branch,** type locality W360D-4, el. 1,800 ft., also localities W360D-5, el. 1,800 ft., Winne and Welch 1936, W360D-1, approximate el. 2,050-2,150 ft., Russ 1933, Lemke 1934, W360D-2, approximate el. 2,250-2,350 ft., Russ 1933, W360D-1-2, Heine 1934; **South Waieli Gulch South Branch,** W360E-1,

approximate el. 2,000-2,250 ft., Russ 1933, Heine 1934, W360E-2, el. 1,750 ft., Winne and Welch 1936; **Central Waieli Gulch Central Branch,** locality W360B-1, approximate el. 2,250-2,500 ft., Mr. and Mrs. Heine 1934; **South Waieli-Kaluaa Ridge,** localities W370-1, approximate el. 2,000 ft., W370-2, el. 2,100-2,200 ft., Lemke 1934, region of W370-1-2-3, Heine 1932; **North Kaluaa Gulch,** W370A-2, el. 1,800 ft., W370A-3, el. 1,850 ft., Christophersen and Welch 1932; **North-North Central Kaluaa Ridge,** W371B-1, approximate el. 1,750-2,000 ft., Heine 1932, Welch 1933; **North Central Kaluaa Gulch,** W370B-1a, approximate el. 1,700 ft., Russ 1931, W370B-2a, approximate el 1,800-1,900 ft., Heine 1932, Cooke 1913; **North-South Central Kaluaa Ridge,** W370C-1, probable el. 1,850-2,000 ft., Cooke 1913, Heine 1932; **South Central-South Kaluaa Ridge,** locality W370D-1, approximate el. between 1,900-2,000 ft., Heine 1932 (maps 12, 12a, p. 98).

The shells in localities W370A-2, W371B-1, W370B-1a, W370C-1 are dominantly dark color forms similar to figure 7, plate 9, post-embryonic whorls below the white sutural and subsutural bands are prouts brown spirally banded with seal brown. Figure 7 also shows the typical form of a sinistral shell. Locality W370D-1 has specimens with a color pattern very close to *A. m. bicolor* and the shells can be considered intermediate between typical *bicolor*, *popouwelensis* and *popouwelensis* var. of area 61a (p. 102).

A narrow form of the shell and a light color pattern measures, length 19.0 mm., greater diameter 11.6 mm., spire height 10.0 mm., number of whorls 6½; post-embryonic whorls shade from light drab to drab on the penultimate whorl, last whorl tawny olive spirally banded with snuff brown, impressed sutural band white, subsutural band white shading to pale cinnamon pink on the last whorl, the spire is less concave than the type (pl. 9, fig. 6). An obese shell (pl. 9, fig. 6a) measures, length 19.6 mm., greater diameter 13.0 mm., spire height 10.0 mm., number of whorls 6½, the color pattern is similar to that of figure 6.

Table 22. Achatinella mustelina popouwelensis Welch. Area 59.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Heine	W360B-1(?)	68		19.5	17.5-21.5	130	5
Russ	W360D-1	33		20.0	17.5-22.5	58	
Russ	W360D-2	91		19.5	17.5-21.5	119	7
Heine	W360D-1-2(?)	68		20.0	17.5-22.5	153	31
Welch	W360D-4	12	47	19.5	17.5-21.5	18	80
Welch	W360D-5					3	13
Russ	W360E-1	37		19.5	18.5-21.5	65	12
Heine	W360E-1(?)	159		19.5	17.5-22.5	257	83
Welch	W360E-2	6	29	19.5	17.5-21.5	44	11
Heine	W370-1-2-3(?)	105		20.0	17.5-22.5	258	59
Welch	W370A-2		26	19.5	17.5-21.5	76	50
Welch	W370A-3	39	39	19.0	16.5-21.5	17	54
Welch	W371B-1					7	3
Heine	W371B-1(?)	30		19.5	17.5-21.5	63	
Cooke	W370B-2a(?)	105		20.5	18.5-23.5	32	178
Heine	W370B-2a(?)	54		19.5	17.5-21.5	15	56
Russ	W370B-1a(?)	24		19.5	16.5-21.5	23	1
Cooke	W370C-1(?)	34		20.5	17.5-22.5		87
Heine	W370C-1(?)	118		19.5	17.5-21.5	12	147
Heine	W370D-1(?)	7		19.0	18.5-19.5		22

While most of the localities recorded in table 22 are approximate, the shells of the accurately plotted and less definite localities show little difference, most of the shells having a mean value of 19 + mm. North of Kaluaa Gulch, the composite localities of W360D-1-3 and W370-1-3 cannot be counted as significant for the exact point where most of the shells were collected is not known. Locality W360D-1 is at the lower end of a ridge, so that on that ridge some size differentiation with altitude appears to exist. The other two localities in area 59 without a mean value of 19 + mm. are W370B-2a(?) and W370C-1(?) both collected by Cooke, and since they do not agree with Heine's lots from supposedly the same regions may be wrongly plotted. Probably the Cooke lots came from a lower elevation or a different place. Below these localities, however, are localities W370B-1a(?) and W371B-1(?) with a mean length of 19 + mm. These facts raise the question concerning a size differentiation between the shells collected in 1913 and those collected in 1932. From what is known to occur in Pukaloa, Kapuna and other localities in the Waianae Mountains, I do not think this is the case. Most probably at points in Kaluaa Gulch where Cooke collected there is a size increase in the shells over restricted areas. Since Cooke, to my knowledge, usually collects in more restricted areas than Heine, I believe Cooke's lots represent a highly localized place while Heine's lots are from a much wider locality. This may account for the size differences in the separate lots. Another point of interest in table 22, is that although the shells from W370A-2 and W370A-3 are all dead specimens, no difference is noted in the mean value of the shells from that of the surrounding localities. Dead shells then do not have a different mean value from live specimens.

Achatinella mustelina popouwelensis var. (pl. 9, figs. 8, 8a).

Distribution, area 60: **South Waieli Gulch North Branch,** locality W360D-3, approximate el. 2,400-2,500 ft., Russ 1933; **South Waieli-Kaluaa Ridge,** W370-4, approximate el. 2,250-2,350 ft., Lemke 1934, W370-3-4, approximate el. 2,250-2,350 ft., Russ 1933, W370-5, approximate el. 2,400-2,500 ft., Russ 1933, Lemke 1934; region of W370-2-5, Cooke 1913; **North Kaluaa Gulch,** localities W370A-4, el. 1,900 ft., W370A-5, el, 2,050 ft., W370A-6, el. 2,200 ft., W370A-7, el. 2,250 ft., W370A-8, el. 2,300-2,350 ft., Welch and Christophersen 1932; **North-North Central Kaluaa Ridge,** W371B-2, approximate el. 2,150-2,250 ft., W371B-3, approximate el. 2,300-2,400 ft., Heine 1932; **North Central Kaluaa Gulch,** W370B-3a, approximate el. 1,950-2,000 ft., Russ 1934, Cooke 1913; **North Central-South Central Kaluaa Ridge,** W370C-2, approximate el. 2,150-2,350 ft., Cooke 1913 (maps 12, 12a, p. 98). Other collectors of *A. m. popouwelensis* from area 59 and its variety in area 60 are Wilder, Thurston, Emerson, C. S. Judd, Davis, Hume, and Thwing.

Above the area occupied by typical *popouwelensis,* a light gray form of *popouwelensis* occurs, conspicuously banded with brown. This form, however, so intergrades with typical *popouwelensis* that it is not possible to separate it out as a distinct subspecies. A typical pattern shown in figure 8, plate 9, has the post-embryonic whorls below the impressed sutural and subsutural

band pale drab gray, penultimate whorl banded with drab, last whorl above the periphery banded with drab and sayal brown, below the periphery, the shell is banded with white and sepia, lip pale pinkish buff, columella callus white. The last whorl may be drab gray lined with white, the base banded with snuff brown (pl. 9, fig. 8a). All manner of intergrades occur between these light forms and typical *A. m. popouwelensis*.

Table 23. Achatinella mustelina popouwelensis var. Area 60.

Collector	Locality	Live adults	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Russ	W360D-3	29	18.5	16.5-20.5	47	14
Russ	W370-3-4	61	19.5	16.5-22.5	46	45
Russ	W370-5	7	19.5	18.5-21.5	16	9
Cooke	W370-2-5(?)	71	19.5	16.5-22.5	87	129
Welch	W370A-4					7
Welch	W370A-5				1	4
Welch	W370A-6				4	2
Welch	W370A-7				2	1
Welch	W370A-8				3	7
Heine	W371B-2(?)	97	19.5	17.5-22.5	176	4
Heine	W371B-3(?)	14	20.0	18.5-21.5	20	9
Cooke	W370B-3a(?)				1	10
Russ	W370-3a(?)	95	19.5	17.5-22.5	100	49
Cooke	W370C-2(?)	5	19.5	17.5-21.5	18	2

The forms in area 60 are uniform in size. In W360B-3 the shells are smaller, showing a decrease in size with elevation or the proximity to the top of Puu Hapapa with a greater precipitation than the lower localities. Locality W370B-3(?) may have an unusually large mean length because of the small number of shells. A larger series might yield a mean length of 19 + mm.

Achatinella mustelina popouwelensis var. (pl. 9, figs. 9, 10).

Area 61a: South Central-South Kaluaa Ridge, localities W370D-2, el. 2,150-2,200 ft., W370D-3, el. 2,200 ft., W370D-4, el. 2,250 ft., Cooke, Spalding, Pilsbry and Welch 1933, Heine 1932 (maps 12, 12a, p. 98).

This area contains shells which are not typically *A. m. lathropae* var. of area 61 and not the lined form of *A. m. popouwelensis* of area 60. The shells are intermediate between the two forms with the banding of the shells of area 60 but the shade of color pattern similar to the shells of area 65a or 61. The shells of area 61a differ from both regions on either side by the fact that the suture is not white but the color of the ground. The embryonic whorls can be pinkish buff, post-embryonic whorls pinkish buff covered with axial streaks and faint bands and lines of ochraceous tawny, last whorl below the periphery banded with sudan brown, lip light pinkish cinnamon, columella

callus white (pl. 9, fig. 9). A more banded and common color pattern is figured in figure 9, plate 10, post-embryonic whorls pale pinkish buff banded with sayal brown shading to snuff brown on the last whorl. Other collectors of this intermediate form are Meinecke and Thwing.

Table 27. Achatinella mustelina popouwelensis var. Area 61a.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Heine	W370D-2-3(?)	16		19.0	16.5-21.5		51
Heine	W370D-3-4(?)	84		19.5	17.5-21.5	91	92
Welch	W370D-2	2					6
Welch	W370D-3	11	5	19.0	18.5-21.5	13	38
Welch	W370D-4	2	3	19.5	18.5-20.5	11	1

No size differentiation is seen in table 27 nor any size variation from that found in the other areas of Kaluaa Gulch.

Achatinella mustelina lathropae, new subspecies (pl. 9, figs. 15-17).

The shell is narrower, has a more elongate spire and a different color pattern from *A. m. bicolor* or *A. m. popouwelensis*; upper fourth of embryonic whorls white, lower three fourths hair brown, on first whorl shading to isabella color and army brown on the later embryonic whorls, first half of the first post-embryonic whorl chocolate lined with white, impressed sutural band walnut, subsutural band white, last half of whorl fuscous lined with white, impressed sutural band walnut, penultimate smoke gray lined with fuscous, olive brown, last whorl banded with pale smoke gray, buffy brown, cinnamon buff above the periphery, below saccardo's umber, snuff brown, and a black band about the umbilicus, impressed sutural band white, upper edge tinted with walnut, lip vinaceous brown, columella callus pale brownish vinaceous shading to vinaceous brown (pl. 9, fig. 15). Length 19.5 mm., greater diameter 11.2 mm., spire height 11.3 mm., number of whorls 6½.

Distribution, area 64: **South Huliwai Gulch,** locality W400B-8, el. 1,800 ft., on lantana, *pua* and other native shrubs and trees, Winne and Welch 1936. Also found in **Central Huliwai Gulch,** localities W400A-1a, el. 1,800 ft., W400A-1b, el. 1,800 ft., Winne and Welch 1936; **South Huliwai Gulch,** localities W400B-1, el. 2,000 ft., W400B-2, el. 2,000 ft., W400B-3, el. 2,350 ft., W400B-7, el. 2,050-2,150 ft., Meinecke 1934; **Huliwai-Ekahanui Ridge,** localities W410-1, el. 2,350 ft., W411-1, el. 1,900 ft., fossil bed, 9 dextral specimens, Winne and Welch 1936 (maps 12, 12a, p. 98).

The type locality was discovered by Miss Jane Lathrop Winne for whom the subspecies is named. The shells in the type locality W400B-8 are 99 percent sinistral. Figure 16, plate 9, shows a dextral shell, impressed sutural band white on last three post-embryonic whorls, first post-embryonic whorl and a half pale smoke gray banded with hay's brown and black finely axially streaked with black, last whorl and a half banded with prout's brown, black and pale olive buff. Another shell has the penultimate whorl light drab, streaked with tilleul buff, last whorl tilleul buff spirally lined with dresden brown, base banded with mummy brown and black, impressed sutural band white, subsutural band prout's brown, lip light russet vinaceous, columella callus white

(pl. 9, fig. 16a). A single specimen is found to be profusely banded and streaked on the last three whorls with chocolate so that the color is almost solid, lightened only by faint bands of pinkish buff (pl. 9, fig. 16b). One or two specimens are found similar to figure 16c, plate 9, in the type locality, post-embryonic whorls pale smoke gray spirally banded with drab gray, shading on the last whorl to pale smoke gray faintly tinted with sayal brown, last fourth whorl axially streaked with sayal brown, the color being solid behind the edge of the lip, peripheral band drab, basal band sepia. A rare, gray color pattern in area 64 has the first two post-embryonic whorls olive gray axially streaked with white, and spirally lined with clove brown, last whorl lined and banded with buffy brown, olive brown and clove brown (pl. 9, fig. 17). The last two whorls may be unbanded, being tawny olive obscurely axially streaked and lined with pale pinkish buff (pl. 9, fig. 16d). The form of the shell varies from narrow shapes shown in figure 16b, plate 9, length 19.9 mm., greater diameter 10.7 mm., spire height 11.2 mm., to a rare extremely obese form shown in figure 16e, plate 9, length 18.5 mm., greater diameter 12.3 mm., spire height 9.8 mm., of which this is a single example. Figure 16c, plate 9, is a more usual form of an obese shell, length 20.1 mm., greater diameter 11.8 mm., spire height 10.5 mm.

Table 24. Achatinella mustelina lathropae Welch. Area 64.

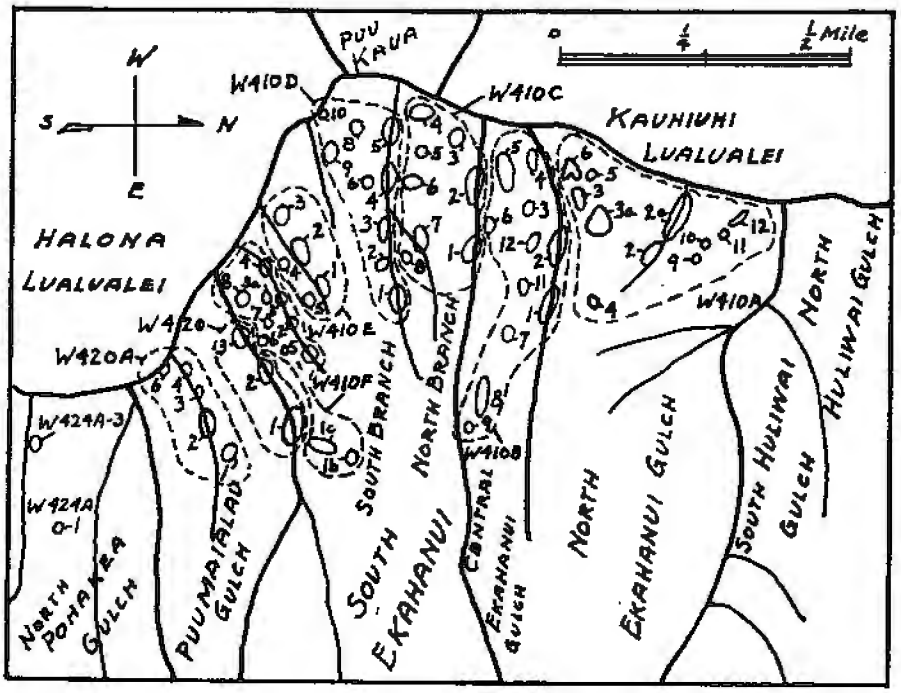
Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W400B-8	25	56	19.5	17.5-21.5	2	158
Meinecke	W400B-1	7	2	20.5	19.5-21.5		16
Meinecke	W400B-2	13	2	19.5	17.5-20.5	4	15
Meinecke	W400B-3	43		19.0	16.5-21.5	22	36
Meinecke	W400B-7	3					5
Meinecke	W410-1	4					7
Welch	W400A-1a	12	65	19.5	16.5-22.5		77
Welch	W400A-1b	5	10	20.0	18.5-21.5		23

Comparing tables 24 and 26 (p. 109), no change in size is noted with increase of altitude. Here and there localities of larger shells occur at random.

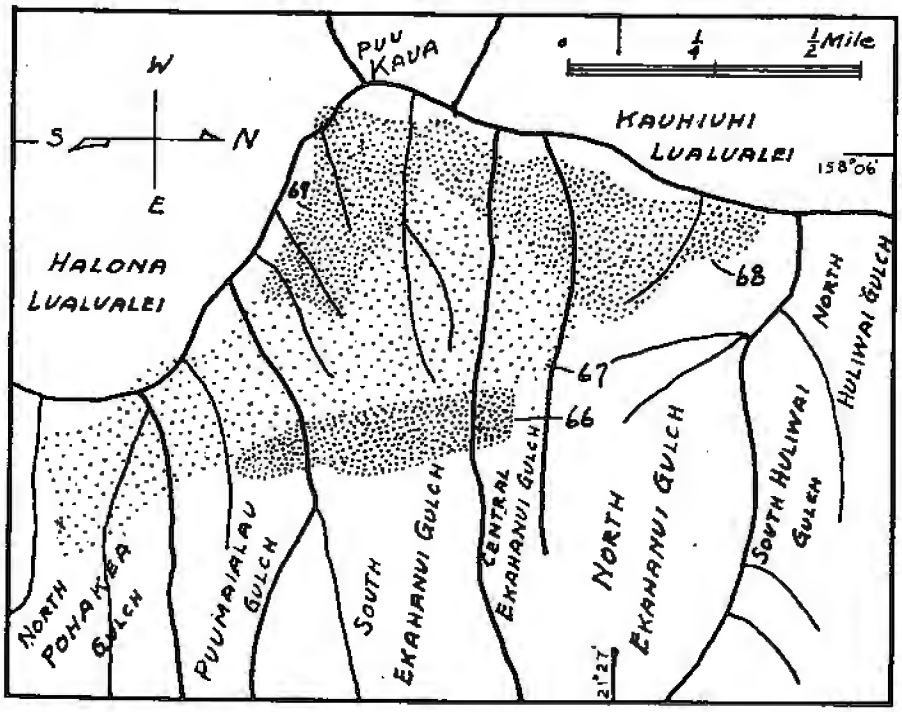
Achatinella mustelina lathropae var. (pl. 9, figs. 18-20; pl. 11, figs. 1-1d).

Area 66: **Central Ekahanui Gulch,** localities W410B-9, el. 1,850 ft., W410B-8, el. 1,800-1,850 ft., Russ and Welch 1936; **South Ekahanui Gulch,** W410F-1b, el. 1,700 ft., Welch 1936, W410F-1c, el. 1,850-2,000 ft., Degener 1936; **Ekahanui-Puumaialau Ridge,** W420-1, el. 2,050 ft., 5 dextrals, Meinecke 1934; **Puumaialau Gulch,** locality W420A-1, el. 1,900-2,000 ft., Meinecke 1934 (maps 13, 13a, p. 105).

The purest locality of *A. m. lathropae* var. south of type area 64 is locality W410B-9. In figure 18, plate 9, the typical form of the shell from W410B-9 is shown, length 19.4 mm., greater diameter 11.9 mm., spire height



MAP 13.



MAP 13a.

9.7 mm., embryonic whorls light buff shading to white, first post-embryonic whorl below the sutural and subsutural bands of sayal brown axially streaked with cinnamon buff, pale drab gray streaked with white, impressed sutural band pallid mouse gray on the penultimate whorl shading to a dirty white on the last whorl, penultimate pallid mouse gray, tinted with faint axial streaks and faint spiral bands of buffy brown, just above edge of periphery a strong band of buffy brown, last whorl above the periphery light drab faintly spirally lined with dresden brown and faintly axially streaked with prout's brown at the periphery and below the periphery prout's brown with a line and a basal band of clove brown, lip natal brown streaked with light vinaceous fawn, columella callus white shading to natal brown, the sutural band may be entirely white on the last few whorls. Three percent of the shells are dextral. Figure 18a, plate 9, shows a typical dextral specimen, embryonic whorls white, first post-embryonic whorl white axially streaked with drab gray below, the impressed sutural band of russet on the penultimate and last whorl impressed sutural band white with a central band of russet, subsutural band white, ground of the penultimate whorl drab gray with a line of russet on the lower half of the whorl, last whorl tilleul buff above the periphery axially streaked and banded with buffy brown, bister and black. The usual dark color form is shown in figure 18b, plate 9, embryonic whorls white, ground of post-embryonic whorls shade from white to mouse gray to tawny olive banded with warm sepia on the first post-embryonic whorl, on the last two whorls sepia, saccardo's umber and black, last whorl profusely axially streaked with sepia so that the color is almost solid. In locality W410B-8 the shells are slightly different from those of locality W410B-9, more pronounced spirally banded shells and lighter color patterns are found. The dark color patterns are similar to figure 16, plate 9. The lightest color form is shown in figure 19, plate 9, embryonic whorls white, first post-embryonic whorl a very light shade of pale smoke gray banded above the periphery with buckthorn brown, last whorl banded with pale smoke gray and white above the periphery, at the periphery and below light buff banded and lined with buckthorn brown and dresden brown. The first half of the embryonic whorl may be deep mouse gray; last half upper portion white; lower portion mouse gray, the mouse gray fades out on the next embryonic whorl, last embryonic whorl pallid mouse gray, penultimate whorl a faint shade of pallid mouse gray axially streaked with light mouse gray; last whorl tinted pale pinkish buff and pallid mouse gray above the periphery, below the periphery clay color basally banded with black, impressed sutural band light, pinkish cinnamon (pl. 9, fig. 19a). The shell may be more profusely banded, last whorl and a half pinkish buff, spirally banded with snuff brown and bister (pl. 9, fig. 19b).

In South Ekahanui a usual pattern is shown in figure 20, plate 9, embryonic whorls white, post-embryonic whorls pallid mouse gray, shading to pale olive gray spirally lined and axially streaked with light brownish olive, last whorl banded with dresden brown. The other patterns in South Ekahanui are those of figures 16d, 18a, 19, 19a, and 19b, plate 9.

The typical form of the shell in Puumaialau Gulch is shown in figure 1, plate 11, penultimate whorl pallid mouse gray axially streaked with mouse gray, last whorl a dirty white, spirally banded with buffy brown, impressed sutural band white, lip white, outer edge cream buff, columella callus white. The impressed sutural band and the ground of the post-embryonic whorls light buff, penultimate whorl axially streaked with mummy brown, last whorl banded with mummy brown and mars brown, columella callus white, lip white edged with light vinaceous cinnamon (pl. 11, fig. 1a). Figure 1b, plate 11, shows a dextral specimen with color pattern similar to figure 1a, plate 11. The last two whorls are drab gray and light drab lined with white; basal band fuscous, impressed sutural band wood brown, columella callus and lip cream buff (pl. 11, fig. 1c). The color of the shell may be that of figure 1c, plate 11, but banded at the periphery of the last two whorls with warm sepia and snuff brown, impressed sutural and subsutural bands white (pl. 11, fig. 1d). Figure 1d, plate 11, is an extreme elongate form.

Table 25. Achatinella mustelina lathropae var. Area 66.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W410B-9	11	20	19.5	16.5-22.5	3	74
Welch	W410B-8	4	115	20.5	18.5-23.5	23	206
Welch	W410F-1b		37	20.5	18.5-24.5	4	100
Degener	W410F-1c	1	18	20.5	17.5-23.5	8	34
Meinecke	W420A-1	23		19.0	17.5-21.5	12	29

The size of the shells as a whole is greater in area 66 than in area 64 (tables 24 and 25). But all the lots are composed of dead shells except W410B-9 which has smaller shells than the other localities. Is, therefore, the increase of size a question of the shells being dead specimens? This does not seem to be so, because in Kaluaa Gulch, the size of the shells is not dependent on the state of the specimen. Locality W410B-9 is probably an exception being the lowest known locality in Central Ekahanui Gulch. The smallness of size may be due to a factorial element due to the dying out of the forest. The same may apply to locality W420A-1.

Achatinella mustelina lathropae var. (pl. 11, figs. 4-9).

Area 64a: **Kaluaa-Huliwai Ridge,** localities W400-3, el. 2,350-2,400 ft., W400-4, el. 2,400 ft., W400-5, el. 2,500 ft., Welch, Lemke and Lemke, Jr. 1932, W400-6, el. 2,400-2,500

ft., Meinecke 1934; **North Huliwai Gulch,** locality W400-11, el. 2,100-2,150 ft., 1934, region of W400-11-12a, approximate el. 2,000-2,250 (?) ft., Meinecke 1915; **Central Huliwai Gulch,** localities W400A-1, el. 1,950-2,000 ft., W400A-2, el. 2,050-2,150 ft., **South Huliwai Gulch,** localities W400B-4, el. 2,350 ft., W400B-5, el. 2,250-2,400 ft.; **Huliwai-Ekahanui Ridge,** locality W410-2, el. 2,350-2,400 ft., Meinecke 1934.

In area 64a, a series of intermediate forms occur between *A. m. lathropae* and *A. m. christopherseni,* which are dominantly *christopherseni* forms banded or tinted with brown. The nearer the locality to area 64, the more similar the patterns are to *A. m. lathropae.* Typical color patterns of both subspecies occur throughout area 64a and some color patterns are found which are peculiar to this area. Post-embryonic whorls white, first post-embryonic whorl and a half banded with dark livid brown, last whorl banded with clay color, bands flecked with bister, base tinted and lined with black (pl. 11, fig. 4). First post-embryonic whorl and a half mikado brown darkening to chocolate, spirally lined with pale olive gray, last whorl and a half olive gray spirally lined with olive brown, buffy brown, base banded with tawny olive (pl. 11, fig. 5). Post-embryonic whorls pale smoke gray, last whorl and a fourth axially streaked with wavy lines of snuff brown spirally lined with pale mouse gray, the last 6 mm. of the last whorl behind the edge of the lip almost solid sayal brown faintly lined and streaked with the ground color (pl. 11, fig. 5a). Embryonic whorls white shading to buckthorn brown, first half post-embryonic whorl chocolate, last two and a half whorls prout's brown, band about the umbilicus warm sepia, impressed sutural band pinkish buff, shading to white on the last whorl, outer margin of the lip light buff, shading to white on inner margin and at columella callus (pl. 11, fig. 6). These four patterns are the usual ones on the Kaluaa-Huliwai Division Ridge.

The usual intermediate patterns in Huliwai Gulch are shown in figures 7, 8, 8a, 9, plate 11. First post-embryonic whorl mikado brown, last three whorls spirally banded with olive brown, buffy brown, pale olive gray, and axially streaked with pale olive gray and mouse gray, lip and columella callus pale vinaceous fawn (pl. 11, fig. 7). The last three whorls white spirally lined with pallid quaker drab shading to drab gray, and buffy brown on the last whorl, below the periphery of the last whorl the bands are drab gray and buffy brown, lip vinaceous buff (pl. 11, fig. 8). The shell may be elongate of spire, first post-embryonic whorl and a half white axially streaked with light neutral gray, penultimate and last whorl spirally lined with snuff brown and verona brown, impressed sutural band and ground white (pl. 11, fig. 9). First two post-embryonic whorls shade from white to pale olive gray, last whorl pale olive gray spirally banded with tawny olive, lip light vinaceous fawn (pl. 11, fig. 8a).

Table 26. Achatinella mustelina lathropae var. Area 64a.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W400-3	15		19.0	16.5-20.5	2	35
Meinecke	W400-3-4	6		18.5	17.5-19.5		13
Meinecke	W400-5	6		19.0	17.5-19.5		23
Meinecke	W400-6	3	5	19.5	18.5-21.5		12
Meinecke	W400-11	9	2	19.5	18.5-20.5		13
Meinecke	W400-11-12a	180		19.5	17.5-22.5		268
Meinecke	W400A-1						1
Meinecke	W400A-2	12		20.5	19.5-22.5		57
Meinecke	W400B-4	22	14	19.0	17.5-21.5		65
Meinecke	W400B-5	16	9	20.0	16.5-23.5		39
Meinecke	W410-2	5		20.0	18.5-21.5		18

Achatinella mustelina lathropae var. (pl. 9, figs. 11-14).

North of area 64, in areas 61 and 65a, the shells are more yellowish and banded and streaked with yellowish browns such as cinnamon brown and russet. The form of the shell is intermediate between *A. m. lathropae* and *A. m. popouwelensis* or *A. m. bicolor*. Area 61 includes the following localities: **Maunauna-Manuwaielelu Ridge,** region of W390D-1, Isle 1936, Heine 1932; **Kaluaa-Manuwaielelu Ridge,** W390D-2, el. 2,350 ft., Lemke, Lemke, Jr. and Welch 1932, Meinecke 1934, Mr. and Mrs. Heine 1932; **Manuwaielelu Gulch,** W390D-3, el. 2,300 ft., Meinecke 1934, W390D-4, el. 2,000 ft., W390D-5, el. 2,000 ft., R. Vetelson, C. Littel and Welch 1936; **Manuwaielelu-Huliwai Ridge,** region of W400-1a, in the vicinity of 2,350 ft., Heine 1933, W400-1, el. 2,400 ft., Meinecke 1934, Heine 1933, W400-2, el. 2,450 ft., Meinecke 1934, Mr. and Mrs. Heine 1933, W400-2a, el. 2,050-2,350 ft., Meinecke 1915. Area 65a: **South Kaluaa Gulch Second South Branch,** locality W370F-1, el. 1,850 ft., a mixed colony containing specimens of *A. m. bicolor* and *A. m. lathropae* var., C. Littel, R. Vetelson, and Welch 1936, habitat native trees and shrubs, lantana, *Bidens* (*kokolau*). Locality 390D-1 is also a mixed locality being a border one between *A. m. bicolor* and *A. m. lathropae* var. Others who undoubtedly collected shells in the region of area 61 are W. D. Wilder, L. A. Thurston, E. W. Thwing, J. S. Emerson, A. F. Judd (maps 12, 12a, p. 98).

An example of the shell form and color pattern found in area 61 is shown in figure 11, plate 9, first embryonic whorl white, tinted on the lower half of whorl with smoke gray, next two whorls white, post-embryonic whorls below the pinkish buff impressed sutural band and the white subsutural band shade from pale drab gray spirally lined and axially streaked with snuff brown to cinnamon buff, spirally lined and axially streaked with cinnamon brown, below the periphery spirally ornamented with cinnamon brown bands, lip outer margin vinaceous fawn shading to white on the inner margin and on the columella callus, length 19.2 mm., greater diameter 11.5 mm., lesser diameter 11.1 mm., number of whorls 6½.

A dextral shell with a color pattern similar to figure 11 is illustrated in figure 12, plate 9. The color pattern may be darker, embryonic whorls buckthorn brown, first half post-embryonic whorl white axially streaked with avellaneous, last three whorls shade from buffy brown lined with olive brown

to ochraceous tawny finely axially streaked with cinnamon brown on the last whorl, impressed sutural band and the three bands below the periphery of the last whorl mars brown, the subsutural line shades from white to ochraceous tawny on the last whorl, lip vinaceous fawn darkening to natal brown on the basal portion (pl. 9, fig. 13). Dark shells similar to figure 13a, plate 9, which are olive brown axially streaked and spirally lined with bone brown and have a sutural band of vinaceous buff or white, are difficult to separate from intermediate forms of *A. m. bicolor* and *A. m. popouwelensis* and may be considered intermediates between *A. m. bicolor* and *A. m. lathropae* var. Light color forms also are found, the last three whorls pale pinkish buff faintly spirally lined with cinnamon buff, impressed sutural band russet lightening to cinnamon and cinnamon buff on the last whorl, first subsutural band pale pinkish buff, second subsutural band sayal brown (pl. 9, fig. 14). The color pattern of figure 11 is very close to that of *Achatinella decora* Férussac found in the region between Kawailoa and North Helemano in the Koolau Range. The two forms are easily separated in that *A. decora* is usually a far more obese shell and has a dark patch on the first post-embryonic whorl. The color pattern of figure 14, plate 9, also resembles the light color forms of *A. decora*, but the *decora* forms usually have a white sutural band.

Table 27. Achatinella mustelina lathropae var. Areas 61 and 65a.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W390D-2	26		19.0	17.5-21.5		91
Meinecke	W390D-2	39		19.5	17.5-20.5	2	61
Heine	W390D-2(?)	19		20.0	17.5-22.5		40
Meinecke	W390D-3	6		19.5	17.5-18.5		8
Welch	W390D-4	4	77	20.0	17.5-22.5	87	12
Welch	W390D-5		11	20.5	18.5-21.5	3	13
Heine	W400-1a(?)	17		20.0	18.5-21.5	1	35
Heine	W400-1(?)	29		20.0	17.5-22.5		47
Heine	W400-2(?)	39		19.0	17.5-20.5	1	67
Meinecke	W400-2a(?)	73		20.0	16.5-23.5	3	161
Meinecke	W400-2	25		20.0	16.5-21.5		43
Meinecke	W400-1	5					5

Although the size of the shells in table 27 are almost always 20+ mm., the upper localities on the Kaluaa-Manuwaielelu Ridge show a decrease in size while no size differentiation is noted on the Manuwaielelu-Huliwai Ridge. Thus while a decrease in size occurs in localities on one side of the valley, the other side is not differentiated. The approximate localities cannot be dealt with in this discussion because their exact location is not certain.

Achatinella mustelina christopherseni, new subspecies (pl. 10, figs. 1-3; pl. 11, fig. 10).

The shell is sinistral, conic, slender, similar in form to *A m. lathropae,* but differs in color pattern and variations of form, first embryonic whorl darkened with benzo brown, remaining embryonic whorls a dirty white or pale gull gray, post-embryonic whorls pale gull gray spirally banded or lined with black, axially streaked and splotched with pale gull gray so that the lines are broken, the edges of the lines not always clear cut but jagged, behind the edge of the lip the bands fade out to cinnamon buff and the ground fades to white, outer margins of lip pinkish buff shading to white within, columella callus pale pinkish cinnamon, impressed sutural band white, length 19.3 mm., greater diameter 11.3 mm., lesser diameter 10.2 mm., spire height 10.0 mm. (pl. 10, fig. 1).

Distribution, area 63: **North-Central Huliwai Ridge,** type locality W400A-14, lot 123278, el. 2,500-2,600 ft., collected by Meinecke 1921, also collected by Meinecke 1934, Welch, Lemke and Lemke, Jr. 1932. Also found in **South Kaluaa,** locality W370E-3, el. 2,100-2,250 ft., **Meinecke** 1934; **Kaluaa-Huliwai Ridge,** region of locality W400-7-9, el. 2,550-2,600 ft., Welch, Lemke and Lemke, Jr., 1932, W400-8, el. 2,500 ft., W400-9, el. 2,600 ft., Meinecke 1934; **North Huliwai Gulch,** W400-10, el. 2,500 ft., Meinecke 1934; **North-Central Huliwai Ridge,** locality W400A-4, el. 2,250-2,450 ft., Meinecke 1934; **Central Huliwai,** localities W400A-3, el. 2,150-2,250 ft., W400A-5, el. 2,400-2,500 ft., W400A-6, el. 2,250 ft., W400A-7, el. 2,250 ft., W400A-8, el. 2,250 ft., W400A-9, el. 2,300-2,450 ft., W400A-10, el. 2,450-2,550 ft., W400A-11, el. 2,450-2,550 ft., W400A-12, el. 2,300-2,350 ft., W400A-13, el. 2,300-2,350 ft., W400A-15, el. 2,500 ft., W400A-16, el. 2,700 ft., W400A-17, el. 2,800 ft.; **South Huliwai-North Ekahanui Ridge,** localities W410-3, el. 2,500-2,550 ft., W410-4, el. 2,650-2,700 ft.; **South Huliwai Gulch,** locality W400B-6, el. 2,400-2,450 ft. All localities collected by Meinecke 1934 (maps 12, 12a, p. 98).

The subspecies is named after Dr. Erling Christophersen of the University of Oslo, Norway, who discovered a variety of this form in Kauhiuhi, Lualualei.

The holotype has not quite the typical form, but was chosen because it had the most typical color pattern which is so characteristic of the subspecies. Figure 2, plate 10, shows a specimen having the typical form, length 19.7 mm., greater diameter 11.0 mm., lesser diameter 10.4 mm., spire height 10.6 mm., number of whorls just under 6½, first embryonic whorl worn, second embryonic whorl upper half white, lower half army brown, third embryonic whorl white, post-embryonic whorls diamine brown, with a single line of pale gull gray on the first and penultimate whorls, last whorl has only a trace of two pale gull gray lined bands above and below the periphery seen only faintly on the last half whorl and above the aperture, sutural band white. Figure 2a, plate 10, shows an obese form of the dark color pattern of figure 2, but is more streaked with broken lines of pale gull gray. Some specimens totally lack any gray lines or streaks and are similar to the color of *A. m. bicolor,* but the shells can readily be separated on difference of shape. Some specimens have an impressed sutural band of pinkish cinnamon. The embryonic whorls may have the upper half white and the lower half olive brown, penultimate whorl pale gull gray axially streaked with zigzag lines of diamine brown, last whorl almost solid diamine brown streaked with zigzag streaks and two spiral peripheral bands of pale gull gray or white (pl. 10, fig. 2b).

The lightest color pattern is shown in figure 2c, plate 10, embryonic whorls white, post-embryonic whorls pale gull gray or white, with two faint lines of pale neutral gray and one line just above the periphery of black, below the periphery four lines of black. Figure 3, plate 10, shows a dextral specimen with a wide peripheral band and lines of pale gull gray over a diamine brown ground. Dextral specimens are rare in typical *christopherseni* localities. Between the three usual color forms of typical *christopherseni* in figures 1, 2, 2c, plate 11, all manner of intermediates occur.

On the Huliwai-Ekahanui Ridge, locality W410-4, a very distinct color pattern occurs with the typical *christopherseni* pattern, embryonic whorls white banded at the suture with tawny olive, post-embryonic whorls smoke gray finely axially streaked with deep grayish olive and black, above the periphery a line of pale pinkish buff, below the periphery a band of white, about the base bands of olive brown, lip tinted with pinkish cinnamon (pl. 11, fig. 10).

Table 28. Achatinella mustelina christopherseni Welch. Area 63.

Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
W370E-3	6	7	20.5	18.5-21.5		22
W400-7-9*						5
W400-8	1	12	20.0	18.5-21.5		17
W400-9	21	9	20.0	17.5-21.5		32
W400-10	7	9	20.5	19.5-21.5		39
W400A-3	2	9	20.0	18.5-21.5		23
W400A-4	55		19.5	17.5-21.5		78
W400A-5	3					4
W400A-6						2
W400A-7	6		19.0	17.5-20.5		6
W400A-8	10	3	19.5	17.5-20.5		24
W400A-9	2	7	20.5	19.5-21.5		16
W400A-10						2
W400A-11	9		19.0	18.5-19.5		15
W400A-12						6
W400A-13	7	16	20.0	18.5-21.5		42
W400A-14	104		19.0	16.5-21.5		166
W400A-14	46		19.0	16.5-21.5	1	78
W400A-14*	15		19.5	17.5-21.5		24
W400A-15	23		19.0	17.5-21.5		15
W400A-16	6		19.0	17.5-20.5		14
W400A-17						2
W400B-6	17		19.5	18.5-20.5		25
W410-3	22		20.0	18.5-22.5		39
W410-4	27		19.0	16.5-20.5		44

* All the localities in table 28 are collected by Meinecke, except the two marked * collected by Welch

Size variation in area 63 occurs at random, ranging between 19+ and 20+. No correlation between size and altitude can be found. The lot of 104 shells from W400A-14 collected in 1921 has the same mean value as the series of 15 collected from the same place in 1934, and close to that of the 46 shells obtained in 1932. The size of shells from a restricted Huliwai locality does not vary perceptibly over a period of 13 years, when the exact area is revisited.

A. m. christopherseni has a wider range of distribution than just area 63, which contains the typical color patterns. The subspecies is a highland gray race which extends as a fairly pure unit from Kaluaa Gulch to South Ekahanui at high elevations, and has a multitude of forms and variously gray banded patterns. For convenience the more closely related patterns are grouped into areas and are described in succession, first those to the north of area 63 and then those to the south.

Achatinella mustelina christopherseni var. (pl. 10, figs. 4-5; pl. 11, figs. 2-3).

Area 62: **Valley 13, Kauhiuhi District, Lualualei,** locality W10C-44, el. 2,000 ft., Christophersen and Welch 1932; **Kaluaa-Kauhiuhi Ridge,** region of locality W370E-5, el. 2,500-2,700 ft., Isle 1936; **South-Central Kaluaa Ridge,** localities W370D-5, el. 2,350 ft., W370D-6, el. 2,500-2,700 ft., Cooke, Welch, Pilsbry, Spalding 1933 (maps 12, 12a, p. 98).

The color patterns of figures 1, 2, plate 10, are not found in area 62, but that of figure 2c, plate 10, is found. The shells of locality W10C-44 are of note because they are the only series of live specimens of *Achatinella mustelina* var. from Kauhiuhi in the Bishop Museum collection. The typical form and color pattern, length 19.6 mm., greater diameter 11.3 mm., spire height 10.2 mm., embryonic whorls banded below the suture with chamois, first half post-embryonic whorl sayal brown lined with white, shading to warm sepia on the last half of the whorl, the penultimate and last whorls white axially streaked with pale gull gray and spirally lined and banded with dark mouse gray, impressed sutural band sayal brown, lip and columella callus white (pl. 11, fig. 2a).

The usual dark banded color pattern has clear cut spiral bands unbroken by axial streaks similar to the shell shown in figure 4, plate 10. Embryonic whorls white, post-embryonic whorls pale gull gray axially streaked with light gull gray, and spirally banded with diamine brown and olive brown, impressed sutural band pinkish buff, lip and columella callus pale pinkish cinnamon (pl. 10, fig. 4). A light color pattern has embryonic whorls white banded on the upper half of the last embryonic whorl with cinnamon buff, post-embryonic whorls pale gull gray, spirally lined with benzo brown on the first post-embryonic whorl, impressed sutural band mikado brown, on the penultimate whorl sutural band white, with upper edge tinted with walnut

shading to pure white on the last whorl, last two whorls spirally banded with fuscous, pale mouse gray, mouse gray and broken up by axial streaks on the last whorl of mouse gray and the ground color (pl. 10, fig. 4a). The last whorl may be strongly axially streaked (pl. 11, fig. 3), post-embryonic whorls pale gull gray, banded and lined on the last two whorls with deep mouse gray shading to olive brown on the last half whorl, axially streaked on the last whorl with deep mouse gray, impressed sutural band pinkish buff. The lightest color pattern has the post-embryonic whorls pale smoke gray tinted with tilleul buff, with a band of bister about the base, impressed sutural band pinkish buff (pl. 11, fig. 2). The usual dark color patterns have the embryonic whorls white, impressed sutural band mikado brown lightening to cinnamon on the last whorl, last two whorls a cream shade of pale olive gray spirally banded and axially streaked with black (pl. 10, fig. 4b).

The remaining localities of area 62 are represented by so few specimens that no clear conception of the range of color patterns can be had. In general the usual color patterns resemble those of figures 2c and 4, plate 10. A usual color pattern resembles figure 4b, plate 10, and the obese form of the shell is shown in figure 5, plate 10. The last two whorls gull gray banded with black and only faintly axially streaked with black.

Achatinella mustelina christopherseni var.

Area 62a: **Kaluaa-Lualualei Ridge,** region of locality W370B-6, el. 2,650 ft., Isle 1936; **Central Waieli-Lualualei Ridge,** localities W360B-3, el. 2,850 ft., W360B-2, el. 2,850 ft., Isle 1936.

A mixture of the lined intermediate race of *popouwelensis* and gray *christopherseni* forms occur in area 62a. The usual patterns of figures 2c, 4a, plate 10, are found. In locality W360B-2, a single specimen similar to figure 2, plate 10, is found, but the color is black. Another pattern is a pale gull gray form similar to figure 5, plate 10, but lacking the spiral black bands.

The material from areas 62 and 62a is very scant and most of the localities are questionable as to the exact plotted locus. Therefore these areas should be carefully recollected and plotted on a map. This region is a favorite area for hikers who collect shells, taking everything in sight, juveniles and adults, and mix them all together from Kaluaa-Huliwai Division Ridge to Waieli Gulch. Possibly the dark specimen similar to figure 2, plate 10, found by Isle in locality W360B-2, may have been collected originally on the Kaluaa-Huliwai Ridge and dropped by some careless collector in locality W360B-2.

Achatinella mustelina christopherseni var. (pl. 10, figs. 6-6c).

Area 62b: **Central Kaluaa,** region of locality W370B-4a, approximate el. 2,250-2,400 (?) ft., Cook 1913; 80 adults, mean length 19.5 mm., length range 16.5-22.5 mm., 65 dextrals, 139 sinistrals all alive.

These shells are intermediates between *popouwelensis* var. and *christopherseni* being closer in form to *A. m. christopherseni* var. (area 62) than to the lower form of *popouwelensis* var., but still retaining the brownish color pattern of the intermediate lined form of *popouwelensis* of area 60. These shells of area 62b have been placed as a form of *A. m. christopherseni* because they are closer to *christopherseni* in form. The typical form of the shell is shown in figure 6, plate 10, length 19.4 mm., greater diameter 11.2 mm., spire height 10.2 mm., number of whorls 6½, embryonic whorls pale pinkish buff, post-embryonic whorls white spirally banded with drab and light drab broken by axial streaks of white, a patch of buckthorn brown about the umbilicus, impressed sutural band pale pinkish buff, lip and columella callus white, whorls more convex than the typical form of *christopherseni* (pl. 10, fig. 2). Figure 6a, plate 10, shows a specimen with extreme convex whorls and elongate spire, embryonic whorls light buff shading to warm buff, post-embryonic whorls pale pinkish cinnamon spirally banded with light drab and cinnamon drab, lip edged with honey yellow shading to white with columella callus white, impressed sutural band upper half white, lower half light drab. Figure 6b, plate 10, shows a dextral specimen, post-embryonic whorls tilleul buff faintly spirally banded with avellaneous, at edge of periphery of last whorl a line of natal brown, below the periphery banded with wood brown; an obese dextral form of the shell is shown in figure 6c, plate 10, ground of post-embryonic whorls white tinted with tilleul buff, faintly spirally lined with vinaceous buff, base banded with avellaneous.

Achatinella mustelina christopherseni var. (pl. 10, figs. 7-13).

Area 68: **North Ekahanui Gulch,** locality W410A-2, el. 2,350-2,400 ft., region of W410A-2a, approximate el. 2,250-2,500 ft., 1921, W410A-3, el. 2,300-2,350 ft., 1934, region of W410A-3a, approximate el. 2,150-2,250 ft., Meinecke 1931, W410A-4, el. 2,000 ft., W410A-5, el. 2,200 ft., W410A-6, el. 2,250-2,400 ft., W410A-9, el. 2,150 ft., W410A-10, el. 2,250 ft., W410A-11, el. 2,250 ft., W410A-12, el. 2,350-2,400 ft., Welch and Russ 1936; **North-Central Ekahanui Ridge,** locality W410B-2, el. 2,300-2,400 ft., Meinecke 1934; **Central Ekahanui Gulch,** W410B-3, el. 2,300 ft., W410B-4, el. 2,500 ft., W410B-5, el. 2,450-2,550 ft., Meinecke 1934, W410B-12, el. 2,250-2,300 ft., Welch and Russ 1936; **South Ekahanui Gulch, North Branch,** localities W410C-2, el. 2,550-2,650 ft., W410C-3, el. 2,750 ft., W410C-4, el. 2,750 ft., W410C-5, el. 2,550 ft., Meinecke 1934 (maps 13, 13a, p. 105).

In the Meinecke collection, lot 123293, there are 427 shells, all dextral, from the general region of locality W410A-3a. The typical form of the shell in this lot is shown in figure 7, plate 10, length 21.6 mm., greater diameter 12.2 mm., spire height 11.2 mm., number of whorls 6½, spire concave, embryonic whorls white, post-embryonic whorls pale gull gray or white spirally banded with drab gray and light drab gray, axially streaked with light drab and white breaking up the spiral lineation, impressed sutural band, lip, and columella callus white. The spire may be slightly convex, post-embryonic whorls pale gull gray spirally lined with pale

neutral gray (pl. 10, fig. 7a). A very elongate specimen measures, length 21.4 mm., greater diameter 11.4 mm., spire height 12.0 mm., shell white faintly spirally lined with smoke gray (pl. 10, fig. 7b). The typical form of a shell of the 19.5 mm. class is shown in figure 7c, plate 10, length 19.6 mm., greater diameter 11.7 mm., spire height 10.7 mm., number of whorls 6½, post-embryonic whorls white almost completely covered over with spiral lines and bands of light drab above the periphery, and drab below the periphery, sutural band white. A dark color form and at the same time a very obese form, has a length of 19.6 mm., greater diameter 12.8 mm., spire height 10.3 mm., first post-embryonic whorl dark livid brown darkening to seal brown spirally lined with white, penultimate and last whorl fuscous lined and axially streaked with white, impressed sutural band pale pinkish buff, shading to pinkish buff (pl. 10, fig. 8). Figure 9, plate 10, having the color pattern of figure 7a, shows an elongate specimen of a sinistral shell. Sinistral shells have a similar range of form in most of the localities in area 68 to the dextral ones shown in figures 7, 8, plate 10.

The shells found in the north branch of North Ekahanui, W410A-3a, are slightly different from the shells in the remainder of area 68. Some of the shells have a very obese form and look very much like *Achatinella turbiniformis* var. from Huliwai Gulch (pl. 11, figs. 8, 9a, 11). But, although these shells have been considered *A. m. christopherseni* var. from the similarity to the *christopherseni* color patterns, the precise identification cannot be made until more material is obtained from North Ekahanui from highly restricted localities. The North Ekahanui shells exhibit a case where two species occur in the same region, and have not got distinct color patterns. Since the shape of *Achatinella* varies to such an extent from very obese to narrow forms, the student has little else but color pattern to go on when dealing with certain forms. When the color pattern is not distinct the student is at a loss to determine the difference between certain species and to which form a separate subspecies belongs. Usually, however, *A. turbiniformis* and *A. mustelina,* when they occur together, have subspecies with distinctly different color patterns. Probably after further collecting the exact lowland form of *A. turbiniformis* will be collected with *A. m. lathropae* var. and can be compared with more new material of the highland form occurring with *A. m. christopherseni* var.

The shell of figure 9a, plate 10, has a length of 19.0 mm., greater diameter 12.6 mm., spire height 10.5 mm., embryonic whorls white, first 4 mm. of first post-embryonic whorl mikado brown with a central line of white, the remaining whorls pale gull gray spirally lined with white and black, profusely axially streaked with fine streaks of dark neutral gray and fuscous. Figure 10, plate 10, is banded with smoke gray over a pale gull gray ground, peripheral and subperipheral bands on last whorl olive brown axially streaked and

dotted with pale gull gray, lip and columella callus light vinaceous fawn. Narrower specimens similar to figure 7a, plate 10, are found to have pinkish colored lips in this northern branch of North Ekahanui, but the remainder of area 5 usually has shells with white or yellow-edged lips. The shell of figure 11, plate 10, is olive brown on the last two whorls banded with white, sutural band cinnamon buff. The above descriptions of figures 7-11 describe patterns which have a rather rugose appearance due to the axial streaking. These rugose forms may occur anywhere throughout area 68 but are dominantly North Ekahanui forms.

Also occurring in North Ekahanui, but more usually in South and Central Ekahanui are more polished looking shells with dominant spiral bands and weak or no axial streaking. The usual pattern is that of figure 12, plate 10, entire shell white banded on the post-embryonic whorls with pale gull gray, mouse gray, below the periphery the bands are chaetura drab or hair brown tinted 3 mm. behind the edge of the lip with clay color, lip white edged with cinnamon. Figure 12a, plate 10, shows a dextral specimen, post-embryonic whorls pale gull gray spirally banded and lined with benzo brown shading to fuscous and a band of dark neutral gray just above the periphery, penultimate whorl spirally banded with neutral gray axially broken by streaks the color of the ground and fading out near the last whorl, last whorl above the periphery banded and lined with pale neutral gray axially streaked with pale neutral gray, peripheral and basal band brownish olive weakly axially streaked here and there with streaks of pale gull gray. The entire shell may be white banded at and below the periphery with pale mouse gray (pl. 10, fig. 13). A pattern rarely found in any other part of area 68 except Central Ekahanui is shown in figure 12b, plate 10, the entire shell white except for the first two whorls which are worn and lack the shell nacre, lip edged with cream buff, within the aperture pale pinkish cinnamon. Some specimens are white, others are white spirally lined with pale gull gray and a few lines of sayal brown (pl. 10, fig. 12c). An unusual pattern occurs in which the shell is banded with a dark shade of diamine brown over a white ground axially streaked with white (pl. 10, fig. 12d). One specimen is known from Central Ekahanui and a sinistral one from North Ekahanui. The patterns of figures 12c and 12d are very similar to typical *A. m. christopherseni* patterns from area 63.

Table 29. Achatinella mustelina christopherseni var. Area 68.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Welch	W410A-4	3	26	21.5	19.5-22.5	3	55
Meinecke	W410A-2	15		19.5	18.5-21.5		32
Meinecke	W410A-2a	338		20.0	16.5-23.5	58	330
Meinecke	W410A-3a	264		21.5	16.5-24.5	427	
Meinecke	W410A-3	1	11	20.0	18.5-21.5	8	13
Welch	W410A-5		3				8
Welch	W410A-6	2	22	20.0	18.5-21.5	3	39
Welch	W410A-9		1				7
Welch	W410A-10	28	6	20.0	17.5-21.5		55
Welch	W410A-11	1	34	20.0	17.5-22.5		69
Welch	W410A-12	3					4
Meinecke	W410B-2	23		20.5	17.5-22.5	8	40
Meinecke	W410B-3	19	15	21.0	19.5-22.5		37
Meinecke	W410B-4	51		20.5	18.5-22.5	7	60
Meinecke	W410B-5		7	21.0	19.5-23.5	1	11
Welch	W410B-12		23	20.5	18.5-22.5		38
Meinecke	W410C-2	9		20.5	18.5-21.5	22	3
Meinecke	W410C-3		5	20.5	20.5-22.5	19	
Meinecke	W410C-4	5		20.0	18.5-20.5	2	4
Meinecke	W410C-5		3				3

Achatinella mustelina christopherseni var. (pl. 10, figs. 14-17).

Area 69: **South-Central Ekahanui Ridge,** localities W410D-4, el. 2,600-2,700 ft., W410D-5, el. 2,750-2,800 ft.; **South Ekahanui Gulch South Branch North Fork,** locality W410D-6, el. 2,500 ft., W410D-8, el. 2,550-2,650 ft., W410D-9, el. 2,500-2,650 ft.; **South Ekahanui-Halona Ridge,** locality W410D-10, el. 2,900 ft., Russ 1936; **South Ekahanui-South Branch North-Central Fork Ridge,** localities W410E-1, el. 2,050-2,150 ft., W410E-2, el. 2,250-2,400 ft., W410E-3, el. 2,500-2,550 ft.; **South Ekahanui Gulch South Branch Central Fork,** localities W410E-4, el. 2,200 ft., W410E-5, el. 2,000 ft.; **South Ekahanui Gulch South Branch, Central-South Fork Ridge,** locality W410F-4, el. 2,250-2,300 ft., all collected by Meinecke 1934.

The usual color patterns of area 69 are those of figures 2c, 5, 7a, and 12c, plate 10. A variation of figure 12c is shown in figure 14, plate 10, the first post-embryonic whorl is lined with diamine and white axially streaked with white, below the white sutural band and just above the edge of the periphery are bands of black flecked with white subperipheral banding similar to figure 12c. The post-embryonic whorls may be pale gull gray or white axially streaked with light gull gray and occasionally streaks (seven on the penultimate) of black, last whorl faintly spirally banded below the white sutural band with black shading to neutral gray and pale neutral gray, below the periphery banded with bands of black thickened into knoblike splotches about 1½ mm. apart on the aperture side of last whorl, on the last half of last whorl the bands are cut by axial streaks of black and white, 3 mm. behind the edge of the lip the bands fade out, then overlie two bands of clay color which

continue to the edge of the lip (pl. 10, fig. 14a). The light color patterns of figures 12c, 14, 14a, are most common in localities W410E-1 and 2.

The color pattern of a small number of shells which occurs on about two or more shells in most of the colonies of South Ekahanui is a dark one resembling figure 1, plate 10. The pattern differs from the dark *A. m. christopherseni* form in shell shape, size, and in the distribution of the gray spiral and axial ornamentation, although the difference is very small in certain specimens. The shell can have the embryonic whorls pale pinkish buff banded with pinkish buff on the upper half of the last embryonic whorl, first post-embryonic whorl shades from sayal brown to burnt umber, last two whorls and a half shade from light seal brown to black, faintly spirally lined with lines of white broken up by fine axial streaks of the ground color (pl. 10, fig. 16). The shell may be axially streaked with white or pale gull gray and black heavily banded with light seal brown or black, below the periphery the ground is pinkish cinnamon (pl. 10, fig. 15). A very characteristic pattern of area 69 which is more abundant in locality W410D-6 has the last three whorls light gull gray axially streaked with fine wavy lines of black, last fourth whorl tinted with pinkish buff or cinnamon buff, base banded with black and pinkish buff, impressed sutural band cinnamon buff, lip pale pinkish cinnamon (pl. 10, fig. 16a). Sometimes the ground is pinkish buff finely streaked with diamine brown, banded about the periphery and base with diamine brown (pl. 10, fig. 16b). An unusual pattern (pl. 10, fig. 17) occurs in which the post-embryonic whorls are white spirally banded with bands made up of zigzag streaks of black and cinnamon broken up by streaks of white, lip white, corrugate or tuberculate similar to that of *A. m. kapuensis*.

Table 30. Achatinella mustelina christopherseni var. Area 69.

Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
W410D-4	7		21.5	19.5-23.5		10
W410D-5	6		22.0	20.5-23.5		12
W410D-6	46		21.0	19.5-23.5	26	46
W410D-8	1	5	20.0	18.5-22.5		9
W410D-9		10	21.0	19.5-23.5	7	8
W410E-1	29	7	20.5	18.5-24.5	11	31
W410E-2	26	5	20.5	18.5-23.5		46
W410E-3	26	6	19.5	16.5-21.5	22	20
W410E-4	1	9	22.0	20.5-24.5	1	10
W410E-5					3	3
W410F-4	26	6	20.5	19.5-22.5	3	38

Achatinella mustelina christopherseni var. (pl. 11, figs. 11-16d; pl. 12, fig. 1).

Area 67: **Central Ekahanui Gulch,** localities W410B-1, el. 2,250-2,300 ft., W410B-6, el. 2,350-2,400 ft., Meinecke 1934, W410B-7, el. 2,000 ft., W410B-11, el. 2,050 ft., Russ and Welch 1936; **South Ekahanui Gulch North Branch,** localities W410C-1, el. 2,250-2,400 ft., W410C-6, el. 2,550 ft., W410C-7, el. 2,300-2,400 ft., W410C-8, el. 2,300 ft., Meinecke 1934; **South Ekahanui North South Branch Ridge,** localities W410D-1, el. 2,000-2,100 ft., W410D-2, el. 2,150 ft., W410D-3, el. 2,500 ft.; **South Ekahanui Gulch South Branch Central Fork,** localities W410F-1, el. 1,900-2,000 ft., W410F-2, el. 2,050 ft., W410F-3, el. 2,250 ft., W410F-3a, el. 2,100 ft., W410F-5, el. 2,000 ft., W410F-6, el. 2,050 ft., W410F-7, el. 2,100 ft., W410F-8, el. 2,300-2,350 ft.; **Ekahanui Ridge North Puumaialau,** localities W420-2, el. 2,050 ft., W420-3, el. 2,100-2,150 ft; **North-South Puumaialau Ridge,** localities W420A-2, el. 2,100-2,150 ft., W420A-3, el. 2,200 ft., W420A-4, el. 2,300 ft., all collected by Meinecke 1934; **South Puumaialau-Halona Ridge,** locality W420A-6, el. 2,400-2,500 ft., on *Bidens,* Russ 1936; **North Pohakea Gulch,** localities W424A-3, el. 2,000 ft., Meinecke 1936, 3 dead shells, W424A-1, el. 1,750 ft., Winne and Welch 1936, 2 adults, 8 juveniles all sinistral, fossil shells.

The major portion of area 67 is composed of shells having gray *christopherseni* patterns, accompanying which are a few shells in each locality which have brown bands instead of gray. The number of brown banded forms varies with the position of the locality. As a general rule, the lower the colony the greater the number of brown banded forms, which are intermediate forms between *A. m. lathropae* var. and *A. m. christopherseni* var. Figures 11-15b, plate 11, show some of the usual brown banded forms in area 67; the gray patterns also occurring in this area are the same as those found in areas 5 or 6, depending on which area is above the locality. The shell is white lined with cinnamon and black, peripheral line sepia, basal band sepia, sutural band pale pinkish buff, lip pale ochraceous salmon (pl. 11, fig. 11). Shell white, first post-embryonic whorl benzo brown finely lined and streaked with white, last half of whorl lined with deep neutral gray, penultimate whorl lined with light drab, last whorl lined with tawny olive, light drab, below the periphery banded with pinkish buff, and sepia about the base (pl. 11, fig. 12). First post-embryonic whorl and a half pale gull gray banded with dark livid brown, last whorl and a half shades from pale gull gray to white spirally lined and banded with snuff brown, bister and sepia, lip light vinaceous fawn streaked with army brown (pl. 11, fig. 13). An unusual color form known only from three or four specimens from the region of South Ekahanui South Branch is shown in figure 14, plate 11. Embryonic whorls pale pinkish buff banded on the upper half of the last embryonic whorl with pinkish buff, post-embryonic whorls pale pinkish buff widely banded and lined with cinnamon buff and cinnamon, lip and columella callus white. This form resembles the pattern of the light yellow form of *A. m. kapuensis* var. from Kaaikukai Gulch. The ground is white, lined and banded with sayal brown, cinnamon, warm sepia, impressed sutural band pinkish buff, edge of lip cinnamon buff, shading to white (pl. 11, fig. 15). The shell can be entirely white except for a few

bands of bister streaked with white and tinted with cinnamon about the base (pl. 11, fig. 15a). Figure 15b, plate 11 shows an extremely light gray color form, the entire shell white tinted and very faintly banded with pale gull gray.

In locality W420A-6 a very small form of *A. m. christopherseni* occurs, having the usual gray patterns of area 68 and a few brownish banded forms, which is the reason for including this locality in area 67. The usual form of the shell is that of figure 16, length 18.9 mm., greater diameter 10.5 mm., spire height 10.7 mm., embryonic whorls worn, last two whorls pale gull gray and axially streaked with black and tinted on the last half whorl with tawny olive. First two post-embryonic whorls dark livid brown lined with a line of white, last two whorls banded with black and white, impressed sutural band shades from dark livid brown on the first post-embryonic whorl to pinkish buff on the last whorl (fig. 16a). The last three whorls pale gull gray lined and banded with black (fig. 16b). An obese form measures, length 18.0 mm., greater diameter 11.7 mm., spire height 9.4 mm., ground pale gull gray or white axially streaked and banded with pale mouse gray, banded with black about the base, sutural band white, lip outer margin cinnamon buff, remainder of lip and columella callus white (fig. 16c). Embryonic whorls white, penultimate whorl pale neutral gray lined with white, last whorl banded above the periphery with a band of pale neutral gray, finely streaked and lined with cinnamon brown, below and at the periphery banded with a band of drab axially streaked with sepia and bands of hair brown, bister, and snuff brown (fig. 16d).

The specimens from the fossil bed in locality W424A-1 are intermediates between *A. m. christopherseni* and *A. m. russi*. Figure 1, plate 12, shows one of the two adults from this locality. The spire is very much like that of the type of *A. m. russi*, but the last whorl, base, and impressed sutural band are more like *A. m. christopherseni* var. The shells from locality W424-3 are definitely *A. m. christopherseni* forms. Therefore, since so little can be told about the form variation of the shells in W424A-1 until more shells are collected, I have placed them under *A. m. christopherseni* var. and considered them to be a lower variant of the shells of locality W424A-3. This fossil locality is of great importance because it links together the separate forms of *A. m. russi* and *A. m. christopherseni*.

Table 31. Achatinella mustelina christopherseni var. Area 67.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.	Dextral	Sinistral
Meinecke	W410B-1	10		19.5	17.5-21.5	6	22
Meinecke	W410B-6	8	7	21.0	19.5-22.5	3	29
Welch	W410B-7	4				7	
Welch	W410B-11	6	35	20.0	18.5-22.5		88
Russ	W410B-11	43		20.5	18.5-23.5		45
Meinecke	W410C-1	8	8	20.5	18.5-21.5	16	3
Meinecke	W410C-6	2	2			10	3
Meinecke	W410C-7	7			18.5-22.5	3	16
Meinecke	W410C-8		7	21.5	18.5-23.5		12
Meinecke	W410D-1	30	1	20.0	18.5-22.5	29	22
Meinecke	W410D-2	15		20.5	18.5-22.5	52	2
Meinecke	W410D-3	8		21.0	19.5-22.5	8	5
Meinecke	W410F-1	41	1	20.5	17.5-23.5	72	13
Meinecke	W410F-2	66		21.0	18.5-23.5	61	40
Meinecke	W410F-3	9	7	22.0	19.5-22.5	17	4
Meinecke	W410F-3a	13	7	21.0	19.5-22.5	17	16
Meinecke	W410F-5	22		21.0	19.5-22.5	40	
Meinecke	W410F-6	17	10	20.5	18.5-22.5	2	35
Meinecke	W410F-7	37	4	20.5	18.5-22.5	61	3
Meinecke	W410F-8	41	9	19.5	17.5-21.5		66
Meinecke	W420-2	45		21.5	18.5-24.5	59	6
Meinecke	W420-3	31		19.0	17.5-21.5	2	38
Meinecke	W420A-2	26		19.5	18.5-21.5		26
Meinecke	W420A-3	13		21.0	19.5-22.5		16
Meinecke	W420A-4	76	1	19.5	16.5-22.5		86
Russ	W420A-4	23		20.0	18.5-21.5		23
Russ	W420A-6	22		18.0	16.5-19.5		22
Welch	W420A-1						10
Meinecke	W424A-3						3

If all the localities plotted on map 13 from Ekahanui and Puumaialau are considered statistically from the data given in tables 24, 29, 30, and 31, the size of the shells is found to vary at random without any constant size variation with altitude. Comparing the shells from localities to the north plotted on map 12 which are usually 19 + mm., shells from localities on map 13 to the south are found to be generally larger, being 20 + or 21 + mm. Therefore shells in the central section of the Waianae Mountains decrease in size the nearer the general area is to the northern section of the Waianae Mountains.

In table 31, one upland locality, W420A-6, is found to have much smaller shells than the immediate lower localities. The shells in W420A-6 were collected on grass and *Bidens*, while the lower shells were collected on native trees. The size factor in this case may be dependent on the food the animal can get from the barren, grassy, precipitous slope.[1] This locality may give a

clue to the possibility of obtaining small shells in this region if only the high division ridge were collected. With the exception of W420A-6, all the localities with a measurable series of shells are at a considerable distance below the crest of the division ridge between Lualualei and Ekahanui. This may be a reason why no 18 + mm. localities are known in Ekahanui.

Another point of interest in table 31 is the difference in the mean length of the Meinecke and Russ lots from supposedly the same region of locality W420A-4. Possibly Russ collected at a slightly lower elevation than Meinecke, and as the lower shells in W420A-3 are larger, this would account for the size difference between the lots.

In area 69 (table 30) the high W410D localities immediately below Puu Kaua in South Ekahanui are composed of larger shells than lower localities in the same general region. So in this sector there is a size increase with increase of elevation.

3. *Achatinella mustelina,* subspecies of the southern section of the Waianae Mountains (map 2).

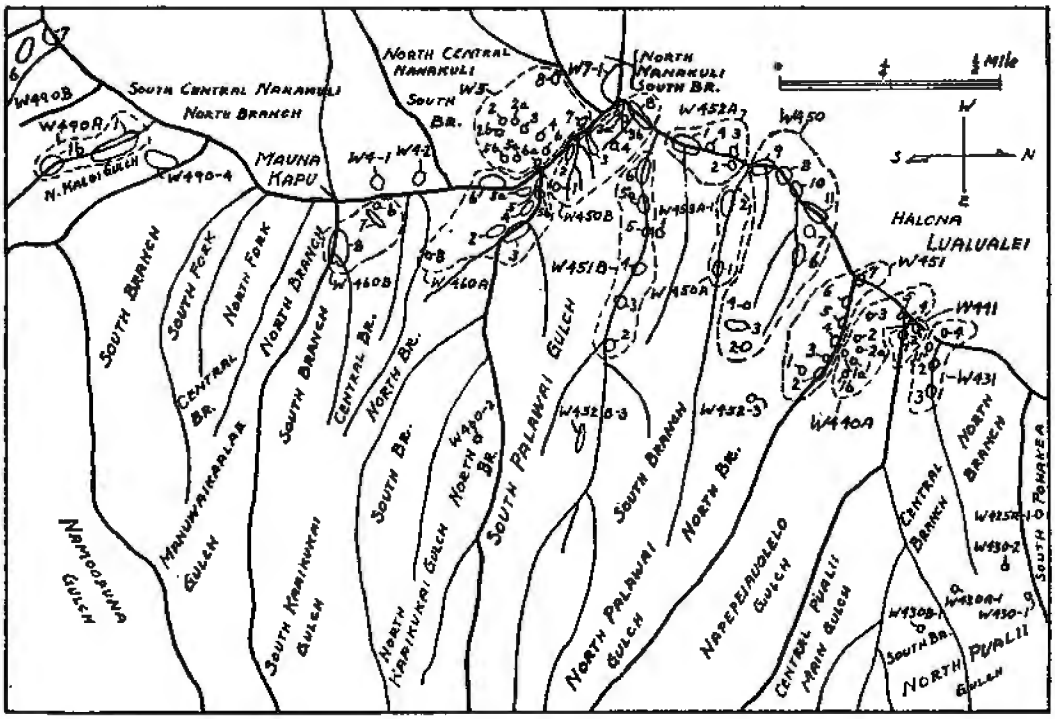
Achatinella mustelina russi, new subspecies (pl. 12, figs. 3-4c).

The shell slender, spire elongate, the form is intermediate between the *A. m. christopherseni* forms of area 67 and *A. m. lymaniana.* The embryonic whorls are tilleul buff, tinted on the second embryonic whorl with a dull shade of honey yellow, last half of last embryonic whorl white, last three post-embryonic whorls a dirty white or white tinted with tilleul buff, axially streaked on the first post-embryonic and penultimate whorl with vinaceous buff and fawn color, or a drab gray faintly spirally lined on the penultimate with white, last whorl almost a solid shade of grayish brown between wood brown and a light drab, spirally lined and banded with white, lip and columella callus white, impressed sutural band white, tinted on the lower half with avellaneous, length 22.1 mm., greater diameter 11.0 mm., spire height 12.3 mm., number of whorls 6¾ (pl. 12, fig. 3).

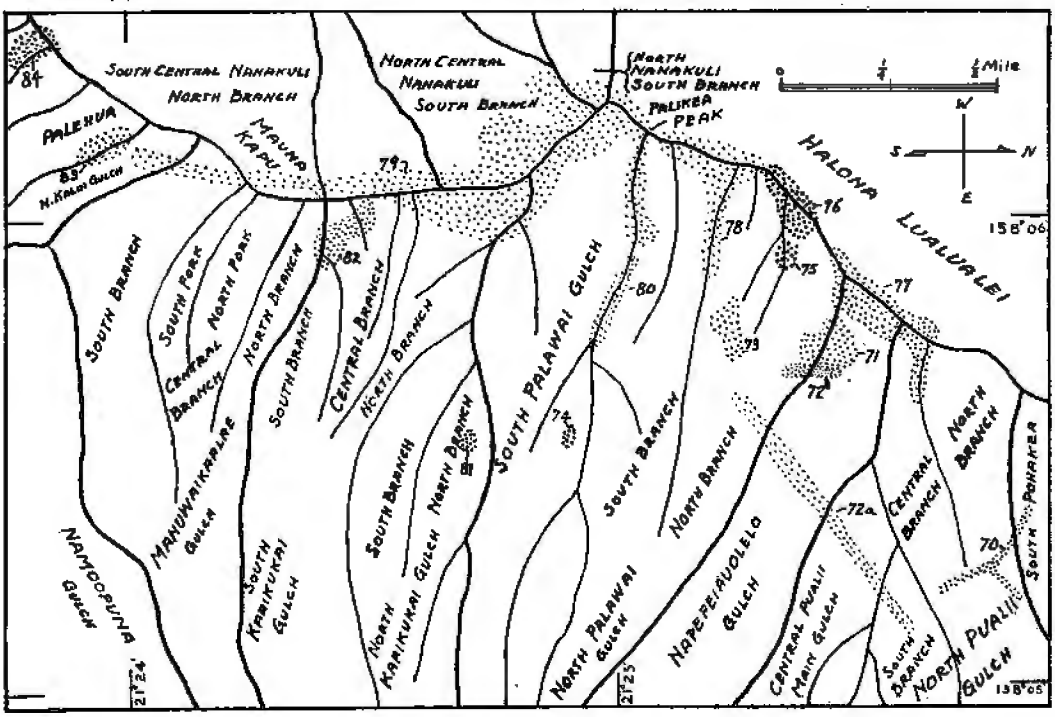
Distribution, area 72: **Napepeiauolelo-Palawai Ridge,** type locality W451-2, el. 2,250-2,500 ft., Russ 1933, Meinecke 1934; also W451-1, el. 2,200 ft., Russ 1933, Meinecke 1934; **Napepeiauolelo Gulch,** locality W440A-1b, el. 2,250 ft., Russ 1933. Also in area 72a, **North Palawai Gulch,** locality W452-3, el. 1,900 ft., shells in fossil state; **North Pualii Gulch South Branch,** locality W430B-1, el. 1,550 ft., Welch and Winne 1936 (maps 14, 14a p. 124).

The subspecies is named after G. W. Russ, former assistant forester of the Territory of Hawaii, who has collected a large amount of the material used in this paper.

The form of the shell may be very elongate, length 23.0 mm., greater diameter 10.7 mm., spire height 13.3 mm., number of whorls 7, post-embryonic whorls a very light shade of drab gray or white, spirally banded with wood brown on the last two whorls shading to sayal brown near the edge of the lip (pl. 12, fig. 4). A very common form, more obese than the holotype, is shown in figure 4a, plate 12, length 22.7 mm., greater diameter 12.7 mm., spire height 12.4 mm., number of whorls 6½, post-embryonic whorls white axially streaked and banded with a shade between wood brown and



MAP 14.



MAP 14a.

buffy brown. Twenty percent of the shells have a dark color pattern found more usually in area 71 (pl. 12, fig. 5a). A single specimen from the type locality has a very gray color pattern, first post-embryonic whorls banded with army brown, which band is streaked with pallid mouse gray, first half penultimate whorl white, banded with pallid mouse gray, finely banded with army brown, last whorl and a half light mouse gray, banded with white and black, impressed sutural band, on the last whorl and a half bone brown, upper edge white, lip and columella callus pale pinkish buff (pl. 12, fig. 4c). Another single specimen similar to figure 4c was collected by Meinecke in W451-1, none having been taken in W440-1b. The shell may be entirely white with only the lip edged with pale brown (pl. 12, fig. 4b).

Table 32. Achatinella mustelina russi Welch. Area 72.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.
Russ	W451-1	9		22.5	20.5-24.5
Meinecke	W451-1	4	6	23.0	21.5-26.5
Russ	W451-2	22		23.0	19.5-24.5
Russ	W440A-1b	9		23.5	22.5-24.5

The shells are larger than those of any of the neighboring localities (table 32) having a mean length of 23 + mm. Like all the forms of *A. mustelina* south of Pohakea Pass, the turn of the coil is invariably sinistral. The Russ lot from W451-1 is smaller than the Meinecke lot from the same locality. The difference may be due to the small number of shells in the Russ lot.

Achatinella mustelina russi var. (pl. 12, figs. 5, 5a).

Area 71: **Napepeiauolelo-Palawai Ridge,** localities W451-3, el. 2,550 ft., W451-4, el. 2,500 ft., W451-5, el. 2,550 ft., Meinecke 1934, W451-3-4 and W451-4-5, Russ 1933; **Napepeiauolelo Gulch,** localities W440A-1, el. 2,150-2,250 ft., W440A-1a, el. 2,400-2,500 ft., W440A-2, el. 2,250 ft., W440A-2a, el. 2,250 ft., Meinecke 1934 (maps 14, 14a, p. 124).

The light color patterns of area 72 are rare in area 71. The usual color patterns are darker, similar to figures 5 and 5a, plate 12. The typical form and color pattern of the shell is more obese than typical *A. m. russi,* length 22.5 mm., greater diameter 12.3 mm., spire height 11.8 mm., embryonic whorls white, post-embryonic whorls white faintly banded up to the last whorls with avellaneous, last whorl banded with avellaneous, fawn color and army brown, lip white, edged with sayal brown on the extreme outer margin, columella callus white, lip strongly tuberculate, much more so than the shells in the type locality (pl. 12, fig. 5). This rough tuberculate character of the lip is not a constant character in the various areas of *A. m. russi* var. but a very usual one, and similar to what is found in *A. m. kapuensis.* Odd specimens of *A. m. christopherseni* var. from Puumaialau Gulch and other forms

of *A. mustelina* from almost any section of the Waianae Mountains are found to have tuberculate lips but usually very weak and not as evident as in *A. m. russi* and *A. m. kapuensis*. The darkest color pattern so usual in area 71 is shown in figure 5a, plate 12, embryonic whorls white, post-embryonic whorls white, spirally banded and axially streaked with avellaneous darkening to army brown on the last whorl, lip and columella callus white.

Table 33. Achatinella mustelina russi var. Area 71.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.
Meinecke	W451-3	8		23.0	21.5-23.5
Russ and Meinecke	W451-4-5	9		20.5	18.5-22.5
Meinecke	W440A-1		9	22.0	19.5-23.5
Meinecke	W440A-1a	1	27	22.0	19.5-24.5
Meinecke	W440A-2-2a	3	16	22.0	20.5-24.5

While the shells in the upper localities of W451-4-5 are decidedly smaller when observed, the number of shells obtained from these localities is small for any statistical proof of size change. But even with the limited number of specimens, a decided tendency is exhibited toward a size decrease with altitude.

Achatinella mustelina russi var. (pl. 11, figs. 19-21; pl. 12, figs. 6-7).

Area 77: **Napepeiauolelo-Palawai Ridge,** localities W451-6, el. 2,600 ft., W451-7, el. 2,700 ft., Meinecke 1934; **Napepeiauolelo Gulch,** locality W440A-3, el. 2,450 ft., Meinecke 1934; **Napepeiauolelo-Halona Ridge,** localities W440A-4, el. 2,650 ft., W440A-5, el. 2,650 ft., Welch and Isle 1936, also Cooke and Von Holt 1912, in the probable localities of W440A-4 (lot 3314), and W440A-5 (lot 33024); **Pualii-Napepeiauolelo Ridge,** localities W441-1, el. 2,600 ft., Russ 1936, W441-2, el. 2,650 ft., Russ 1936, Welch and Isle 1936; **North Pualii North-Central Branch Ridge,** localities W431-1, el. 2,600 ft., W431-2, el. 2,550 ft., W431-3, el. 2,500 ft., Welch and Isle 1936, region of W441-2-431-1, Cooke and Von Holt 1912; **Pualii-Halona Ridge,** W431-4, el. 2,600 ft., Isle and Welch 1936 (maps 14, 14a, p. 124).

The usual color pattern and form of the shell in area 77 is shown in figure 19, plate 11. Length 20.6 mm., greater diameter 11.0 mm., spire height 11.3 mm., embryonic whorls worn, color white, first post-embryonic whorls russet, spirally banded with white, post-embryonic whorls tilleul buff spirally lined with avellaneous darkening on the last half whorl to army brown, 2 mm. behind the edge of the lip the color pattern stops and there is a streak of white, lip and columella callus white, outer margin of lip edged with honey yellow. Figure 20, plate 11, exhibiting a slender form, has a length of 20.3 mm., greater diameter 10.5 mm., spire height 11.0 mm. Figure 20a, plate 11, shows an obese form, length 20.1 mm., greater diameter 12.2 mm. Both figures 20 and 20a have color patterns which are similar in color to figure 19.

Dark colored specimens are similar to figure 21, plate 11, post-embryonic whorls pallid vinaceous drab spirally banded and axially streaked with light vinaceous drab, darkening to dark vinaceous drab on the last whorl. In the region between Pualii and Napepeiauolelo along the division between Lualualei and Honouliuli going north, gray color forms are found. These gray forms (pl. 12, figs. 6, 7) are probably remnants of the intermediate race now extinct, as far as is known, which existed between North Pualii Central Branch and Puumaialau. The change from the *A. m. russi* form of figures 4c, 5, plate 12, and figure 19, plate 11, to the very usual gray color form of the Puumaialau shells shown in figures 16b and 16c, plate 11, was probably a gradual one. Pohakea Pass was probably the central region where the color patterns and forms of the two races were mixed together. The shell on the last three whorls is pale mouse gray spirally lined with benzo brown up to the last whorl, last whorl spirally banded with buffy brown (pl. 12, fig. 6). The last two whorls pale purplish gray, shading to light neutral gray on the last whorl, last whorl axially streaked and spirally banded with deep neutral gray (pl. 12, fig. 7).

Figures 17, 17a, 18, plate 11, show Puumaialau forms which are very similar in shape to figures 4a, 7, plate 12, and 20a, plate 11. Figure 18 has a rough lip with a single tubercle on it.

Table 34. Achatinella mustelina russi var. Area 77.

Collector	Locality	Live adults	Mean length in mm.	Length range in mm.
Cooke	W440A-4(?)	34	20.5	18.5-22.5
Cooke	W440A-5(?)	11	19.5	17.5-20.5
Russ	W441-1	24	21.0	18.5-22.5
Russ	W441-2	14	20.5	19.5-21.5
Welch	W441-2	14	19.5	17.5-21.5
Welch	W431-1	38	20.5	18.5-22.5
Welch	W431-2	5		
Cooke	W431-1-W441-2(?)	80	20.5	18.5-22.5

The Cooke lots in area 77, although marked with a query, are undoubtedly close to being correct, because with Dr. Cooke's help the approximate localities were marked on a map. These were recollected in the field and checked with the material found in the plotted localities. The size of the shells is definitely smaller than in area 72. *A. m. russi* therefore definitely shows a decrease in size with elevation, but does not do so by completely changing the form of the shell and the color pattern forming a new race as the typical *A. m. mustelina* does (table 34).

Achatinella mustelina russi var. (pl. 12, figs. 2-2a).

Area 70: **North Pualii Gulch North Branch,** localities W430-1, el. 1,700 ft., W430-2, el. 1,600 ft.; **North Pualii Gulch Central Branch,** W430A-1, el. 1,500 ft.; **South Pohakea**

Gulch, W425A-1, el. 1,750 ft., all fossil shells collected by Winne and Welch 1936, along the contour trail (maps 14, 14a, p. 124).

The shells have the typical spire and form of *A. m. russi*, or in the case of a few specimens the form is closer to that of *A. m. christopherseni* var. of area 67. The typical form which resembles *A. m. russi* is figured in figure 2, plate 12, length 20.9 mm., greater diameter 10.3 mm., spire height 12.3 mm. Figure 2a, plate 12, shows a specimen with a more flattened base than typical *A. m. russi* and is similar to *A. m. christopherseni* var. of figure 17a, plate 11. These two specimens are examples of the two forms of the shell occurring in W430-2 which definitely tie up *A. m. christopherseni* with *A. m. russi.*

The only locality with a measurable series of adults in area 70 is W430-2. Of 42 sinistrals, 20 adults are found, ranging in length from 19.5-22.5 mm., mean length 21.0 mm. The size of the shells is unusually small comparing the shells with those of area 72. But in a comparison of size with the shells of *A. m. christopherseni* var. there is not much size difference. This locality and W424A-1 (p. 121) most probably are the turning points where *A. m. christopherseni* grades into *A. m. russei.* More collecting should be done in this area to verify this point.

Achatinella mustelina russi var. (pl. 12, figs. 8-8d).

Area 73: North Palawai Gulch North Branch, locality W450-2, el. 2,000 ft., 3 sinistral adults, length range 22.5-24.5 mm., W450-3, el. 2,050-2,300 ft., 52 live and 4 dead adults, mean length 22.0 mm., length range 19.5-24.5 mm., 76 sinistrals, W450-4, el. 2,050 ft., 4 dead sinistrals, length range 21.5-22.5.

Area 75: North Palawai Gulch North Branch, locality W450-6, el. 2,500-2,600 ft., 5 live and 3 dead adults, mean length 20.5, length range 19.5-23.5, 13 sinistrals, Meinecke 1934.

Area 74: South Palawai Gulch First North Branch, locality W452B-3, el. 1,900 ft., fossil shells, Welch and Winne 1936 (maps 14, 14a, p. 124).

All that is known statistically about the shells of area 73 is based mostly on the series of 76 shells collected by Meinecke in locality W450-3, because the other localities are represented by so few specimens. The typical form of the shell measures, length 21.6 mm., greater diameter 11.2 mm., spire height 12.2 mm., number of whorls 6½; embryonic whorls white or pale pinkish cinnamon slightly worn, lacking shell enamel, post-embryonic whorls white faintly banded with tilleul buff, lip and columella callus white; outer edge of the lip chamois, impressed sutural band white (pl. 12, fig. 8). The shell may be more obese, length 21.6 mm., greater diameter 13.0 mm., spire height 11.1 mm., embryonic whorls pale pinkish buff, first half of first post-embryonic whorl a faint shade of cinnamon, lined with white, last two whorls and a half and the impressed sutural band a grayish shade of avellaneous (pl. 12, fig. 8a). The two color patterns of figures 8 and 8a, plate 12, are the dominant ones in area 16. It is only in locality W450-3 that 32 percent of

the shells have a gray pattern similar to the gray patterns of Ekahanui Gulch, or *A. m. christopherseni* var. The embryonic whorls are white faintly tinted with pale vinaceous fawn, post-embryonic whorls banded with neutral gray and deep neutral gray axially streaked with neutral gray and pale neutral gray, lip and columella callus white (pl. 12, fig. 8b). The post-embryonic whorls are pale neutral gray or white banded with dark neutral gray (pl. 12, fig. 8c). An obese form, length 20.7 mm., greater diameter 12.5 mm., spire height 10.8 mm., has a more triangular appearance to the spire, which is straight in outline, the whorls not as convex as in figure 8, the embryonic whorls vinaceous buff, the last two post-embryonic whorls white banded and lined with deep neutral gray and dark neutral gray, at the edge of the periphery a single band of mikado brown (pl. 12, fig. 8d).

Above area 73 in area 75, North Palawai North Branch, locality W450-6, el. 2,600 ft., the shells have similar color patterns to those of area 16, but are smaller, being intermediate forms between areas 16 and 13, but being closest to the shells of area 73 in color and form. The faded fossil shells found in area 74 are closest in form to the shells of area 73 and shall be considered *A. m. russi* var. until more material is obtained which may prove them to be closer to *A. m. kapuensis*.

Achatinella mustelina lymaniana Baldwin (pl. 8, figs. 1-2; pl. 13, figs. 2-5).

Achatinella lymaniana Baldwin: Proc. Acad. Nat. Sci. Phil., 1895, p. 219, pl. 10, figs. 12, 13 (July 2, 1895).—Pilsbry and Cooke, Man. Conch. 22: 350, pl. 61, figs. 8-9b, 11, 1912-1914.

Shell sinistral, very minutely perforated, solid, ovate; spire convexly conical, apex subacute; surface shining, covered with fine incremental lines, under a strong lens showing minute decussating striae; apical whorls smooth when not eroded. Color dark purplish brown, sometimes with longitudinal or transverse white flecks or zigzag lines; a white line traversing the suture; apex light chestnut. Whorls 6, lightly margined above, somewhat convex; suture moderately impressed. Aperture oblique, white within, sublunate; peristome acute, thickened within, expanded, the columella margin slightly reflexed and covering the small perforation, color white on both face and the reverse; columella white, terminating in a slightly developed flexous fold. Length, 20½; diam., 11½ mm. Habitat, Waianae Mts., Island of Oahu.

Named in honor of Mr. Ernest Lyman, to whom science is indebted for many additions to Hawaiian land shells (Baldwin).

The type lot of *A. m. lymaniana* is in the Baldwin collection in Bishop Museum. The original label of this lot of four shells has "original types" written in Baldwin's handwriting. Out of the lot, one shell (pl. 13, fig. 2) was found to match Baldwin's figure 13, reproduced on plate 8, figure 1, and answers the description in every detail except the measurements (length 19.6 mm., greater diameter 11.0 mm., lesser diameter 10.5 mm.). Although the measurements are not the same, the difference in size of a millimeter more or less is probably due to different methods of measuring, since my measurements of Baldwin's types do not agree with his published measure-

ments, or Baldwin may have taken his measurements from the shell of figure 12, reproduced in figure 2, plate 8. No specimen from the labeled type lot or any of the Baldwin specimens of *A. m. lymaniana* in his collection in Bishop Museum agrees with his figure 12 (pl. 8, fig. 2). Probably this specimen is in the Academy of Natural Sciences of Philadelphia, although I did not come across it there. From the original description it appears that the shell of figure 1, plate 8, represents what Baldwin considered his typical color form of *A. m. lymaniana* and his figure 12 a variation of that form. Specimen 54934 in Bishop Museum is considered the lectotype and all determinations are based on this specimen.

The lectotype has the first two whorls eroded and colored cinnamon buff, last embryonic whorl pale pinkish buff, post-embryonic whorls shade from mikado brown to chocolate on the last whorl, impressed sutural band pale pinkish buff on the last whorl, on the penultimate whorl the pinkish buff line is present but the suture not impressed, last whorl axially streaked with cinnamon and with a subsutural line of pinkish buff, last two whorls spirally ornamented with thin lines slightly darker than the ground, lip edged with cinnamon buff (pl. 13, fig. 2).

The type of *lymaniana* came from a lot of shells collected by Ernest Lyman in the company of W. A. Lowrie. In Bishop Museum, there are 35 shells of the original lot. Four are in the C. M. Cooke, Jr. collection made by Lowrie; 32 in the Lyman collection, and 9 in the Baldwin collection. Mr. Lyman's original label reads "Waianae Mountains, Oahu, back of Ewa Plantation."

Occurring with the typical color pattern is a light color form, embryonic whorls pinkish buff shading to pale cinnamon pink, first post-embryonic whorl and a half tilleul buff axially streaked with cinnamon, last whorl and a half tilleul buff axially streaked and faintly spirally lined with verona brown, outer margin of lip cinnamon buff, inner portion and columella callus white (pl. 13, fig. 3). The shell may be darker, last two and a half whorls axially streaked with burnt umber or chocolate, spirally lined and axially streaked with zigzag and straight streaks of white, tilleul buff, and a very light shade of pale gull gray (pl. 13, fig. 4). A distinct yellow form, which occurs in most *A. lymaniana* localities is found in the paratype lots. Last three whorls pale pinkish buff, spirally banded with cinnamon buff, outer margin of lip cinnamon buff, inner margin and columella callus white (pl. 13, fig. 3a).

Distribution, area 83: **North Kaloi Gulch,** on the ridge between the north and south branches in the proximity of the Harry Von Holt's mountain residence, Palehua, or the region of locality W490A-1-1b, collected by Cooke 1903, which contains specimens identical in form and color pattern with the paratypes, and may be considered the locus of the type locality. Later during 1908 and 1912, Cooke collected shells in North Kaloi Gulch, locality W490A-1-1b, el. 2,400-2,500 ft., and locality W490A-1, el. 2,400-2,500 ft., in 1912 and 1914 (maps 14, 14a, p. 124).

Dr. Cooke questions the purity of the 1908 and 1912 lots from this locality, for he was later informed that shells had been transplanted sometime after 1903 from other nearby parts of the Waianae Mountains to trees in the immediate vicinity of the house at Palehua.

After examining all the Cooke material, I can see no difference in form or color between the 1903 lots and any of those collected later. Of the four lots, the 1908 lot of shells, locality W490-1, is the only one containing one shell out of thirty with the gray pattern of the forms to the north. The color on the last three whorls of the shell is white, spirally lined with pale gull gray and deep purplish gray, embryonic whorls worn as in so many specimens from this region (pl. 13, fig. 5). This gray specimen could have occurred in W490A-1, since odd gray specimens are found to the south in locality W490B-6. Possibly the shells transplanted were on trees in the vicinity of the house, other than those on which Cooke collected, for the lots appear to be pure and shall be considered so in this paper.

Achatinella mustelina lymaniana var. (pl. 13, figs. 6-6a).

Area 84: **North Kaloi Gulch South Branch**, region of locality W490B-6, approximate el. 2,300 ft., Cooke 1912, C. M. Cooke, Jr., C. M. Cooke III, and R. Von Holt 1914, W490B-7, el. 2,400 ft., Russ 1933, 1 juvenile specimen (maps 14, 14a, p. 124).

The shells in this region are larger and usually more obese than typical *A. m. lymaniana*. The color pattern of the holotype of *lymaniana* does not occur here. Forty percent of the shells have a color pattern similar to figure 3, plate 13; 23 percent are like figure 6, plate 13; 36 percent resemble figure 3a, plate 13. The typical form of the shell is shown in figure 6, plate 13, length 22.5 mm., greater diameter 13.2 mm., spire height 10.5 mm., embryonic whorls cartridge buff, post-embryonic whorls pale pinkish buff spirally banded with warm sepia and cinnamon buff, axially streaked with pale gull gray on the penultimate whorl, and pinkish buff on the last whorl. Figure 6a, plate 13, is a light grayish color form of figure 3a, post-embryonic whorls white tinted with a few axial streaks of pale mouse gray, below the periphery of the last whorl pale mouse gray streaked with white.

Table 35. Achatinella mustelina lymaniana Baldwin, and var. Areas 83 and 84.

Collector	Year	Locality	Live adults	Mean length in mm.	Length range in mm.
Lyman and Lowrie		W490A-1-Ib	22	20.5	18.5-22.5
Cooke	1903	W490A-1-Ib	14	21.5	18.5-22.5
Cooke	1908	W490A-1-Ib	20	20.0	17.5-21.5
Cooke	1912	W490A-1-Ib	10	20.0	18.5-22.5
Cooke	1912	W490A-1	5	19.5	17.5-20.5
Cooke	1914	W490A-1	9	18.5	17.5-20.5
Cooke	1914	W490A-1	5	18.5	17.5-19.5
Cooke	1912	W490B-6	30	22.5	19.5-22.5

In the Cooke lots listed in table 35 from North Kaloi Gulch, the shells collected in the immediate vicinity of the house at Palehua, locality W490A-1, are apparently smaller than the lots of shells collected from the broader locality of W390A-1b. All these localities are only approximate and should be recollected to determine for a certainty whether the lowland forms in the general region of locality W490A-1b are larger than the shells obtainable from the upper area in the vicinity of the house, locality W490A-1. From what we know of the change in size of shells at different elevations on the north side of Mauna Kapu, locality W460B-6, and W460B-7, it is possible that there may be a size change in Kaloi Gulch which can be correlated with that found elsewhere in the Waianae Mountains. The type of *A. m. lymaniana,* from the data at hand may have come from the lower section of Kaloi Gulch in the vicinity of locality W490A-1b. The large size of the shells in W490B-6 may be accounted for by the decrease in elevation of the backbone south of the Manuwaikaalae-Kaloi Ridge at Palehua. This size decrease is correlated with the condition found in the shell localities in the northwestern limit of the Waianae Mountains.

Achatinella mustelina kapuensis, new subspecies (pl. 13, figs. 7-10a).

Shell spire straight in outline more tapering and pointed than *A. m. lymaniana* to which it is closely related, first embryonic whorl worn, pinkish buff, remaining embryonic whorls tilleul buff, first post-embryonic whorl avellaneous spirally lined with pale pinkish cinnamon, penultimate whorl drab faintly lined and streaked with white, lined with clove brown, last whorl buffy brown lined and banded with bone brown, specked with white, upper half of impressed sutural band white, lower half natal brown, outer margin of lip honey yellow, inner margin corrugate, white, columella callus strong, white, length 22.8 mm., greater diameter 13.0 mm., spire height 11.6 mm., number of whorls 6½ (pl. 13, fig. 7).

Distribution, area 82: **South Kaaikukai Central Branch Manuwaikaalae Ridge below Mauna Kapu,** type locality, region of W460B-8, approximate el. 2,250-2,550 ft., Cooke 1908, also Cooke and Von Holt 1912, and in **South Kaaikukai Gulch Central Branch below Mauna Kapu,** localities W460B-6, el. 2,600 ft., W460B-7, el. 2,450-2,600 ft., Welch and Yamaguchi 1936, region of W460B-6-7, Cooke 1912 (maps 14, 14a, p. 124).

The lightest color form found with the typical color pattern is shown in figure 8, plate 13, post-embryonic whorls tawny olive shading to buffy brown on the last whorl, spirally banded on the last two whorls with natal brown. The darkest color pattern is a rare one resembling the typical color pattern of *A. m. lymaniana* only the ground color is of a dull hue, being mixed with drab gray. The last three whorls are dark livid brown shading to warm blackish brown faintly spirally lined with pale gull gray, lip unusually corrugate (pl. 13, fig. 8c). A variation of figure 8c is a shell colored on the last two post-embryonic whorls with vinaceous brown deepening to seal brown on the last whorl and a half, last whorl and a half spirally lined with light grayish olive (pl. 13, fig. 8a). Sixty-six percent of the shells in the combined Cooke lots from W460B-6-7-8 have a color pattern similar to figures 7,

8, 8a, plate 13, or a combination of the patterns of figures 8 and 8a. The remaining 34 percent have a gray color pattern not found in areas 83 or 84, first post-embryonic whorl and a half mikado brown, lined and streaked with pale pinkish cinnamon shading on the last two whorls and a half to pale gull gray or white spirally ornamented with lines and bands of dark livid brown deepening to warm blackish brown broken with straight and zigzag streaks of the ground color, lip thickened and corrugate (pl. 13, fig. 8b).

In the Welch lots from W460B-6-7, only two color patterns are found. Thirty-six percent are of the typical pattern of figure 7, 64 percent the gray color pattern of figure 9, plate 13. The first two and three fourths embryonic whorls worn, lacking nacre, vinaceous buff, last embryonic whorl pale vinaceous fawn, last three and a fourth post-embryonic whorls pale gull gray spirally banded and lined with black, faintly axially streaked with dark gull gray and deep neutral gray (pl. 13, fig. 9). While locality W460B-7 extends quite a distance in altitude most of the shells were collected on lantana and on native trees in the bottom of a small ravine at the lower part of the locality at about 2,400 feet. The tan pattern of figure 3a, plate 13, is not found in this locality. In locality W460B-6, the form of the shells is similar to figures 10 and 10a, and they are smaller in size than the shells in locality W460B-7. The typical drab color patterns of figures 10 and 10a are found on 68 percent of the shells, 26 percent have the gray pattern of figure 9, and six percent have the yellow pattern of figure 3a. Locality W460B-6 is a border locality between the forms across the ridge in Nanakuli and typical *A. m. kapuensis,* being the western limit of where typical *kapuensis* is dominant. The post-embryonic whorls of figure 10, plate 13, shade from tilleul buff lined with army brown and natal brown to drab gray lined with chaetura drab on the penultimate, last whorl drab gray almost entirely covered over with spiral lines and bands of black, about the umbilical region a band of pinkish buff, impressed sutural band white. In figure 10a, plate 13, the post-embryonic whorls are light drab, last whorl profusely banded and lined with chaetura drab. No color patterns similar to figure 8c, plate 13, are found in the Welch localities of W460B-6-7. Since the Cooke lot from supposedly the same region does not have the same shade of dark color patterns, I am inclined to believe that the Cooke shells came from a point farther to the south near locality W460B-8. However, dead specimens from localities W460B-6 and W460B-7 which have been badly faded have a livid brown or reddish brown color. It is possible that the Cooke lots when collected were darker and have faded to their present color. Therefore, the dark pattern of *A. m. kapuensis,* if collected in the type locality, may have a different color pattern when freshly collected from the material described in this paper.

Achatinella mustelina kapuensis var.

Distribution, area 80: **North-South Palawai Ridge,** localities W451B-2, el. 2,250-2,500 ft., W451B-3, el. 2,550 ft., Meinecke 1934, and Welch and Degener 1936, W451B-4, el. 2,500 ft., Welch and Degener 1936 (maps 14, 14a, p. 124).

Distribution, area 81: **North Kaaikukai Gulch South Branch,** locality W460-2, el. 1,750 ft., Welch 1936, a single fossil faded specimen of *A. m. kapuensis.* The form and probable color pattern of the shell from the remains of the color is similar to figure 8b, plate 13.

Only three live specimens are known from locality W451B-2. One shell has the typical *kapuensis* color pattern (pl. 13, fig. 7); another has a light gray pattern similar to figure 9, plate 13, and the third a light tan pattern resembling figure 8, plate 12, of *A. m. russi* var. The higher localities of W451B-3 and W451B-4 have color patterns which are fairly equally divided between those of figures 7 and 9, plate 13. The form of the shell in locality W451B-3 varies from that of figure 9 to that of figure 10, plate 13. In locality W451B-4 the form of all the shells is closest to that of figure 10, plate 13.

Table 36. Achatinella mustelina kapuensis Welch, and var. Areas 82 and 81.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.
Cooke	W460B-8	50		23.5	21.5-26.5
Cooke	W460B-8	26		23.0	21.5-24.5
Cooke	W460B-6-7	8		22.0	20.5-22.5
Welch	W460B-6	25	6	23.0	20.5-25.5
Welch	W460B-7	24	5	21.5	19.5-23.5
Welch	W460-2		1		26.0
Meinecke	W451B-2	1	1		20.5-21.5
Meinecke and Welch	W451B-3	8		22.5	20.5-25.5
Welch	W451B-4	10		20.0	18.5-21.5

Table 36 indicates that shells from the lower localities are larger than those from the upper ones. It would be interesting to obtain more specimens from locality W460-2 in order to determine the range of variation of the lowest known locality of this form. Possibly the mean length would be greater than that of the shells of W460B-8 and W460B-7.

Achatinella mustelina kapuensis var. (pl. 13, figs. 11-11d).

Area 79: **North Kaloi Gulch North Branch,** locality W490-4, el. 2,450-2,500 ft., G. P. Wilder 1934, a border colony between typical *A. m. lymaniana* and the gray race of *A. m. kapuensis* var.; **South Central Nanakuli Gulch North Branch,** localities W4-1, el. 2,250-2,500 ft., Meinecke 1925, W4-2, el. 2,250-2,500 ft., Cooke and R. Von Holt 1910; **North Central Nanakuli Gulch South Branch,** localities W5-2, el. 2,250 ft., W5-4, el. 2,500 ft., Cooke and Welch 1931, W5-2, W5-2a, el. 2,300 ft., W5-2b, W5-3, el. 2,350 ft., W5-5b, el. 2,500 ft., W5-6, el. 2,600 ft., W5-6a, el. 2,600 ft., W5-7, el. 2,675 ft., Meinecke 1934, W5-5a, el. 2,500 ft., W5-8, el. 2,600 ft., Welch 1932, 1936, region of W5-5a-5b-6, Cooke

1910, 1912 with R. Von Holt, 1922 with Neal; **North Nanakuli Gulch South Branch,** locality W7-1, el. 2,750-2,900 ft., Meinecke 1925, region of W7-1, Cooke and R. Von Holt 1912; **South Kaaikukai Gulch North Branch,** localities W460A-2, el. 2,550-2,650 ft., Cooke and Welch 1931, Meinecke 1934, W460A-3, el. 2,750 ft., Meinecke 1925, W460A-4, el. 2,600-2,650 ft., Cooke and Welch 1931, W460A-5, el. 2,650 ft., Cooke and R. Von Holt 1914, Meinecke 1934, W460-5a, el. 2,650 ft., Meinecke 1934, W460-5b, el. 2,650 ft., Cooke and Neal 1922, W460A-9, el. 2,200 ft., Welch 1936; **Kaaikukai-Nanakuli Ridge,** region of locality W460A-6, approximate el. 2,750 ft., Meinecke 1913, 1923, 1934; **South Palawai Gulch,** localities W450B-1, el. 2,550 ft., Cooke and Neal 1922, W450B-2, el. 2,650-2,750 ft., Cooke 1910, 1912, 1914, 1922, 1931 accompanied by R. Von Holt, Neal and Welch, also Meinecke 1934, general region of W450B-2-3-3a, Russ 1930, W450B-3, Cook 1922, 1931, W450B-3, el. 2,650-2,750 ft., Cooke and R. Von Holt 1922, Cooke and Welch 1931, W450B-4, Cooke and Welch 1931, el. 2,650-2,750 ft., W450B-3a-3b, el. 2,550-2,900 ft., Cooke and Neal 1922, W450B-8, el. 3,050-3,098 ft., Cooke 1908, 1914, 1922, Meinecke 1934, Welch 1936; **North-South Palawai Ridge,** localities W451B-5, el. 2,750 ft., Welch 1936, W451B-5a, el. 2,850-2,900 ft., W451B-6, el. 2,900 ft.; **North Palawai Gulch South Branch,** locality W453A-1, el. 2,500-2,550 ft. Meinecke 1934 (maps 14, 14a, p. 124).

The three basic color patterns in area 79 are the typical *lymaniana* pattern (pl. 13, fig. 2) the yellow pattern (pl. 13, fig. 3a) and the gray pattern (pl. 13, fig. 8b). The typical pattern when freshly collected may have the embryonic whorls pinkish buff shading to cinnamon, last three whorls shading from burnt umber to hay's maroon on the last whorl, and with a subperipheral band of cartridge buff, lip and umbilical callus white (pl. 13, fig. 11). The yellow pattern may be colored on the last three whorls a light shade of cartridge buff or white with a few faint spiral pinkish buff lines above the aperture (pl. 13, fig. 11a) or may be darker, cartridge buff closely axially streaked and spirally banded with ochraceous tawny so that the last whorl is almost solid ochraceous tawny (pl. 13, fig. 11b). This yellow color pattern has all manner of intergrades between figure 11 and 11b and also the typical *lymaniana* and gray pattern. The gray pattern may be similar to figure 11c, plate 13, embryonic whorls worn a dirty white, three post-embryonic whorls slightly tinted with pale gull gray axially streaked with wavy lines, banded and faintly spirally lined with blackish brown, umbilical region banded with cartridge buff. This gray form may be similar to figure 8b, plate 13, or may have more of the typical color pattern mixed with it as in figure 11d, plate 13, last three whorls pallid mouse gray or white spirally banded with hay's maroon and axially streaked with zigzag lines the color of the ground.

The almost total absence of the yellow pattern of figure 11a, plate 13, in the typical *kapuensis* localities below Mauna Kapu may indicate that the yellow form is a migratory race that spread over Nanakuli and invaded the Honoulituli side of the range wherever conditions were favorable for traveling. This race could have been pure in the southern section of Nanakuli and extended across the range at Kaloi Gulch. Mauna Kapu being very rocky and precipitous could have offered a barrier to the yellow shells so that they were not able to mix with the gray *kapuensis* shells. Farther along nearer

the Palawai-Kaaikukai Ridge, the yellow form is again found on the Honouliuli side of the ridge. From Kaaikukai to the North-South Palawai Ridge, it is found in nearly every locality, and also its occurrence in Palawai and Kaaikukai is commoner than it is in Nanakuli, in all of the W-5- localities.

The presence of the yellow form is, therefore, so difficult to explain that until further localities are discovered in Nanakuli, no attempt should be made to work out a possible hypothesis of origin of this striking yellow color pattern. In general, the Nanakuli shells rarely have the typical *lymaniana* or *kapuensis* pattern, the gray color form being the usual one. The typical pattern of *A. m. lymaniana* occurs in South Palawai, Kaaikukai, and on the North-South Palawai Ridge; but all through the region of area 79 the dominant pattern is the gray pattern of figures 8b, 11c, 11d, plate 13, with a great many intermediate forms having a mixture of the typical and gray patterns.

Table 37 shows the size range of the mean length to be between 20+ and 21+ mm. The series of collections made by Dr. C. M. Cooke, Jr., in W450B-2 over a period of 20 years are interesting. All the lots have a constant mean length value of 21+ mm. This is another proof that shells from a definitely localized region when collected in consecutive years yield shells of the same size. This locality is accurately plotted, and was located in the field by Dr. Cooke and me in 1931. There is, therefore, no doubt of the accurate location of the earlier collection from this limited region, which was selected by Dr. Cooke because of its isolation. The Meinecke lot from the same locality in 1934 yielded a smaller mean length. Possibly he collected in a slightly different region, farther to the south or north, or at a higher elevation. Highland races above 2,250 feet are not small forms in this section of the Waianae Mountains. No elevation range is very noticeable. The possible reason for this is that the elevation range is limited to a single upland area.

Achatinella mustelina kapuensis var. (pl. 12, figs. 11-11d).

Area 78: **North Palawai South Branch North Fork-Halona Ridge,** localities W452A-1, el. 2,950 ft., Fosberg 1935, W452A-2, el. 2,950 ft., W452A-3, el. 2,900-2,950 ft., W452A-4, el. 2,950 ft., Welch and Isle 1936; **North Palawai North-South Branch Ridge,** localities W450A-1, el. 2,650 ft., W450A-2, el. 2,750-2,800 ft.; **North Palawai North Branch South Fork-Halona Ridge,** locality W450-9, el. 2,900-2,950 ft., Meinecke 1934, region of W452A-1-450A-9, Cooke and Von Holt 1912, C. S. Judd 1922 (maps 14, 14a, p. 124).

A race of *A. m. kapuensis* occurs in area 78, the shells of which are intermediate in form between *A. m. russi* of area 77 and *A. m. kapuensis* var. of area 79. Their color patterns are also intermediate between those of areas 79 and 76 but are closer to those of area 79. So many of the patterns are so similar to those of figures 11b, 11c, 11d, plate 13, that the race has not been considered a separable subspecies from the shells of area 79. The typical form of the shell is shown in figure 11, plate 12, length 20.0 mm., greater diameter

Table 37. Achatinella mustelina kapuensis var. Area 79.

Collector	Year	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.
Wilder		W490-4	18		21.0	19.5-22.5
Cooke		W460A-2	13		22.0	20.5-23.5
Meinecke		W460A-3	76		21.0	16.5-23.5
Cooke		W460A-5	8		21.0	18.5-24.5
Cooke		W460A-5	33		21.0	19.5-23.5
Meinecke		W460A-5	65		20.5	17.5-23.5
Meinecke		W460A-5a	40		21.5	18.5-24.5
Cooke		W460A-5b	108		20.5	18.5-23.5
Meinecke	1934	W460A-6	17		21.0	19.5-22.5
Meinecke	1923	W460A-6	51		21.0	17.5-24.5
Meinecke	1913	W460A-6	43		21.0	18.5-23.5
Cooke		W450B-1	8		21.0	18.5-22.5
Meinecke		W450B-2	3	25	21.0	19.5-22.5
Cooke	1910	W450B-2	29		21.5	19.5-23.5
Cooke	1912	W450B-2	44		21.0	19.5-24.5
Cooke	1914	W450B-2	106		21.0	17.5-24.5
Cooke	1922	W450B-2	133		21.0	19.5-23.5
Cooke	1931	W450B-2	12		21.5	18.5-22.5
Meinecke	1934	W450B-2	41		21.0	17.5-22.5
Russ		W450B-2-3-3a	447		20.0	17.5-24.5
Cooke		W450B-3	32		21.0	18.5-22.5
Cooke		W450B-3	45		20.0	18.5-24.5
Meinecke		W450B-3	71		21.5	18.5-23.5
Cooke		W450B-3a-3b	25		21.0	18.5-22.5
Cooke		W450B-3a-3b	47		21.5	17.5-24.5
Cooke		W450B-3b-8	14		21.5	18.5-23.5
Cooke		W450B-8	9		20.0	18.5-21.5
Meinecke		W451B-5	16		21.0	18.5-23.5
Meinecke		W451B-5a	6		20.0	18.5-22.5
Meinecke		W451B-6	23		20.5	18.5-23.5
Meinecke		W450B-8	2			
Welch		W451B-5	5			19.5-21.5
Meinecke		W453A-1		5		19.5-21.5
Cooke		W5-5a-W460A-5	14		20.5	18.5-22.5
Cooke		W460A-5-W5-5a-5b	12		20.5	19.5-22.5
Meinecke		W4-1	159		21.5	17.5-25.5
Cooke		W4-2	2			24.5-27.5
Meinecke		W5-2		8	21.0	19.5-22.5
Meinecke		W5-2a		6	21.5	19.5-23.5
Meinecke		W5-2b	18	2	21.5	19.5-24.5
Meinecke		W5-3		7	21.5	20.5-22.5
Cooke		W5-4	9	5	21.0	19.5-22.5
Meinecke and Welch		W5-5a-5b	1	4		21.5-23.5
Meinecke		W5-6	15	10	21.0	19.5-23.5
Meinecke		W5-6a	12		21.5	18.5-25.5
Meinecke		W5-7		5		20.5-22.5
Meinecke		W7-1	54		21.5	17.5-23.5

11.6 mm., spire height 9.8 mm., embryonic whorls white, first post-embryonic whorl spirally lined with cinnamon shading to mikado brown, penultimate whorl lined with mars violet over a white ground; last whorl banded and lined with mars violet, dull purplish black, neutral gray and pallid neutral gray, 3 mm. behind the edge of the lip the color pattern fades out to pale pinkish buff, lip and columella callus white, lip edged with clay color. A pattern peculiar to this area shades on the last two whorls from dark livid brown to dark neutral gray on the last half whorl, streaked with zigzag and straight axial streaks of white (pl. 12, fig. 11a). A pattern similar to the typical *lymaniana* pattern (pl. 13, fig. 11) is shown in figure 11b, plate 12, embryonic whorls white, first post-embryonic whorl ochraceous tawny shading to russet and mars brown, last two whorls chocolate shading to black on the last whorl spirally banded or lined with white, broken by axial streaks of the ground color, impressed sutural band mars brown shading to black, lip and columella callus white.

A color form similar to figure 11b, plate 13, is shown in figure 11c, plate 12, embryonic whorls white, first post-embryonic whorl and a half axially streaked and spirally banded with ochraceous tawny and ochraceous buff over a ground of white, last half of penultimate and first half of last whorl light buff shading to ochraceous buff, spirally lined with sudan brown, last half whorl above the periphery banded with argus brown, below the periphery mars brown with a band of white, the color fades out 3½ mm. behind the edge of the lip; the pattern fades out above and below the periphery to white, impressed sutural band ochraceous tawny. A light gray color pattern is shown in figure 11d, plate 12, post-embryonic whorls white, spirally lined and axially streaked with wavy lines of pale purplish gray and neutral gray on the penultimate whorl, last whorl lightly banded above the periphery with black, heavily banded with black below the periphery, impressed sutural band white except on the first post-embryonic whorl where it is russet.

Table 38. Achatinella mustelina kapuensis var. Area 78.

Collector	Locality	Adults live	Adults dead	Mean length in mm.	Length range in mm.
Meinecke	W450A-1	6		20.5	19.5-22.5
Meinecke	W450A-2	12		20.0	17.5-22.5
Meinecke	W450-9	37		19.5	16.5-22.5
Fosberg	W452A-1	10		20.5	18.5-22.5
Welch	W452A-2	28	7	20.5	18.5-22.5
Welch	W452A-3	16		22.5	21.5-24.5
Welch	W452A-4	13		19.5	17.5-22.5

The usual mean length in area 78 is 20 + mm., but the size may vary in certain spots without any special order or sequence (table 38). Locality W452A-3 is especially noteworthy because of the large size of the shells. They were collected on the west slope of the Palawai-Halona Ridge about 50 feet away from locality W452A-2 on the east slope of the same ridge. This is an example of how easy it is to obtain series of shells of entirely different mean length values when collecting in almost the same limited locus.

Achatinella mustelina kapuensis var. (pl. 12, figs. 9-10a; pl. 13, figs. 1-1a).

Area 76: **North Palawai Gulch North Branch**, locality W450-7, el. 2,650-2,750 ft., Meinecke 1934; **North Palawai North Branch-Halona Ridge**, W450-8, el. 2,900-2,950 ft., Meinecke 1934, W450-10, el. 2,900 ft., W450-11, el. 2,800 ft., Welch and Isle 1936, region of W450-8-9-10, Cooke and R. Von Holt 1912 (maps 14, 14a, p. 124).

Area 76 is composed chiefly of gray color forms; to the north the light ridge forms of *A. m. russi* of area 77 become increasingly numerous, while to the south, the gray form is more dominant the farther away one goes from area 77. The usual form and color pattern on the backbone ridge between Halona and Palawai Gulches is shown in figure 10, plate 12, length 19.8 mm., greater diameter 11.7 mm., spire height 9.3 mm., embryonic whorls worn; post-embryonic whorls white spirally banded with deep neutral gray and black axially streaked with deep neutral gray, black, and white, lip and columella callus white, outer margin of the lip cream buff. The shell may be white banded just above the edge of the periphery and on the first post-embryonic and penultimate whorls with a band of vinaceous fawn darkening to dark vinaceous brown and seal brown, spirally lined with white, on the last whorl one band above the periphery of avellaneous, below the periphery a band 3.5 mm. wide of deep plumbago gray lined with white fading out on the last half whorl to pearl gray and three lines of black; the third or lower band neutral gray (pl. 12, fig. 9). This is a rare pattern; only three specimens have been known from all the collections from area 76. The usual form having a *russi* patterned shell is shown in figure 10a, plate 12, post-embryonic whorls white, spirally lined and axially streaked with vinaceous buff. In locality W450-7 the shells are more narrow and elongate, length 19.2 mm., greater diameter 10.5 mm., spire height 10.5 mm., last two post-embryonic whorls finely axially streaked with wavy lines of deep neutral gray and neutral gray, spirally banded with white and a band of deep neutral gray below the periphery (pl. 13, fig. 1).

The usual form of the *russi* pattern in locality W450-7 is shown in figure 1a, plate 13, with a pattern similar to figure 10a, plate 12, and also with the usual form of the shells in locality W450-7.

Table 39. Achatinella mustelina kapuensis var. Area 76.

Collector	Locality	Live adults	Mean length in mm.	Length range in mm.
Meinecke	W450-7	29	19.0	17.5-20.5
Welch	W450-10			
Welch	W450-11	16	19.0	18.5-20.5
Meinecke	W450-8	17	19.5	17.5-20.5

Area 76 has surprisingly small shells. On either side at approximately the same elevations much larger shells are usual.

At locality W450-11, there is a very low gap on the Palawai-Halona Division Ridge, which appears to be a region of greater precipitation than the other areas, possibly due to the collecting of clouds in this gap. Their size may be influenced by moisture conditions. Locality W450-8 is intermediate between W450-11 and W450-9 in shell size. The shells of locality W450-8 may cross more readily with the smaller shells in W450-11 than with those of the adjacent locality of W450-9. More collecting should be done in this region to ascertain the reason for this remarkable change.

Achatinella mustelina dautzenbergi, new subspecies (pl. 13, figs. 12-14).

This shell is the largest known specimen of any form of *A. m. mustelina,* with a length of 27.5 mm., greater diameter 15.0 mm., lesser diameter 13.7 mm., spire height 14.1 mm., number of whorls 7. The form is the typical one of *A. m. lymaniana* from Kaloi Gulch, locality W490B-5, embryonic whorls lacking shell enamel, first two post-embryonic whorls widely, axially ornamented with streaks of army brown and natal brown measuring 1 to 4 mm. in width, and tilleul buff, last whorl and a half pale drab gray and drab, axially streaked with natal brown and hair brown and faintly spirally banded with hair brown, on the last two whorls above the periphery the ground tilleul buff, sutural band not impressed but colored on the upper half with pale pinkish buff and on the lower half with cinnamon buff. Lip greatly thickened, outer margin cream buff, inner and columella callus white; umbilical pore open (pl. 13, fig. 13).

The paratype (pl. 13, fig. 14) is a juvenile specimen, the tip intact and an impressed sutural band, first two embryonic whorls cinnamon buff, third embryonic whorl, pale pinkish buff lined with cinnamon buff; first post-embryonic whorl axially streaked with verona brown, warm sepia and lined and streaked with pallid mouse gray, penultimate whorl pallid mouse gray axially streaked and lined with benzo brown; last whorl pallid mouse gray spirally lined with hair brown, about the open umbilicus a band of pale pinkish buff.

The subspecies is named after Dr. Ph. Dautzenberg who gave to Dr. Cooke Bishop Museum's first two specimens. One of the Dautzenberg shells is much smaller than the holotype and paratype which I bought in 1934 from Sowerby and Fulton in London.

The Dautzenberg specimen figured is 22.7 mm. in length, greater diameter 12.7 mm., spire height 11.4 mm., number of whorls just under 7. The shell

enamel is worn off all the earlier whorls up to the penultimate, penultimate and last whorl axially streaked with natal brown, light mouse gray and mouse gray over a tilleul buff ground, lip bordered with cream buff, inner margin and columella callus white, the sutural band is not impressed, color white (pl. 13, fig. 12). None of the shells has any locality data. It is quite possible that they are shells collected at a low elevation in the district of Nanakuli. Possibly the specimen of figure 12 came from a different locality than did the holotype. In the future localities may be found in Nanakuli containing fossil *Achatinella*. Until then the probable locality can only be estimated. Perhaps these shells were collected at the same time that *Achatinella concavospira concavospira* Pfeiffer was collected. Dr. Frick probably collected some of this early material. He sent most of his material to Cuming who gave a great deal of it to Pfeiffer for description.

SUMMARY AND DISCUSSION

The species *Achatinella mustelina* Mighels and its subspecies from the Waianae Mountains on the island of Oahu are considered in detail in this paper. All forms of *A. mustelina* previously described were studied and type specimens photographed in 1933 and 1934 at the British Museum and Academy of Natural Sciences of Philadelphia. If the type had not been previously designated, the specimen in closest accord with the original published figure was selected as the type. Dr. Pilsbry and I went over the subspecies published by Pilsbry and Cooke and he designated the holotype if he had not previously done so. *A. m. bicolor* Pfeiffer was the only type not personally studied, but through the kindness of Colonel Peile at the British Museum, I was able to obtain a figure of what is undoubtedly the original type.

Twenty new subspecies from a total of 25 subspecies were recognized. Fifteen thousand, one hundred seventy-six adult specimens of *A. mustelina* and its varieties were collected from 582 localities of which 6,749 came from the northern section of the Waianae Mountains, 5,556 from the central section and 2,883 from the southern section. Each locality is plotted on the advance sheets of the maps of the U. S. Geological Survey of Oahu, and ranges in extent from 20-30 square feet to about 100-200 square feet. A few wide localities (approximately 24) range from 400 feet to a quarter of a mile in length by possibly 100 to 200 feet in width. The major portion of the shells were collected during 1931 to 1936. All the specimens were measured to the nearest millimeter, and the biometric mean length found for the shells of each locality, having a series of at least five shells or more.

A. Taxonomic grouping of subspecies.

The shells of the Waianae Mountains can be subdivided into highland and lowland groups of shells based on form, size, and color pattern. All dis-

tinct races separable from other races are described as subspecies. All forms resembling or close in form, size, or color pattern to another race, are considered variants of the nearest subspecies. Each subspecies, and its variants, has its area of distribution plotted on a map. In this manner, the various forms of *Achatinella mustelina* are found logically arranged about the central cone of Mount Kaala in the northern section, and along the east slope of the southern and central portions of the mountains.

B. Local size differentiation and the question of migration.

The forms of *Achatinella mustelina* are highly localized arboreal inhabitants, apparently remaining in certain restricted regions without migrating any distance into upper or lower regions. Shells collected from 10 to 20 years ago in definitely known restricted regions do not vary to any extent from shells found today in the same places. The region where shells apparently change in size and color pattern appears to be fixed, and no migration is known to occur though the country in a large number of places is most favorable to migration as far as the terrain is concerned. In one or two places as Makaha Valley and Pahole Gulch, the presence of certain forms in some localities raises the question as to whether migration has occurred in these valleys from some other place. As far as is known to me, however, no noticeable migration is known to have taken place during the last 20 years. If migration has occurred, it was probably many years ago.

These conditions in *A. mustelina* do not agree with Crampton's findings in his study of the genus *Partula* from the island of Moorea (3, p. 206). He says: "Without recalling the details relating to the various colonies, especially important in the case of Uufau, the conclusion is presented that a tide of migration from the original headquarters of *Partula suturalis vexillum* has borne this variety to the most remote areas of the northwest and northeast, that the outer waves of this tide were sinistral in character, and a subsequent change to the direct mode of coil has likewise worked outward from Vaianai Valley. My own observations prove that real colonial changes in the last named respect have come about during the comparatively brief period from 1907 to 1924." On p. 119 of the same volume he says, speaking again of *Partula suturalis vexillum*, "By way of summary, the principal points established by the statistical data are two. . . . The second is the reduction of the shells in length in the interval from 1907 to 1924."

C. Barometrical and climatological influence on form, color pattern, dextrality and sinistrality and size and number of subspecies.

The forms of *A. mustelina* from the three major sections of the Waianae Mountains are considered separately, and studied to determine whether any constant change in reference to form and color pattern, dextrality and sinistrality, and size can be correlated with altitude, temperature and precipitation.

1. The shells of the northern section (map 2, section I, p. 10).
   a. Shape and color pattern.

In the northern area about the central high peak of Mount Kaala, the shells change both form and color pattern very noticeably with altitude; the lowest shells are usually elongate forms while the highland shells above 2,000 feet, are for the most part obese, squat shells. The color pattern changes at approximately the same elevation. Three major color groups can be distinguished regardless of subspecies (map 15, p. 144). The most common group is composed of brown color forms such as sayal brown, snuff brown, warm sepia, russet, and similar colors. The next most abundant color group consists of gray color patterns, drab, buffy brown, mouse gray, and light gull gray. The third group has shells colored or banded on the last whorl with reddish brown shades like carob brown, liver brown, seal brown, fawn color, deep slaty brown. In addition to these usual patterns are the rare *makahaensis* patterns, shades of pinkish cinnamon.

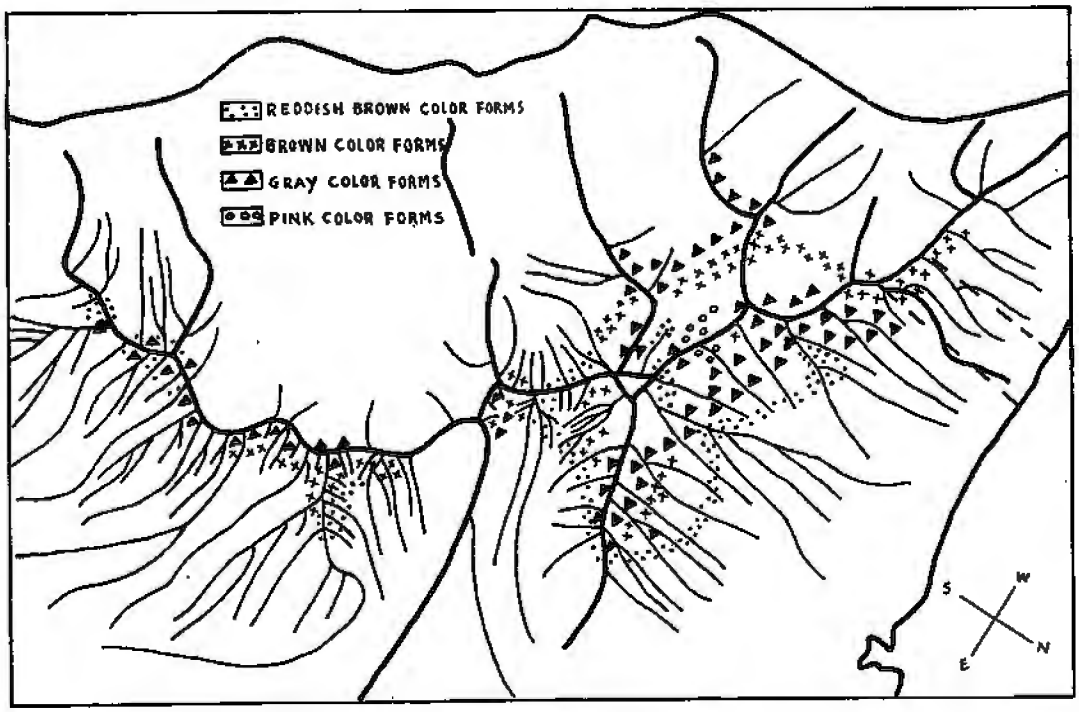
The reddish brown group appear to be the lowland color pattern extending along the eastern and northern sections of the mountains, but may also occur in highland localities. No special altitude has a dominance of brown and gray patterns; the dominance of these patterns appears to be regional. Gray color patterns are more usual on the northeastern sections of the mountains, while brown color forms almost encircle section 1, occurring in the southern, western, and northwestern portions. Gray forms, however, also occur below the brown color forms on the southwestern and western slopes of the mountains. If lowland, southwestern localities were known today, most probably gray races might be found to be as abundant in this region as they are in the northern section of the mountains. Again on the northern slopes, brown color races occur below gray races, and in one place, Kaimuhole Gulch, above the gray color forms.

Pilsbry's statement (p. 3) concerning a possible correlation between altitude and pattern seems to apply in the Mokuleia District of the mountains, where at low elevations the shells have strikingly banded patterns and the higher altitudes streaked or solid colors. On the south side of the mountains, however, streaked patterns occur below banded ones, for example in Makaha and Keaau. Keaau Gulch is extremely dry and the streaked forms are found at a low elevation of 1,500 feet. While a correlation may exist in the higher elevations between humidity, altitude and streaked patterns, no such explanation can account for the streaked patterns of Keaau. In Mokuleia to the north, the lined, lowland patterns stop at Keawapilau Gulch. From there on to the west, the lowland and highland forms are all streaked in areas 29, 32, 33, and 34. Possibly streaked forms may occur at lower elevations, but they are not known to me. While a correlation exists between altitude, humidity, and pattern in one section of the mountains, the presence

of streaked forms at lower elevations in much drier regions shows that streakedness may be produced at high or low elevations irrespective of climate. Humidity is not the main factor for banded patterns, for *A. m. kaalaensis* contains banded as well as streaked forms.

b. Dextrality and sinistrality.

No order can be determined in the distribution of dextral and sinistral forms. The turn of the shells appears to be a random affair which can occur in any locality. Usually every prevailing dextral form has a sinistral form also. In the district of Mokuleia, the lowest localities of a race are usually sinistral grading to dextral at higher elevations; but there are so many exceptions to this rule in other parts and so much of the former lowland *Achatinella* fauna is extinct that no rule can be made. The solving of the problem of the point at which shells change from dextral to sinistral and the possible correlative factors will necessitate intensive collecting in which a larger number of highly restricted localities are collected close together, and the northern section must be very thoroughly covered. All that can be said at present is that pure dextral localities usually grade into sinistral localities.



May 15.—Distribution of shell color groups in the Waianae Mountains.

c. Shell size differentiation with altitude.

One of the most interesting problems in the northern section is the difference of shell size in different places. In discussing this, the mean length value of the shells of a locality will be referred to without repeating the mean length of the shell needlessly. Therefore, the term 20+ or 19+ localities, will be used, instead of saying that the shells of a certain locality or area have a mean length of 20+ mm. The distribution of size values of localities in the Waianae Mountains is outlined on map 16 (p. 148). In general, the lower localities are 20 + or more, decreasing at higher elevations to 18 + or less. At the commencement of my work, first material was obtained from the northern slope of section 1, in the district of Mokuleia, where the altitudinal effect is particularly striking. At the time, there seemed but little doubt that at a certain elevation a definite size of shell was to be expected. But with the acquiring of additional material, elevation was found not to be the deciding factor, for even in the region where shells decreased in size with altitude many exceptions occurred disproving this hypothesis. The highland forms of the southeastern slope of Mount Kaala in Haleauau Gulch were 17 +, while at similar elevations elsewhere the size was 18 +. In area 23 in Makaleha Valley, 19 + shells were found. In Keaau, shells at 1,500 feet were decidedly larger than anything else found at a similar elevation. From South Haleauau to Pukaloa, and from Kapuna to Keekee Gulches, the localities were found to vary at random. The Pukaloa shells varied from 18 + to 19 + in area 51a. In area 29, the Kapuna shells also varied at random from 18 + to 20 + in different localities. Upper Pahole, area 33, had large 22 + forms, which occurred above area 34 with 20 + shells, and lower Pahole Gulch had localities of 18 + and 19 + forms. These facts definitely showed that altitude was not the deciding factor, as I had supposed.

d. Size correlated with moisture and temperature.

Table 1 (p. 7) compiled from climatological data from the United States Department of Agriculture's Weather Bureau, gives an indication of the rainfall in the Waianae Mountains (see map A for rain gauge stations). Precipitation is erratic over any one large sector. While the rainfall in 1933 was greater on the top of Mount Kaala than in 1935, the amount in Makaha and Waianae Mauka was greater in 1935 than in 1933. All stations in the Waianae Mountain area below 1,400 feet have less rain than those above. Waianae and Ewa Plantation to the southwest and southeast have the least rainfall. Northward on the east side of the range, the precipitation is increasingly greater with increase in altitude. Waialua Mill at a lower elevation than Schofield Barracks has more rainfall than Waianae and Ewa.

The prevailing winds are north and east in the Waianae Mountains on the west slope of the range. The rain clouds from the Koolau Range are

blown over to the Waianae Mountains where precipitation occurs along the high peaks and ridges. Mount Kaala, the highest peak, has the greatest rainfall as far as the data go. Nearly every day rain clouds can be seen covering its top and it is only rarely that the top is exposed to view. The greatest precipitation is on the eastern side of the Waianae Mountains, the western side being decidedly drier. This is also true of the northern slope, but in this case the northern slope is more humid than the western slope.

If shell distribution is examined and compared with precipitation, a correlation appears to exist between maximum rainfall and minimum size (map 16). Below Kaala to the east in Waianae Uka, where the greatest precipitation may be expected, the shells are 17+ mm. Farther away from this region of maximum rainfall where the ridges are drier, the shells increase in size to 18+ mm., then 19+ mm. in still drier or lower elevations, finally 20 + in still less humid situations. Area 23 (map 4a, p. 25) is an exception to this rule, because the shells are 19 + mm. in a region dominantly composed of 18 + forms. This may be due to some local conditions which affect the increase in size of the shells. In Waianae Kai (map 10), a mixture of 18+ and 19+ localities occurs in a series of localities at the base of the cliffs in different valleys. The elevations of the shells in this district are difficult to obtain because of the character of the terrain, so that differences in size may be due to differences in altitude which might indicate varying amounts of precipitation. Then again the rainfall in the Hawaiian islands is highly localized. These differences in size may be due to local moisture conditions. In Pukaloa (map 11), difference in size in different localities may be due to local moisture conditions. The southeastern portion of Pukaloa was largely burned over about 10 or more years ago, according to Dr. Cooke. With the loss of so much of the upland forest, moisture conditions may have been changed so as to cause differences in the size of shells in different situations.

In area 29 the precipitation is possibly spotty because most of the rain clouds from the northeast and east are collected by the high peaks to the east about Mount Kaala. This would account for the random size values of different localities. The lowland band of 20+ and 21+ sectors undoubtedly has a very uniform rainfall. The small 18+ and 19+ shells in Pahole Gulch (map 11a), areas 31 and 34 (maps 3a, 6a) with their unusually large shells, are unexplained exceptions. Again some unknown factor or set of factors affect size. I know nothing about the moisture conditions here so cannot discuss the matter.

In the main, however, there appears to be a correlation between size and precipitation. If this hypothesis is assumed for the moment to be correct, can anything be said about the amount of precipitation and shell size? The only highland records below Kaala are in Makaha and Waianae Mauka. The size of the shells in Makaha at about 1,400 or 1,500 feet, range between 20+

to 19 + mm. In the region of the station, Waianae Mauka, which I believe is in Kanewai Gulch, few accurately plotted shell localities are known. The large R. A. Cooke and C. M. Cooke, Jr., lots from Kalalua Gulch of *A. m. obesiformis* var. Welch and *A. m. mixta* Welch range in size of mean lengths from 19 + to 20 + mm. From these sketchy data, we can theorize that shells of 19 + or 20 + mm. occur in regions where the precipitation is between 63.53 and 77.88 inches per year.

This concept of a decrease in size with increase of moisture conditions is quite contrary to the usual supposition held by some who believe that shells are larger in humid places than in drier ones. The reason advanced is that because of moist conditions the snails eat more and, therefore, grow bigger. However, I suppose that continual conditions favorable for feeding may hasten maturity, while the interruption of drier regions may postpone maturity till a larger size is attained.

Crampton in his Moorea volume on the genus *Partula* (3, p. 68), comes to a different conclusion concerning altitude and size. He says:

> Just as the several colonies differ from one valley to another, so also the subordinate components present contrasts when they are delimited and compared. For example, the Maramu collections of 1909 and 1919 were taken in the lower part of the valley, while those of later years were secured higher up. The former are relatively larger. In Tefeo proper the relations are similar, but in Tefeo East they are reversed, although the differences are not very large. Again, in Fareaito where the 1924 series was secured from a slightly higher level than that of 1923, small differences are disclosed. Without labouring the argument, it seems just to conclude that when such differences are observed, their factors belong to the congenital category and are not environmental.

Also on page 158 of the same volume discussing *Partula tæniata,* he finds a size difference with altitude similar to that found in the northern section of the Waianae Mountains.

> When collections were obtained from the same valley in earlier and in later years, the absolute dimensions proved to be generally smaller for the series of the second period; the data for Vaiare-Puutu, Tepu, Maharepa, and middle Paraoro are especially clear. While secular changes are thus indicated with some probability, another consideration enters. Usually the valleys were more deeply penetrated during the later years of field study, and hence the lower dimensional figures for the shells then collected mean that the upper components of a valley association were smaller than those dwelling near the coast. The case of Vaiare-Vaipohe is one where this is certainly true, for the series of 1924 came from the lower reaches of the valley, while that of 1919 was taken far up near the divide. But the two series from middle Paraoro were actually collected from exactly the same sector of the same valley, and they at least attest the fact that colonial changes had come about with the passage of time.

In his resumé of *P. tæniata* (3, pp. 208, 209) Crampton says:

> With reference to the problem of the possible effects of the environment upon structural or other qualities, the only conclusion warranted by the facts is that con-

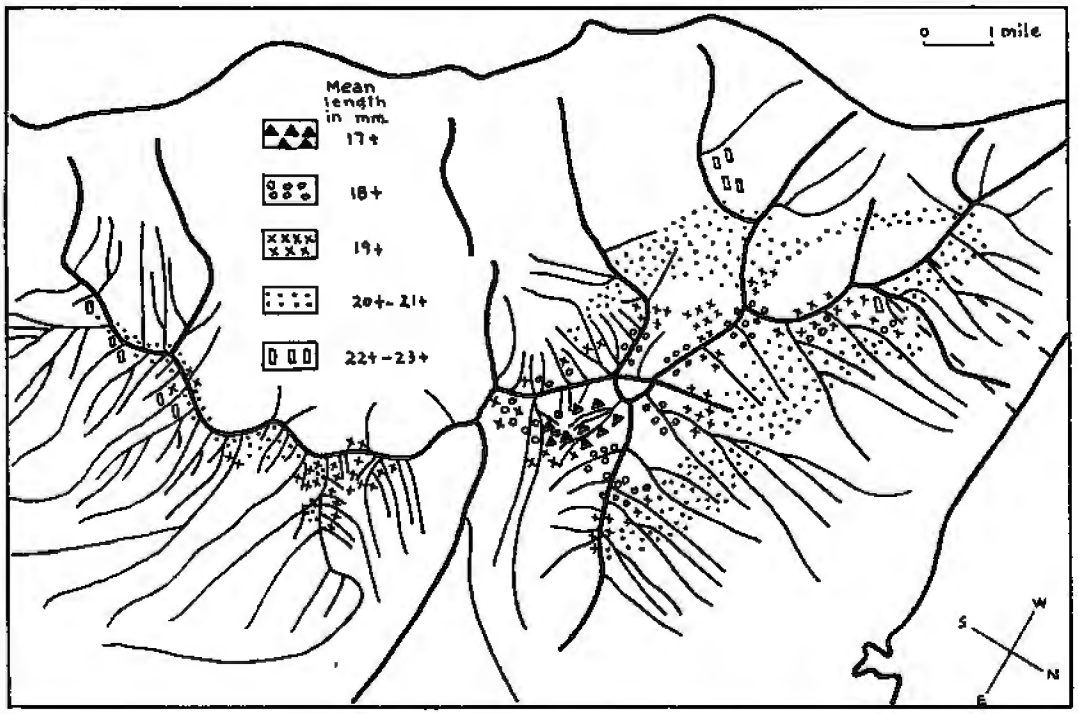
genital factors are solely responsible for the diversities exhibited by the several varieties, by the numerous colonies, and by the individual components of the colonies.

Another important factor of shell differentiation may be temperature. The top of Mount Kaala, with its high precipitation is undoubtedly cooler than places at lower elevations. Table 1a (p. 10) compiled from climatological data shows only a few degrees increase of temperature in Waianae over the other stations in the Waianae Mountains. The western side of the range is, therefore, warmer than the northern and eastern slopes.

As in the case of greatest rainfall, the coolest places are at the highest elevations where precipitation is greatest, and the warmest places the lowland, dry regions protected from prevailing winds. Keaau with its extremely large shells is an example of this dryland situation. Size difference then in different localized spots may be due to combinations of dryness, moisture, and protection from the wind. Although it is not apparent, altitude may be a factor. The combined effect of a series of factors may be the cause of the large size of the shells in area 34, and the small shells in lower Pahole Gulch.

e. Subspeciation considered in relation to altitude, humidity, and temperature.

Pilsbry's idea that evolution in more humid stations would naturally be



Map 16.—Shell size variation in the Waianae Mountains.

more rapid than in lower, less abundantly watered places (p. 3), seems to hold for the forms along the crest of the Makaleha-Makaha Division Ridge. For a distance of about a mile and a half along this ridge, four distinct color forms are found in areas 21, 22, 23, and 26 (p. 25), while lowland forms below them are not so sharply definable. The highland forms on the eastern slope of Mount Kaala in Haleauau are not as strikingly differentiated, but in a similar distance in Makaleha three distinct color patterns are to be noted. There is, therefore, a possible correlation between humidity, elevation, temperature, and the number of varieties of a species.

2. The shells of the central section (map 2, section II, p. 10).

a. Shape and color pattern.

The three major color groups of section I are also found in section II. Here, however, they appear to be ranged in definite zones, the reddish brown patterns at the lowest level, the brown forms in a central band, and the gray forms at the highest level. Some of these gray forms are intermixed with reddish brown patterns (map 15, p. 144). So much of the lowland forest is gone from this region that only a scanty record remains today of former molluscan distribution. Possibly the reddish brown patterns of *A. m. bicolor* were a dominant race extending at low elevations to Haleauau where it intergraded with *A. m. collaris*. Since brown forms occur in lower Puumaialau and Ekahanui Gulches, there is no reason to suppose that *A. m. bicolor* forms did not extend to the south as well.

While the color pattern of the shells varies, the form does not vary to any marked extent with increase in altitude. The greatest form differentiation is shown in the northern section of Section II, in Popouwela, where the lowland forms are obese shells like *bicolor* and the highland forms elongate; this is the reverse of what is found in section I. To the south the form of the upland and lowland shells is practically the same.

No striking, streaked forms without bands or lines occur in section II. The lowland forms are solid or banded patterns, while the highland races are both noticeably axially streaked and spirally banded and resemble somewhat the lowland forms of *A. m. sordida* from Mokuleia.

The *sordida* patterns are usually definitely more banded and less pronounced in axial streaking. Here again in section II an increase of elevation and precipitation appears to be correlated with presence of streaked patterns. May not streakedness be correlated with a definite amount of moisture and a certain temperature range?

b. Dextrality and sinistrality.

While no correlation between altitude and change of the coil of the shell is made out in this section, certain upland sectors are found to be dominantly sinistral. The largest of these are Huliwai, Puumaialau, and Central Ekahanui Gulches. The remaining localities vary from dextrals to sinistrals.

c. Size correlated with altitude.

No variation of size is noted with altitude in the majority of the localities (map 16, p. 148). Two localities W360D-3 and W420A-6 at high elevations are 18+ and may indicate that if more collecting were done along the Lualualei-Honouliuli Division Ridge, more small shells might be found. From the data on hand this does not seem to be the case, and size differentiation is a random affair.

d. Size correlated with moisture and temperature.

While no altitudinal size differentiation is noted in section II, the northern half has dominantly smaller shells than the southern (map 16, p. 148). No highland rain gauge stations are known in this section of the Waianae Mountains south of Kolekole Pass. However, Mount Kaala, the highest point in the Waianae Mountains, has the greatest precipitation. The range decreases in elevation to the south and in like manner the precipitation also appears to decrease the farther one goes from Mount Kaala. The size of shells correlates with this conception. The northern portion of section II would naturally receive the greater rainfall while to the south the rainfall is less. This accounts for the difference in size in the two portions of section II.

Since humidity is correlated with temperature, the southern portion is possibly much warmer than the northern portion. Size then is probably correlated in this section also with temperature as well as moisture. The shells of section II agree more with what Crampton found in Moorea and Guam. But the main difference is that Crampton does not believe that external factors affect size but as he expresses it in the Guam volume (2, p. 42), "Clearly the innate constitutional factors are responsible for the qualities displayed by the regional groups as well as the varying colonial characters of the individual associations." While the genetic constitution undoubtedly plays a very important part I cannot help but believe that shells may be affected by external environmental factors as well.

3. The shells of the southern section (map 2, section III, p. 10).

a. Shape and color pattern.

So little of the original forested area containing shells exists today in section III that it is remarkable that any color differentiation is noticeable with elevation. No brown patterns occur here to the south, only reddish brown and gray forms. The gray forms are wide spread over practically the entire region with reddish brown and reddish brown streaked patterns occupying the southern highland three fourths of the division ridge between the east and west slope of the range.

The form of the shell varies to no appreciable extent, the difference in some places being a size change, but it must be remembered that only a few lowland forms are known which can be compared with highland forms. Pos-

sibly when more fossil localities are discovered at low elevations in Honouliuli more variation will be apparent. Practically no material from the west slope of the Waianae Mountains is known in either section II or III. Undoubtedly fossil beds exist in lower Nanakuli and Lualualei which in the future will tell more about shell distribution.

No differentiation between highland and lowland forms can be made out concerning bandedness and streakedness. Banded and streaked forms occur at high elevations as well as at low ones.

b. Dextrality and sinistrality.

A very remarkable fact is that no dextral forms of *A. m. mustelina* are known to exist south of Pohakea Pass. The question arises as to whether this is due to the fact that all the shells are sinistral in section III or whether this was the case with the upland forms which alone can be obtained today, all the lowland forms having been wiped out. This cannot be answered until more lowland specimens of *A. mustelina* are found, which will be difficult, as for some reason fossil forms of *A. mustelina* forms are exceedingly rare in localities at low elevations along the contour trail at approximately 1,750-1,900 feet in Honouliuli. Perhaps *A. mustelina* never was abundant in this lowland region and this represents the extreme limit of the former distribution of the species.

c. Size correlated with altitude.

In the region of Napepeiauolelo a definite correlation between size and altitude exists (map 16, p. 148). The lowest shells are 23 + and decrease to 20 + mm. on the top of the main division ridge. On the North South-Palawai Ridge there also appears to be a decrease in size with elevation. At a point in the main division ridge, an area of small shells occurs between two sectors of large shells. The small size apparently is not correlated with altitude, because this area is at a similar elevation to areas of larger shells (area 76, map 14a).

However, a definite size is not correlated with a definite altitude because in the fossil bed W430-2, shells at 1,700 feet are 21 + mm. while in Napepeiauolelo the low lying localities are 22 + or 23 + mm. To the north the shells found in fossil beds are large forms similar to those found alive today at a higher elevation. I have no knowledge of the climatological condition, or the amount of forested area in the day when these shells lived, but they are probably not of very great antiquity, possibly not over some hundred years. The shells are found usually buried in fine loose soil under boulders a few inches below the surface of the ground. This process of shells being buried in loose soil can be observed today in localities of live shells in South Ekahanui. I, therefore, do not believe that the size was caused by ancient conditions not prevalent today in localities where they still exist.

d. Size correlated with moisture and temperature.

The top of the main Southern Division Ridge undoubtedly has a greater precipitation than the lower reaches of the range. A correlation can be shown between precipitation increase and shell size decrease (map 16, p. 148). The upland forms are definitely smaller at least in the northern portion of section III at high elevations. The small shells of area 76 may be accounted for by the fact that there is a gap in the main division ridge which may collect clouds in it and produce a greater amount of precipitation, which may influence the immediate area. Since no lowland localities are known in the southern portion of section III, no correlation is possible. The fossil localities in a similar way increase in size the farther to the south as far as can be told from the scanty data on hand. This correlates with what is found in section II, where the northern more humid sections have smaller shells than the drier points to the south.

D. Abundance of forms with respect to the climatological and barometrical data.

Pilsbry says (5, p. xxxvi), "The Achatinellae are not shells of the valleys but of the ridges and upper ravines. The bottoms of the larger valleys often lie below the zone of requisite humidity. This is doubtless much more generally true now than before the valleys were so extensively deforested." Possibly Pilsbry was considering large valleys in the Koolau Range or on islands other than Oahu; nevertheless it is interesting to see whether this applies to shells of the species *A. mustelina,* and also to see if any correlation can be shown between humidity and abundance of specimens.

Much of the collecting prior to 1931 was done on ridges, so that this may be another reason for Pilsbry's thinking *Achatinella* were ridge rather than valley shells. Since 1931, many valleys in the Waianae Mountains have been explored and have yielded large quantities of shells. It is true that the upper part of the valleys alone are collectable, but this upper part may extend for some considerable area. In Mokuleia, *A. mustelina* localities are found over a mile away from the head of the valley.

Humidity does not seem to be the factor conducive for large numbers of shells in all cases. In fact a dry climate, as in sections II and III, proves to be excessively conducive to shell productivity. Then moist climates such as the high localities in Makaleha have not very populous localities; in fact the shells are rather rare. Nevertheless on the east slope of Mount Kaala in Waianae Uka, the humid ridges produce an abundant fauna, which is gradually being despoiled by collectors. The question is not dependent wholly on altitude or humidity but probably another factor must be considered, namely, food.

Pilsbry says (5, p. xxxvi), "The feces of *Partulina confusa* examined by Mr. Henshaw were composed chiefly of remains of fungi or algae. The

contents of the stomachs of *Achatinella mustelina*, and several other species, examined by Dr. Brown and myself, were recognized as fungi, often with shreds of fibres probably of bark, which remain undigested in the intestines." As Pilsbry and others have observed, the leaves of trees and bushes on which snails are found do not show traces of having been eaten. Therefore, the type of tree or bush is not the important food factor, but what may grow on the tree or bush. Fungi and algae, or possibly lichens, are undoubtedly the best probable sources of food for these tree shells. In the future, however, I think it of the utmost importance to discover exactly what kind of fungi or algae the snails eat. When the food is known and it is possible to study *Achatinella* experimentally, then some real facts can be determined concerning distribution, and what really affects shell size, pattern, color and form. The exact condition of the food eaten at a certain period of development may play a very important part in shell differentiation. In flies having the factor for abnormal abdomen it was found that they did not develop abnormal abdomens unless grown in a moist atmosphere.

E. Effect of heredity.

While the individual localities may be pure genetic entities, nothing is known experimentally as to whether they actually are. Is the hereditary makeup of the individual fixed or is it influenced by external factors? What would happen if small, upland, squat shells were transplanted to lowland localities of elongate forms? Would form, color pattern, and size change? Crampton believes that the inherent factors of the individual are not affected by environment. This surely does not seem to be the case in the species *A. mustelina* where the form and size appear to be correlated with altitude, moisture conditions, and temperature. Undoubtedly food also plays a part in shell differentiation as well as in affecting color pattern. But who knows, until some experimental work is done, by breeding races, and keeping shells under different conditions of moisture, at definite temperatures, and at known altitudes and feeding them a known substance?

F. The possible taxonomic importance of the known distribution of *Achatinella mustelina* Mighels.

Although the northern section of the Waianae Mountains is considered to be one entire area, it could be subdivided into five subsections, or subspecific areas where radical form changes occur at approximately the same elevation. Starting on the southeastern portion of section I the following subsections are: 1. Waianae Uka; 2. Mokuleia from Puulu to Keawapilau Gulches; 3. Kapuna to Keekee Gulches; 4. Makua-Makaha; 5. Waianae Kai. The central section of the mountains can be broken up into two subsections: 1. Waieli Gulch to Huliwai Gulch; 2. Ekahanui to North Pohakea Gulch. The southern section also has two possible subsections: 1. South

Pohakea to North Palawai North Branch; 2. North Palawai South Branch to Kaloi Gulch. Future collecting will possibly alter the limits of these subsectors of the Waianae Mountains.

From my work on the species *A. mustelina* and casual observations in the field there seems to be much evidence that the same factors which cause major changes in *Achatinella* are also affecting other forms of snails. Therefore, where *Achatinella* forms change in definite subsections and at different elevations so also may a form change be expected in other species and genera. This hypothesis that there may be areas of subspeciation common to several organisms will have to be further worked out. The possibility also occurs to me that *Achatinella* distribution may not only be of use to detect where new forms of mollusks may be expected, but also induces the hope that some time a correlation between subspecific changes in mollusks and the flora may be drawn.

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INDEX

(Names of synonyms printed in italics. An asterisk denotes the page on which the type or typical form is described.)

INDEX TO PLACE NAMES

(An asterisk after the number of the page indicates that the name is on a map on that page.)

EXPLANATION OF PLATES

(Unless otherwise stated, all specimens figured are in the collection of Bernice P. Bishop Museum.)

PLATE 1

1. *A. m. mustelina* Mighels, typical form selected by Pilsbry, Mokuleia, Gulick, Acad. Nat. Sci. Phil. 92249.
2. *A. m. mustelina* Mighels, type of *A. multilineata* Newcomb in the British Museum.
3. *A. m. mustelina* Mighels, copy of original figure of *A. multilineata* Newcomb.
4-4a. *A. m. mustelina* Mighels, Western Subvalley of Makaleha, W170-3, Russ 133269, 118085.
5. *A. m. mustelina* Mighels, Western Subvalley of Makaleha, W170-2, Meinecke 124034.
6-6a. *A. m. mustelina* Mighels, Western Subvalley of Makaleha, W170-2, Meinecke 124030-31.
7. *A. m. mustelina* Mighels, Western Subvalley of Makaleha, W170-2, Meinecke 124030.
8. *A. m. mustelina* var., Keawapilau Gulch, W160BB-7, Welch 134913.
9. *A. m. mustelina* var., Keawapilau Gulch, W160BB-7, Welch 134914.
10-10a. *A. m. mustelina* var., Keawapilau Gulch, W160B-4a, Meinecke 123452.
11. *A. m. griseipicta* Welch, holotype, Kapuna Gulch, W160A-2a Russ 10401.
12. *A. m. griseipicta* Welch, paratype, Kapuna Gulch, W160A-2a, Russ 133229.
13. *A. m. griseipicta* Welch, Keawapilau Gulch, W160BB-3, Welch 134890.
14. *A. m. mustelina* var., West Makaleha Valley, W170-7, Russ 133318.
15-15b. *A. m. mustelina* var., Central Makaleha Valley, W170E-3-4, Russ 133324, 133326.
16. *A. m. griseitincta* var., East Makaleha Valley, W170G-6, Russ 109032.
17-17c. *A. m. mustelina* var., East Makaleha East-West Branch Ridge, W171G-1, Meinecke 126290-126291.
18-18a. *A. m. griseitincta* var., East Makaleha East-West Branch Ridge, W171G-2, Meinecke 126306-126307.
19-19a. *A. m. sordida* var., Kaawa Gulch, W190-7, Russ 133366-133367.
20. *A. m. decolor* Welch, holotype, Makaleha Valley, Emerson 10402.
21-21b. *A. m. decolor* Welch, paratypes, Makaleha Valley, Emerson 102346.
22-22a. *A. m. decolor* Welch, Makaleha Valley, Emerson 102347.
23. *A. m. decolor* Welch, Mokuleia, Gulick 70391.

PLATE 2

1. *A. m. sordida* Newcomb, copy of original figure.
2-2c. *A. m. sordida* Newcomb, Kaimuhole Gulch, W240-4, Welch 128575, Russ 133512, 133520, 133514.
3-3e. *A. m. sordida* Newcomb, Kaimuhole Gulch, W240-4, Welch 128577, 128579, 128575, Russ 133518.
4. *A. m. sordida* Newcomb, from Sowerby and Fulton, 165918.
5-5a. *A. m. sordida* Newcomb, Mokuleia, Gulick 70399, 70390.
6-6c. *A. m. sordida* var., Alaiheihe Gulch, W230-3, Russ 133468.
7-7b. *A. m. sordida* var., Alaiheihe Gulch, W230-5a, Welch 132592.
8. *A. m. sordida* var., Alaiheihe Gulch, W230-6, 8, Russ 133505.
9. *A. m. sordida* var., Alaiheihe Gulch, W230-5, Russ 133499.
10. *A. m. sordida* var., Alaiheihe Gulch, W230-5a, Welch 132592.
11. *A. m. sordida* var., Alaiheihe Gulch, W230-7, Russ 133501.
12-12c. *A. m. sordida* var., Kaumokunui Gulch, W200-6, Russ 133406-133398.
13-13c. *A. m. sordida* var., Kaawa Gulch, W190-6, Welch 114544-11526.
14. *A. m. sordida* var., Waianae Mountains, E. Lyman 135073.
15-15a. *A. m. sordida* var., Kaumokuiki Gulch, W211-2, Welch 134956.

PLATE 3

1. *A. m. waianaeensis* var., Kapuna-Makua Ridge, W160A-6, Cooke 17333.
2. *A. m. waianaeensis* var., Kapuna-Keawapilau Ridge, W161B-1, Meinecke 123553.
3. *A. m. waianaeensis* var., Kapuna-Makaleha Ridge, W160A-9, Meinecke 123515.
4. *A. m. waianaeensis* Welch, holotype, Pahole-Kapuna Ridge, W160-4, Meinecke 10403.

5-5b. *A. m. waianaeensis* Welch, paratypes, Pahole-Kapuna Ridge, W160-4, Meinecke, 122984-122985, 122987.

6. *A. m. waianaeensis* Welch, Pahole-Kapuna Ridge, W160-4, Russ 133211.

7-7c. *A. m. waianaeensis* var., Pahole Gulch, W150B-1, Russ 133152, 133165, 133184, 133167.

8-8b. *A. m. waianaeensis* var., Kapuna Gulch, W160-2a, Russ 133210.

9-9a. *A. m. waianaeensis* var., Kapuhi-Kahanahaiki Ridge, W140A-2, Meinecke 122891, 122887.

10-10b. *A. m. waianaeensis* var., Kapuhi-Kapuahikahi Ridge, W150A-3, Russ 133150.

11. *A. m. waianaeensis* var., Pahole Gulch, W151B-5, Meinecke 133190.
12. *A. m. waianaeensis* var., Kapuhi Gulch, W140A-1, Russ 133147.

13-13c. *A. m. waianaeensis* var., Kawaiu Gulch, W130-3, Russ 133145, 133451.

14. *A. m. waianaeensis* var., Kawaiu Gulch, W130-4, Russ 133143.
15. *A. m. waianaeensis* var., West Kapuahikahi Gulch, W150-2, Russ 133157.
16. *A. m. waianaeensis* var., Keekee Gulch, W110-3, Welch 133137.

17-17c. *A. m. mustelina* var., Western Subvalley of Makaleha, W170-1, Russ 133249, 133255, 108836, 123255.

18-18a. *A. m. mustelina* var., Makaleha-Kaawa Ridge, Meinecke 124019.

19. *A. m. griseitincta* var., East Makaleha Valley, East-West Branch Ridge, W171G-3, Meinecke 126311.

PLATE 4

1. *A. m. makahaensis* Pilsbry and Cooke, holotype, Makaha, Acad. Nat. Sci. Phil. 108788.

2-2b. *A. m. makahaensis* Pilsbry and Cooke, paratypes, from I. Spalding 165878.

3-3b. *A. m. makahaensis* Pilsbry and Cooke, paratypes, Thurston 131255.

4. *A. m. makahaensis* Pilsbry and Cooke, Makaha Valley, W30D-3, Russ 119656 (dead shell).
5. *A. m. makahaensis* var., Mahaka Valley, Meinecke 122793.

6-6a. *A. m. makahaensis* var., East-Central Makaleha Ridge, W171F-2b, Meinecke 128291.

7-7a. *A. m. makahaensis* var., East-Central Makaleha Ridge, W171F-2, Russ 133355.

8-8a. *A. m. makahaensis* var., East-Central Makaleha Ridge, W171F-3, Meinecke 128289, 128294.

9. *A. m. makahaensis* var., East-Central Makaleha Ridge, W171F-4, Meinecke 128276.
10. *A. m. makahaensis* var., East-Central Makaleha Ridge, W171F-4, Russ 133357.

11-11a. *A. m. altiformis* var., East Makaleha-Makaha Ridge, W172F-4, Meinecke 128260-128263.

12-12d. *A. m. altiformis* var., East Makaleha-Makaha Ridge, W172F-5, Meinecke 128273, 128270.

13. *A. m. altiformis* var., East Makaleha-Mahaka Ridge, W172F-3, Meinecke 128254.
14. *A. m. altiformis* Welch, holotype, West-Central Makaleha Ridge, W171E-2, Meinecke 10404.

15-15a. *A. m. altiformis* Welch, paratypes, West-Central Makaleha Ridge, W171E-2, Meinecke 123917-123918.

16. *A. m. altiformis* Welch, West-Central Makaleha Ridge, W171E-3, Meinecke 123929.

17-17a. *A. m. altiformis* var., West-Central Makaleha-Makaha Ridge, W171E-6, Meinecke 123956, 123957.
18-18a. *A. m. altiformis* var., West Makaleha-Makua Ridge, W171D-5, Meinecke 123973.
19. *A. m. altiformis* var., West Makaleha-Makaha Ridge, W171D-6, Meinecke 123962.
20. *A. m. waianaeensis* var., West Makaleha-Makua Ridge, W171D-3, Meinecke 124015.
21. *A. m. brunicolor* var., Makua Valley, W50G-2, Lemke 165874.

Plate 5

1. *A. m. maxima* Welch, holotype, South Keaau, W41A-3, Russ 10405.
2. *A. m. maxima* Welch, paratype, South Keaau, W41A-3, Russ 165123.
3. *A. m. maxima* Welch, Keaau Gulch, W41A-5, Russ 133079.
4. *A. m. maxima* Welch, Keaau Gulch, W40A-3, 134955.
5. *A. m. maxima* var., Kamaili, Makaha Valley, W30A-13, Welch 119511.
6-6b. *A. m. maxima* var., Kamaili, Makaha Valley, W30A-12, Welch 118051.
7. *A. m. maxima* var., Kamaili, Makaha Valley, W30A-6, Welch 117930.
8. *A. m. maxima* var., Kumaipo Gulch, W27D-2, Russ 132989.
9-9d. *A. m. brunicolor* var., Makaha Valley, W30B-1, Russ 133042, 108811, 108810.
10-10b. *A. m. brunicolor* var., Makaha Valley, W30B-5, Russ 133039.
11. *A. m. brunicolor* var., Makaha Valley, W30D-1, Welch 119629.
12. *A. m. brunicolor* var., Makaha Valley, W30D-1a, Russ 133077.
13-13b. *A. m. brunicolor* var., Makua-Keaau Ridge, W51-1, Russ 133084, 133085.
14. *A. m. brunicolor* Welch, holotype, Makua Valley, W50E-4, Lemke 10406.
15-15b. *A. m. brunicolor* Welch, paratypes, Makua Valley, W50E-4, Lemke 165873.
16. *A. m. brunicolor* Welch, Makua Valley, W50D-3, Welch 108093.
17. *A. m. brunicolor* Welch, Makaha Valley, W30C-8, Welch 107783.
18. *A. m. brunicolor* Welch, Kumaipo Gulch, W27C-2, Welch 107769.
19. *A. m. mixta* var., Makaha Valley, W30C-17, Russ 133049.
20-20a. *A. m. mixta* var., Makaha Valley, W30C-15a, Russ 122862.
21. *A. m. mixta* var., Makaha Valley, W30C-16a, Lemke Jr. 118286.
22. *A. m. mixta* var., East Makaleha-Makaha Ridge, W172F-3, Meinecke 128253.
23. *A. m. mixta* var., East Makaleha East-West Branch Ridge, W171G-5, Meinecke 128228.

Plate 6

1. *A. m. brunibasis* Welch, holotype, Maili-Pulee Ridge, W300A-3, Meinecke 10407.
2-2b. *A. m. brunibasis* Welch, paratypes, Maili-Pulee Ridge, W300A-3, Meinecke 165235.
3. *A. m. brunibasis* Welch, Puulu-pulee Ridge, W300A-4, Meinecke 165238.
4-4c. *A. m. brunibasis* Welch, Puulu Gulch, W270-10, Meinecke 165225.
5-5a. *A. m. brunibasis* var., Manuwai-Alaiheihe Ridge, W231-2, Welch 132556.
6. *A. m. brunibasis* var., Alaiheihe-Pulee Ridge, W232-1, Russ 133469.
7. *A. m. brunibasis* var., Manuwai Gulch, W220-12, Lemke 114291.
8. *A. m. brunibasis* var., Manuwai Gulch, W220-7a, Russ 133461.
9. *A. m. brunibasis* var., Manuwai-Alaiheihe Ridge, W231-6, Welch 132566.
10. *A. m. brunibasis* var., Manuwai-Pulee Ridge, W222-1, Welch 132569.
11. *A. m. kaalaensis* Welch, holotype, South Haleauau Gulch, W320-3, Meinecke 10408.
12-12e. *A. m. kaalaensis* Welch, South Haleauau Gulch, W320-1-7, Meinecke 123047, 123052.
13. *A. m. kaalaensis* var., South Haleauau Gulch, W320C-1-2, Isle 134946.
14. *A. m. kaalaensis* var., South Haleauau Gulch, W320C-4-5, Isle 134748.
15. *A. m. kaalaensis* var., South Haleauau Gulch, W320C-4-5, Hosaka 129160.
16. *A. m. kaalaensis* var., South Haleauau Gulch, W320C-1a, Steel 129540.
17. *A. m. collaris* var., South Haleauau Gulch, W320I-1, Heine 128987.
18. *A. m. collaris* var., South Haleauau Gulch, South Branch, W320J-2, Isle 134945.

19-19d. *A. m. collaris* var., Mohiakea-Pukaloa Ridge, W341-2, Heine 117057, 117049, 117053.
20-20a. *A. m. collaris* var., South Haleauau Gulch, W320H-2, Meinecke 165199, 165198.

Plate 7

1-1c. *A. m. sordida* var., Kihakapu Gulch, W260-1, Russ 133538, 133534, 133544, 117340.
2-2a. *A. m. sordida* var., Palikea Gulch, W250-8, Russ 133564.
3-3b. *A. m. sordida* var., Palikea Gulch, W250-7, Russ 133525, 117355.
4. *A. m. mailiensis* Welch, holotype, Puulu Gulch, W270-8a, Russ 10409.
5-5d. *A. m. mailiensis* Welch, paratypes, Puulu Gulch, W270-8a, Russ 133551, 133553, 117335.
6-6a. *A. m. mailiensis,* South Maili, W290-1, Meinecke 165230.
7. *A. m. diffusa* Welch, holotype, Pulee-Haleauau Ridge, W311-1, Welch 10410.
8. *A. m. diffusa* Welch, paratype, Pulee-Haleauau Ridge, W311-1, Welch 134716.
9-9b. *A. m. diffusa* Welch, Pulee-Haleauau Ridge, W311-1, Heine 129155.
10. *A. m. collaris* Welch, holotype, Mohiakea Gulch, W330-1, Meinecke 10411.
11-11c. *A. m. collaris* Welch, paratypes, Mohiakea Gulch, W330-1, Meinecke 165185, 165186.
12-12d. *A. m. collaris* var., Pukaloa Gulch, region of W340-3-7, Meinecke 123213, 123195.
13. *A. m. collaris* var., Pukaloa Gulch, W340-4c, Welch 117208.
14. *A. m. collaris* var., South Haleauau Gulch, W320J-1a, Meinecke 165169.
15. *A. m. collaris* var., South Haleauau Gulch, W320J-1a, Steel 128934.
16. *A. m. collaris* var., Haleauau-Mohiakea Ridge, W331-1, Heine 117024.

Plate 8

1. *A. m. lymaniana,* copy of original figure 13.
2. *A. m. lymaniana,* copy of original figure 12.
3-3d. *A. m. collaris* var., Kukaki Gulch, W22-3, Russ 132916.
4. *A. m. obesiformis* Welch, holotype, Kanewai Gulch, Waianae Kai, Cooke 10412.
5-5a. *A. m. obesiformis,* Welch, paratypes, Kanewai Gulch, Waianae Kai, Cooke 22900.
6. *A. m. obesiformis* var., Kalalua Gulch, W25A-9, Russ 132952.
7-7a. *A. m. obesiformis* var., Kalalua Gulch, R. A. Cooke and C. M. Cooke, Jr. 22953.
8. *A. m. nocturna* Welch, holotype, South Kalalua Gulch, W25-6, Russ 10413.
9. *A. m. nocturna* Welch, paratype, South Kalalua Gulch, W25-6, Russ 132931.
10-10b. *A. m. nocturna* Welch, South Kalalua Gulch, W25-7, Welch 117529, 117528.
11. *A. m. nocturna* Welch, South Kalalua Gulch, W25-8, Welch 117597.
12. *A. m. nocturna* var., Kanewai Gulch, W24-3, Welch 117768.
13-13b. *A. m. nocturna* var., Kanewai Gulch, W24-1, Welch 117736.
14. *A. m. griseitincta* Welch, holotype, Makaleha-Kaawa Ridge, W191-1, Russ 10414.
15-15b. *A. m. griseitincta* Welch, paratypes, Makaleha-Kaawa Ridge, W191-1, Russ 133358.
16. *A. m. griseitincta* var., Mokuleia, [Kaawa-Kaumokunui Ridge (Welch) W201-2 (?)] Thurston 131303.
17. *A. m. griseitincta* var., East Makaleha East-West Branch Ridge, W171G-4, Meinecke 128222.
18. *A. m. mixta* Welch, holotype, North Kalalua Gulch, W25A-9b, Russ 10415.
19. *A. m. mixta* Welch, paratypes, North Kalalua Gulch, W25a-9b, Russ 132949.
20. *A. m. mixta* Welch, North Kalalua Gulch, W25A-9, Russ 132952.
21. *A. m. mixta* var., Hiu-Kumaipo Ridge, W27-1, Welch 132967.
22. *A. m. mixta* var., Kumaipo Gulch, W27C-1a, Russ 130092.
23. *A. m. mixta* var., Kumaipo-Makaha Ridge, W27B-4, Russ 130107.
24. *A. m. mixta* var., Makaleha-Makaha Ridge, W172F-2, 128251.

Plate 9

1. *A. m. bicolor* "Gulick" Pfeiffer, holotype, Cuming collection, British Museum.
2-2b. *A. m. bicolor* "Gulick" Pfeiffer, Lehue (Lihue) Gulick 106841, 70479.

3-3b. *A. m. bicolor* "Gulick" Pfeiffer, Maunauna Gulch, W380A-2, Heine 166554.
4. *A. m. bicolor* "Gulick" Pfeiffer, Kaluaa Gulch, W370B-1, Heine 114855.
5. *A. m. popouwelensis* Welch, holotype, South Waieli Gulch, W360D-4, Welch 10416.
6-6a. *A. m. popouwelensis* Welch, paratypes, South Waieli Gulch, W360D-4, Welch 166452, 116453.
7. *A. m. popouwelensis* Welch, South Waieli Gulch, W360E-2, Welch 166467.
8-8a. *A. m. popouwelensis* var., Waieli-Kaluaa Ridge, W370-3-4, Russ 133597.
9. *A. mustelina popouwelensis* var., Kaluaa Gulch, W370D-4, Welch 118415.
10. *A. mustelina popouwelensis* var., Kaluaa Gulch, W370D-3, Welch 118398.
11. *A. m. lathropae* var., Manuwaielelu Gulch, W390D-3, Meinecke 126715.
12. *A. m. lathropae* var., Kaluaa-Manuwaielelu Ridge, W390D-2, Lemke 114636.
13-13a. *A. m. lathropae* var., Manuwaielelu-Huliwai Ridge, W400-1a, Heine 116984, 116979.
14. *A. m. lathropae* var., Manuwaielelu-Huliwai Ridge, W400-1, Meinecke 123247.
15. *A. m. lathropae* Welch, holotype, Huliwai Gulch, W400B-8, Welch 10417.
16-16e. *A. m. lathropae* Welch, paratypes, Huliwai Gulch, W400B-8, Welch 165403-165405.
17. *A. m. lathropae* Welch, Huliwai Gulch, W400B-3, Meinecke 126502.
18-18b. *A. m. lathropae* var., Central Ekahanui Gulch, W410B-9, 165304, 165301.
19-19b. *A. m. lathropae* var., Central Ekahanui Gulch, W410B-8, Welch 165305, 165131, 165132.
20. *A. m. lathropae* var., South Ekahanui Gulch, W410F-1b, Welch 165137.

Plate 10

1. *A. m. christopherseni* Welch, holotype, Huliwai Gulch, W400A-13a, Meinecke 10418.
2-2c. *A. m. christopherseni* Welch, paratypes, Huliwai Gulch, W400A-13a, Meinecke 123278.
3. *A. m. christopherseni* Welch, Huliwai Gulch, W400-10, Meinecke 126614.
4-4b. *A. m. christopherseni* var., Kauhiuhi, Lualualei, W10C-44, Welch 113949, 113953.
5. *A. m. christopherseni* var., Kaluaa-Kauhiuhi Ridge, W370E-5, Isle 134842.
6-6c. *A. m. christopherseni* var., Kaluaa Gulch, W370B-4, Cooke 35436, 35437.
7-7c. *A. m. christopherseni* var., North Ekahanui Gulch, W410A-3a, Meinecke 123293.
8. *A. m. christopherseni* var., North Ekahanui Gulch, W410A-3a, Meinecke 123293.
9-9a. *A. m. christopherseni* var., North Ekahanui Gulch, W410A-10, Welch 165335, 165326.
10. *A. m. christopherseni* var., North Ekahanui Gulch, W410A-11, Welch 165335.
11. *A. m. christopherseni* var., North Ekahanui Gulch, W410A-11, Welch 165325.
12-12d. *A. m. christopherseni* var., Central Ekahanui Gulch, W410B-4, Meinecke 125170.
13. *A. m. christopherseni* var., North Ekahanui Gulch, W410A-2, Meinecke 125105.
14-14a. *A. m. christopherseni* var., South Ekahanui Gulch, W410E-2, Meinecke 125828.
15. *A. m. christopherseni* var., South Ekahanui Gulch, W410D-5, Meinecke 125432.
16-16b. *A. m. christopherseni* var., South Ekahanui Gulch, W410D-6, Meinecke 125457, 125456.
17. *A. m. christopherseni* Welch, Huliwai Gulch, W400A-2, Meinecke 126554.

Plate 11

1-1d. *A. m. lathropae* var., Puumaialau Gulch, W420A-1, Meinecke 125960-125963.
2-2a. *A. m. christopherseni* var., Kauhiuhi, Lualualei, W10C-44, Welch 113949.
3. *A. m. christopherseni* var., Kaluaa-Kauhiuhi Ridge, W320E-5, Isle 134842.
4. *A. m. lathropae* var., Kaluaa-Huliwai Ridge, W400-5-9, Lemke 114809.
5-5a. *A. m. lathropae* var., Kaluaa-Huliwai Ridge, W400-3-4, Meinecke 126595.
6. *A. m. lathropae* var., Huliwai Gulch, W400-11-12, Meinecke 123254.
7. *A. m. lathropae* var., Huliwai Gulch, W400A-2, Meinecke 126554.
8-8a. *A. m. lathropae* var., Huliwai Gulch, W400A-1b, Welch 165414.

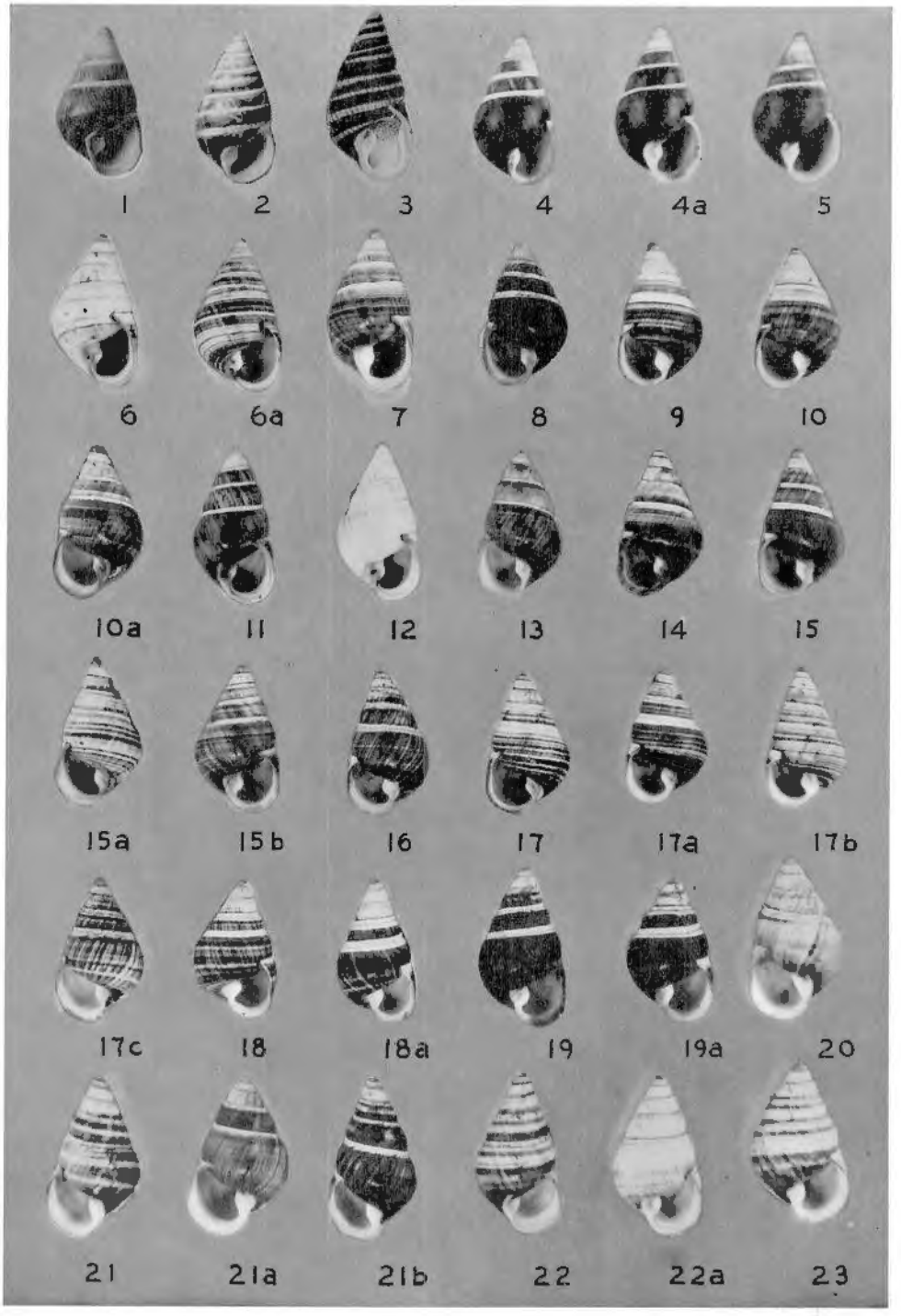
9. *A. m. lathropae* var., Huliwai Gulch, W400A-1a, Welch 165409.
10. *A. m. christopherseni* var., Huliwai-Ekahanui Ridge, W410-4, Meinecke 125100.
11. *A. m. christopherseni* var., Central Ekahanui Gulch, W410B-1, Meinecke 125198.
12. *A. m. christopherseni* var., Central Ekahanui Gulch, W410B-2, Meinecke 125195.
13. *A. m. christopherseni* var., South Ekahanui Gulch, W410C-1a, Russ 134979.
14. *A. m. christopherseni* var., South Ekahanui Gulch, W410D-2, Meinecke 125419.
15-15b. *A. m. christopherseni* var., South Ekahanui Gulch, W410F-2, Meinecke 125620, 125621.
16-16d. *A. m. christopherseni* var., Puumaialau Gulch, W420A-6, Russ 134976.
17-17a. *A. m. christopherseni* var., Puumaialau Gulch, W420A-4, Meinecke 125952.
18. *A. m. christopherseni* var., Puumaialau Gulch, W420A-3, Meinecke 125955.
19. *A. m. russi* var., Pualii Gulch, W431-1, Welch 165287.
20-20a. *A. m. russi* var., Pualii Gulch, region of W431-3-W411-2, Cooke 33026.
21. *A. m. russi* var, Pualii-Napepeiauolelo Ridge, W441-1, Russ 134986.

Plate 12

1. *A. m. christopherseni* var., North Pohakea Gulch, W424a-1, Welch 135001.
2-2a. *A. m. russi* var., North Pualii Gulch North Branch, W430-2, Welch 135005.
3. *A. m. russi* Welch, holotype, Palawai-Napepeiauolelo Ridge, W451-2, Russ 10419.
4-4c. *A. m. russi* Welch, paratypes, Palawai-Napepeiauolelo Ridge, W451-2, Russ 133784, 133761.
5-5a. *A. m. russi* var., Napepeiauolelo Gulch, W440A-1a, Russ 127019.
6. *A. m. russi* var., Pualii-Napepeiauolelo Ridge, W441-2, Welch 165285.
7. *A. m. russi* var., North Pualii Gulch, North-Central Branch Ridge, W431-2, Welch 165296.
8-8d. *A. m. russi* var., North Palawai Gulch, North Branch, W450-3, Meinecke 127353, 127350, 127351.
9. *A. m. kapuensis* var., North Palawai-Halona Ridge, W450-8-11, Cooke 33008.
10-10a. *A. m. kapuensis* var., North Palawai-Halona Ridge, W450-11, Welch 165275-165277.
11-11d. *A. m. kapuensis* var., North Palawai-Halona Ridge, W452A-2, Welch 165264-165263.

Plate 13

1-1a. *A. m. kapuensis* var., North Palawai Gulch, North Brauch, W450-7, Meinecke, 127401, 127403.
2. *A. m. lymaniana* Baldwin, lectotype, Waianae, from E. Lyman, D. D. Baldwin 10420.
3-3a. *A. m. lymaniana* Baldwin, type material, southeast end Waianae Mountains, Lyman 135072, 135071.
4. *A. m. lymaniana* Baldwin, paratypes, from D. D. Baldwin 54936.
5. *A. m. lymaniana* Baldwin, Palehua (North Kaloi Gulch), W490A-1, Cooke 16792.
6-6a. *A. m. lymaniana* var., Palehua (North Kaloi Gulch), W490B-5, Cooke 33210, 38060.
7. *A. m. kapuensis* Welch, holotype, Kaaikukai-Manuwaikaalae Ridge, W460B-8, Cooke 10421.
8-8c. *A. m. kapuensis* Welch, paratypes, Kaaikukai-Manuwaikaalae Ridge, W460B-8, Cooke 16977.
9. *A. m. kapuensis* Welch, South Kaaikukai Gulch, Central Branch, W460B-7, Welch 165109.
10-10a. *A. m. kapuensis* Welch, South Kaaikukai Gulch, Central Branch, W460-6, Welch 165104.
11-11d. *A. m. kapuensis* var., South Palawai Gulch, region of W450B-2-3-3a., Russ 133810.
12. *A. m. dautzenbergi* var., from Dautzenberg 115308.
13. *A. m. dautzenbergi* Welch, holotype, from Sowerby and Fulton 165854.
14. *A. m. dautzenbergi* Welch, paratype, from Sowerby and Fulton 165855.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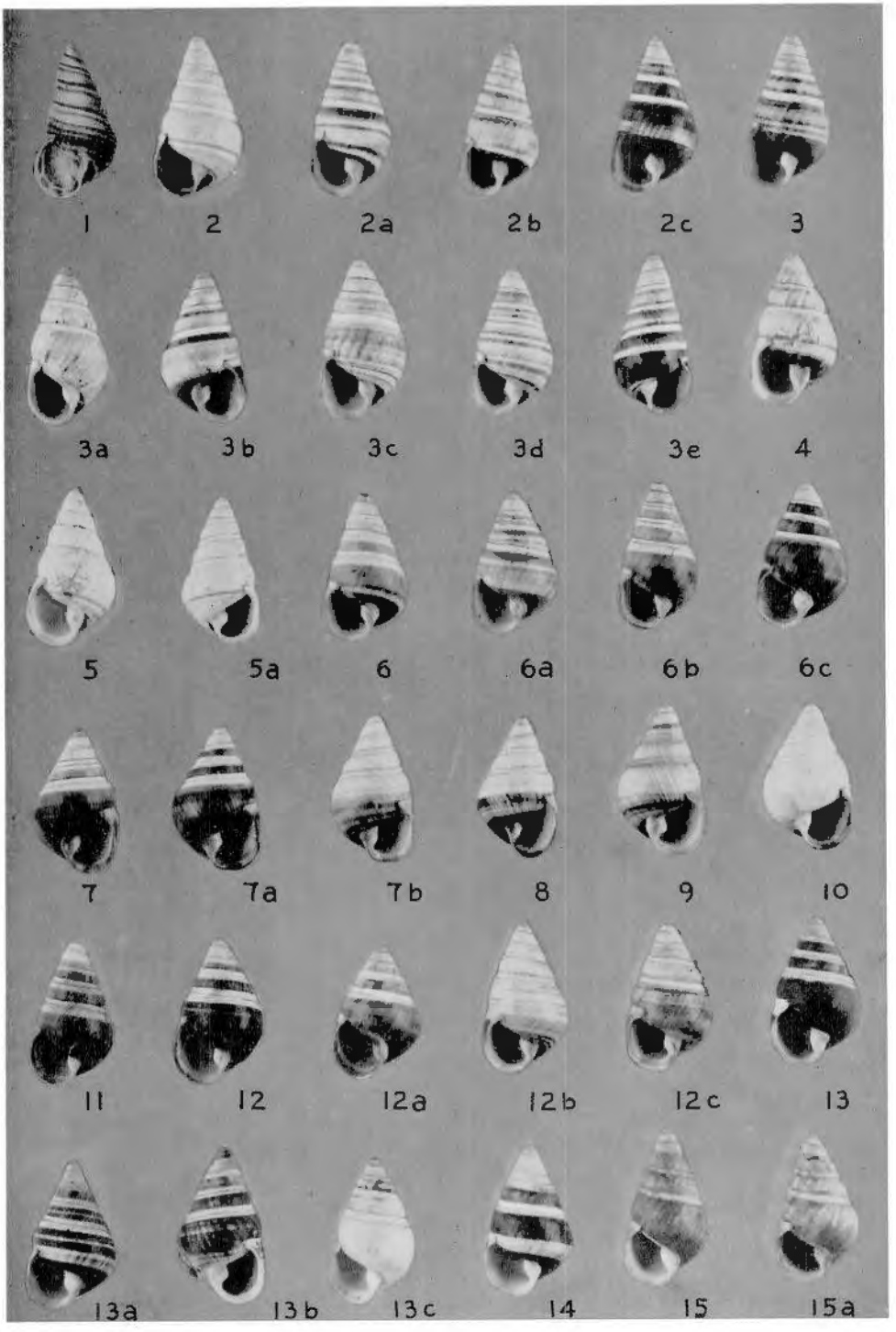
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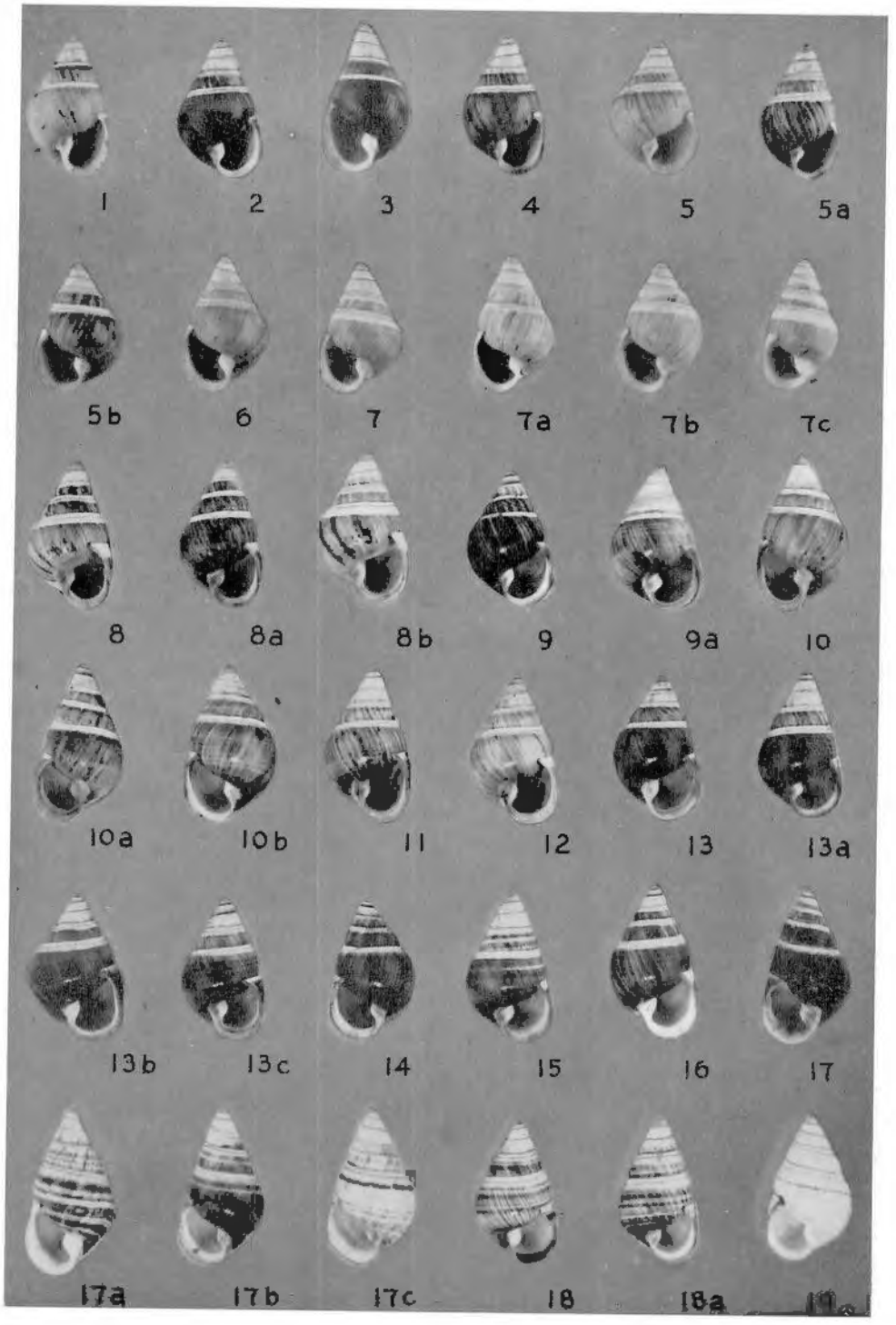
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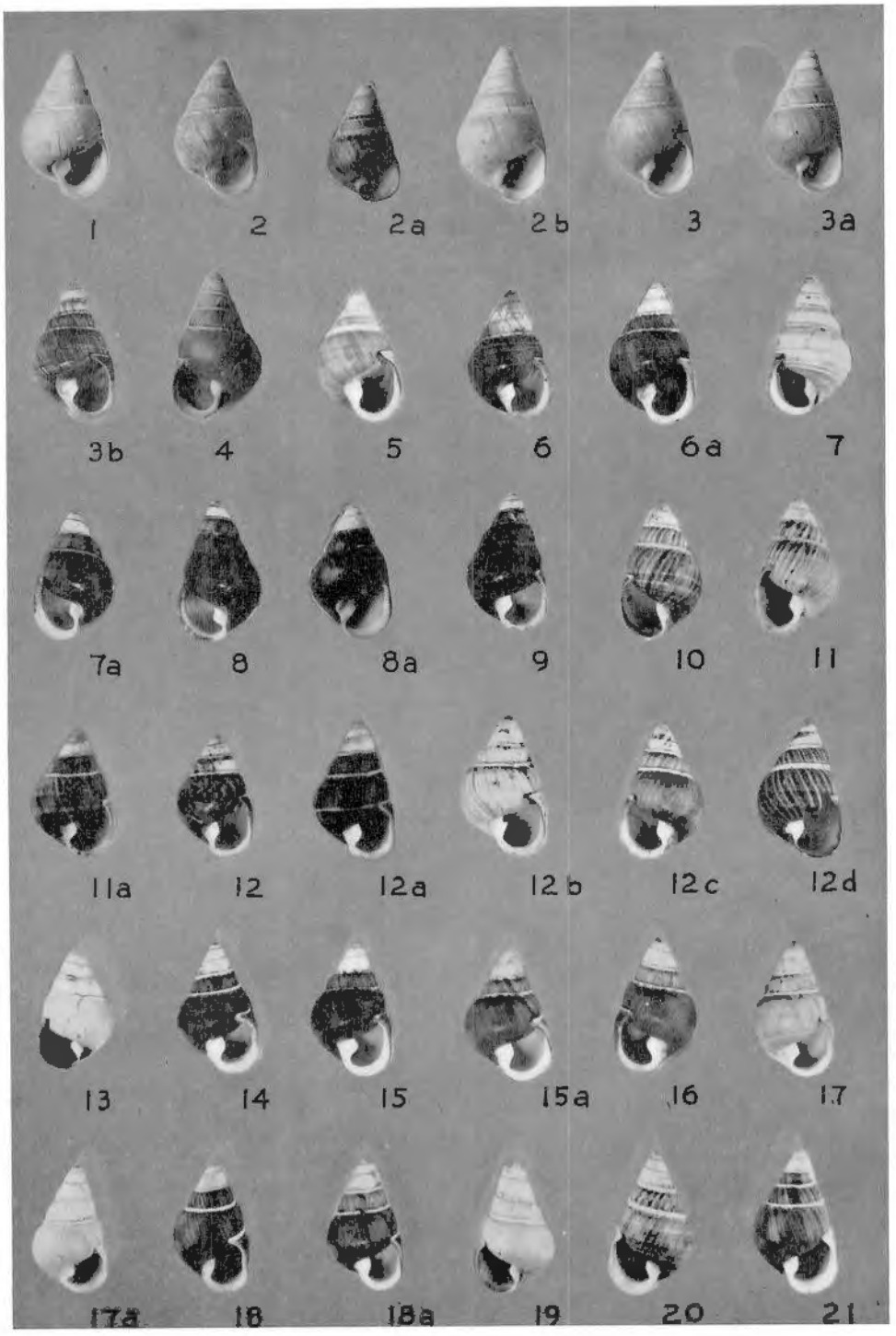
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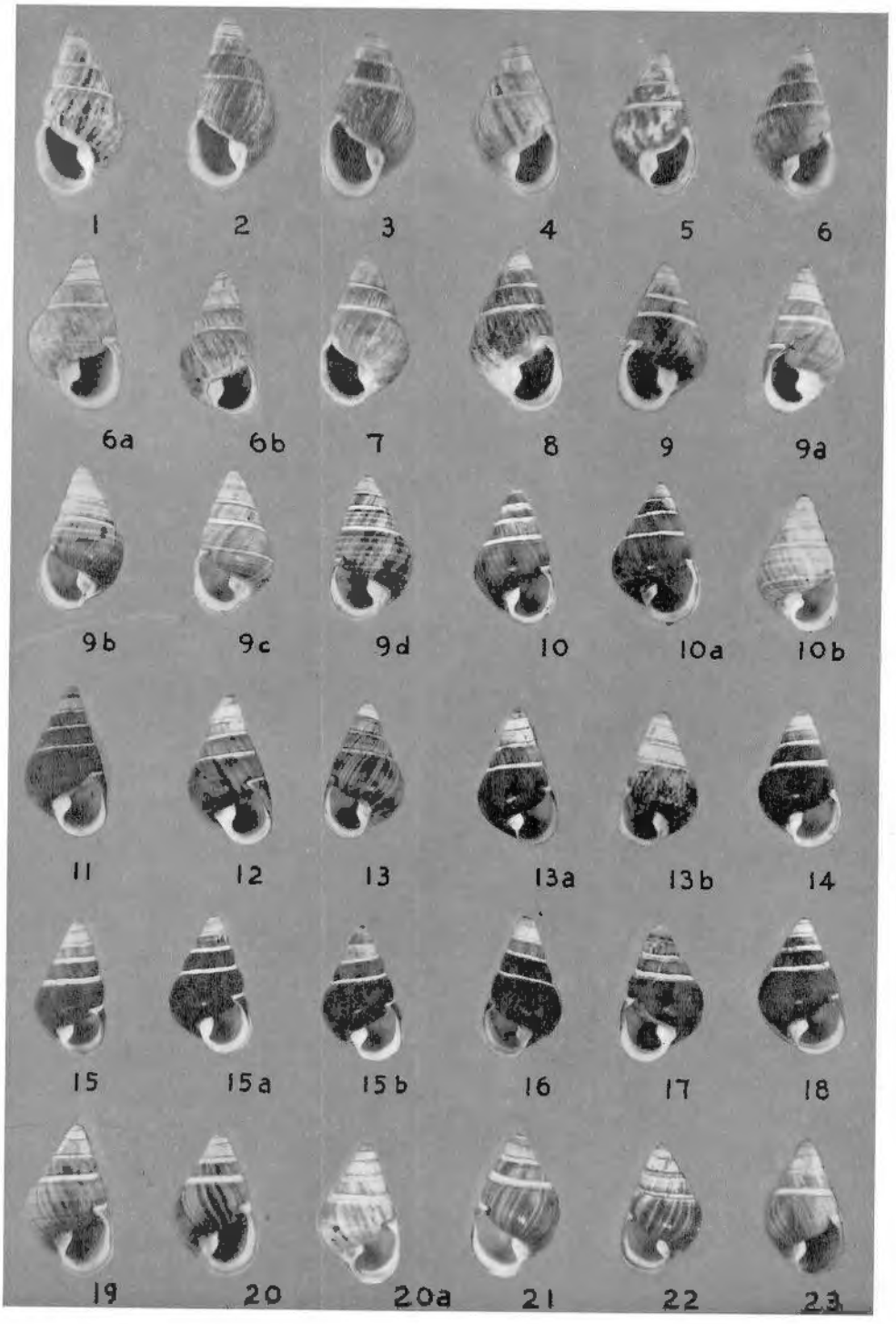
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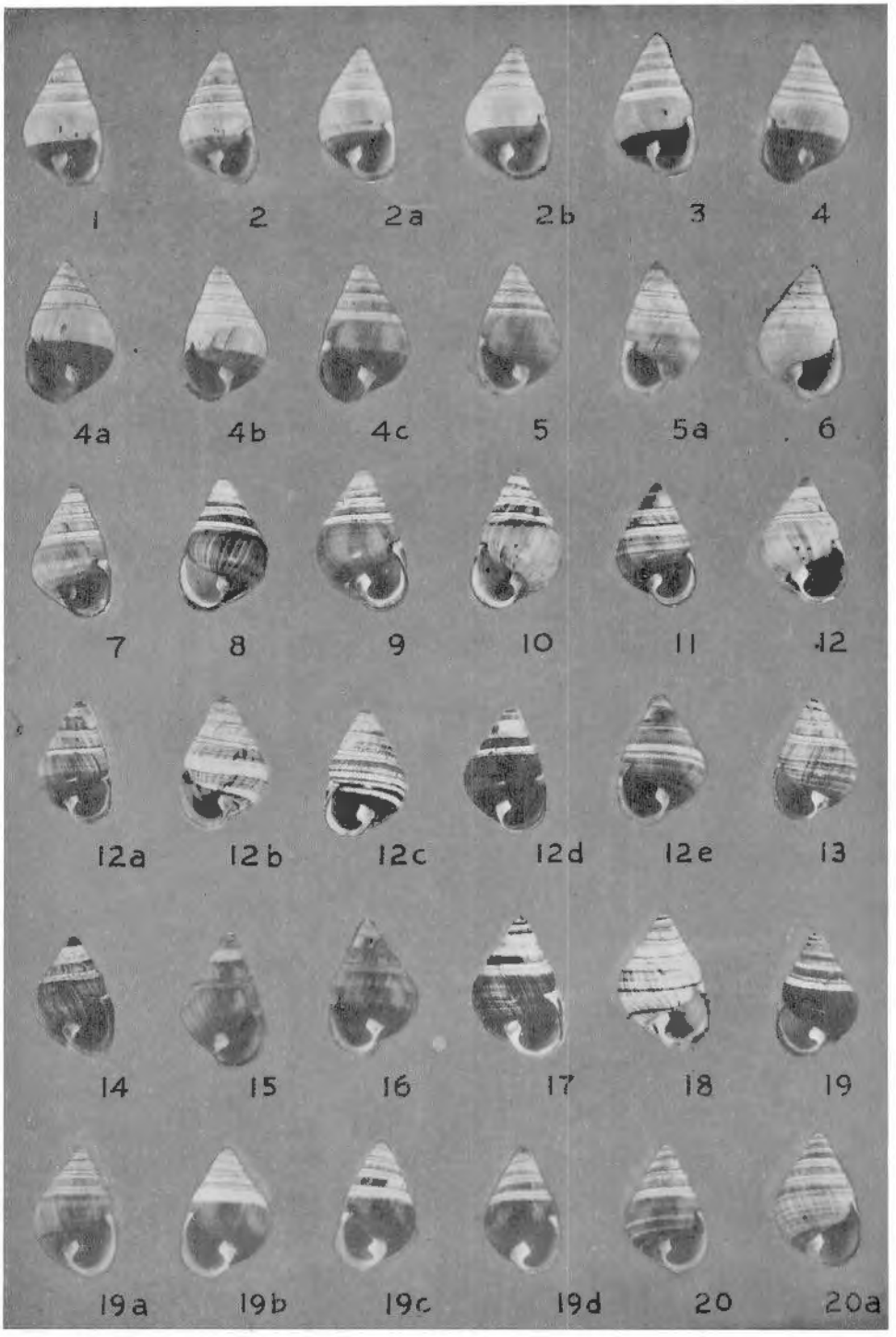
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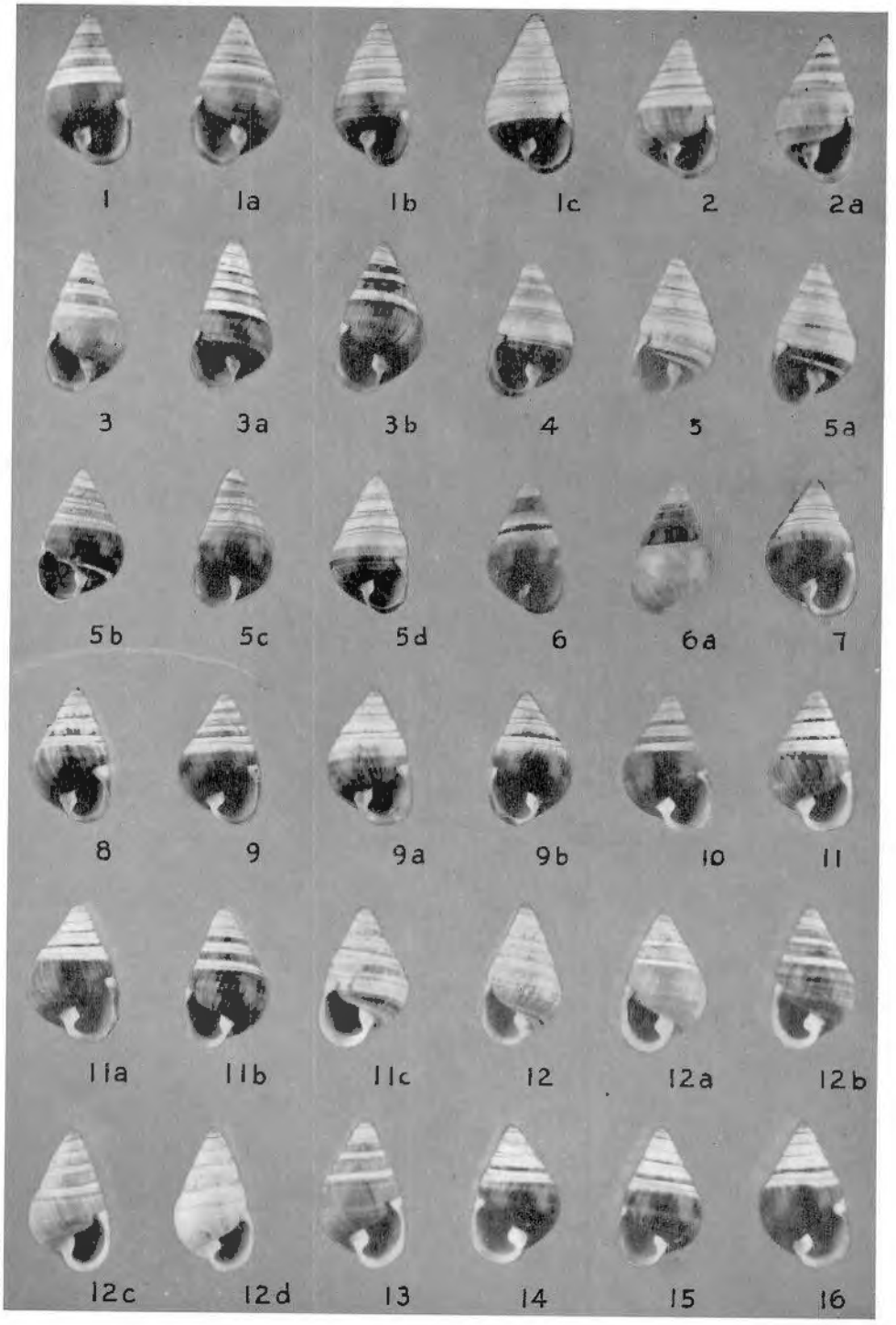
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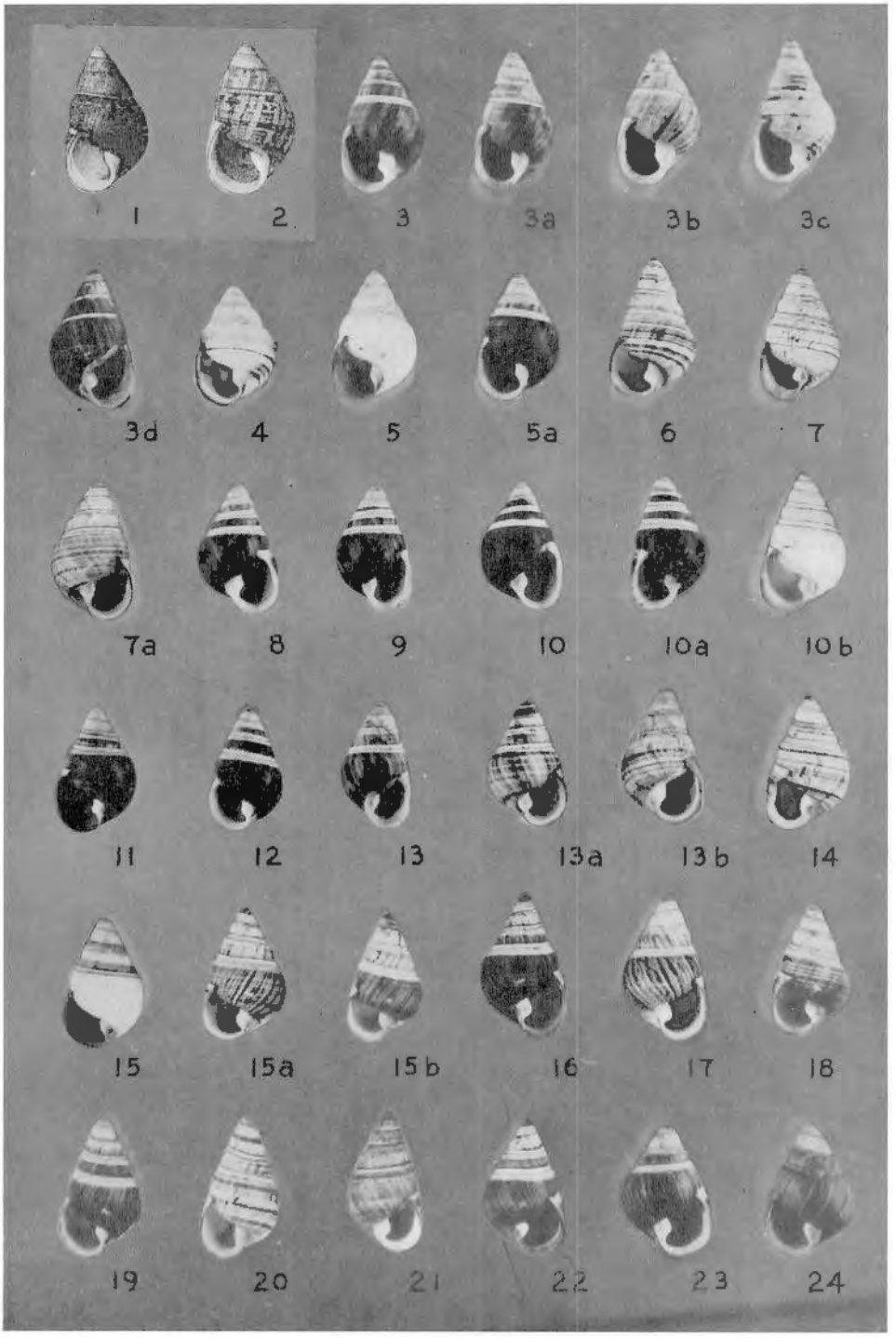
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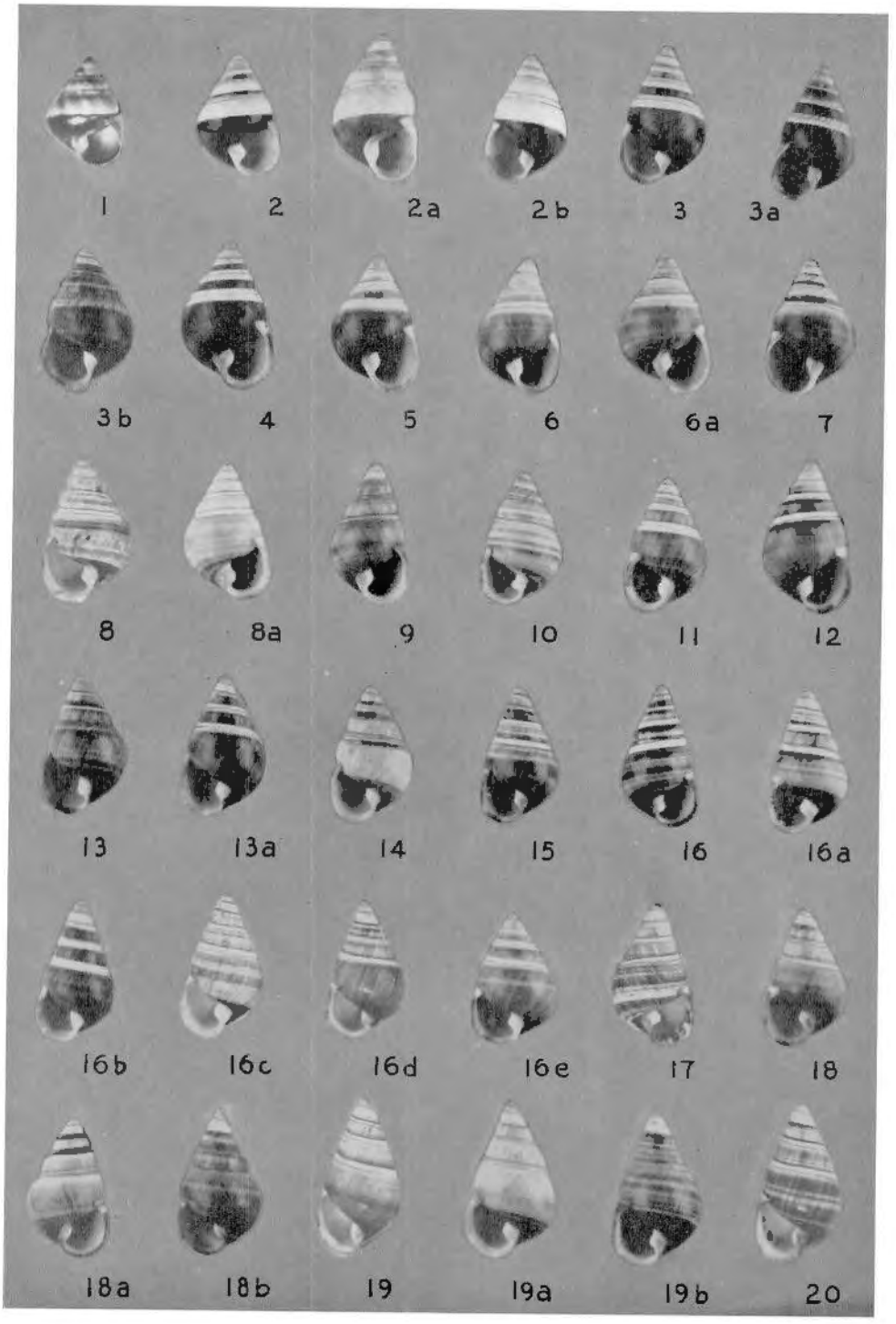
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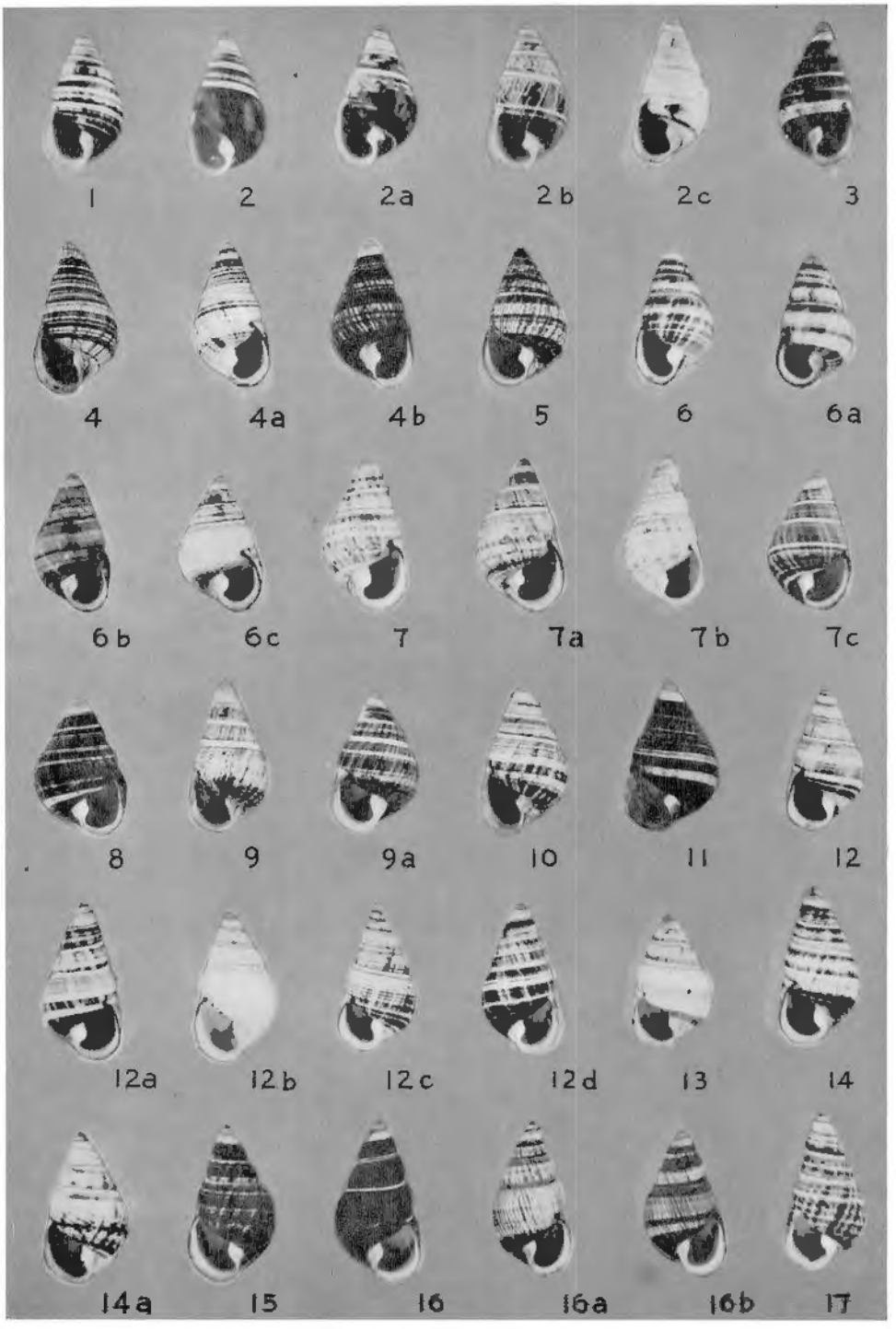
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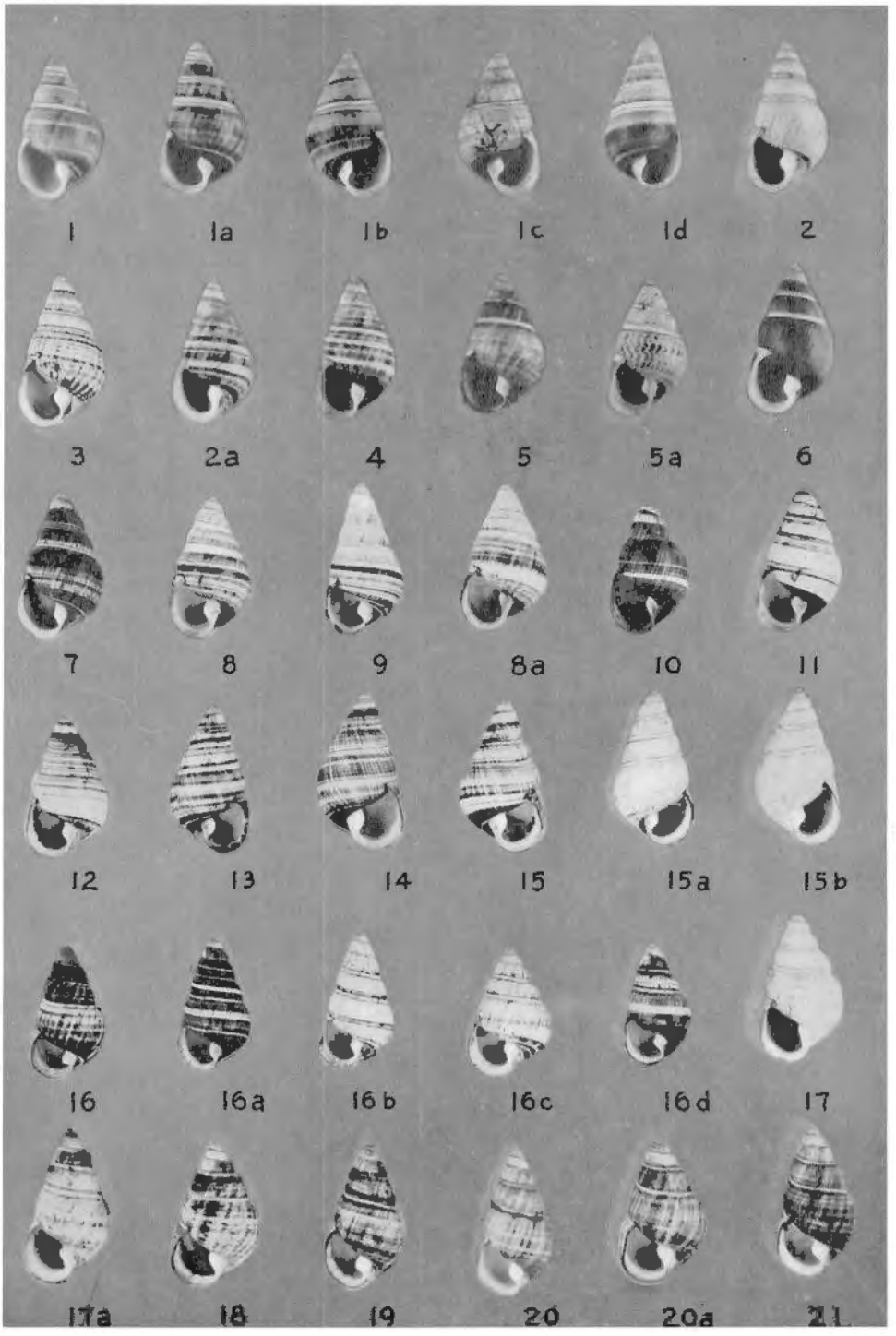
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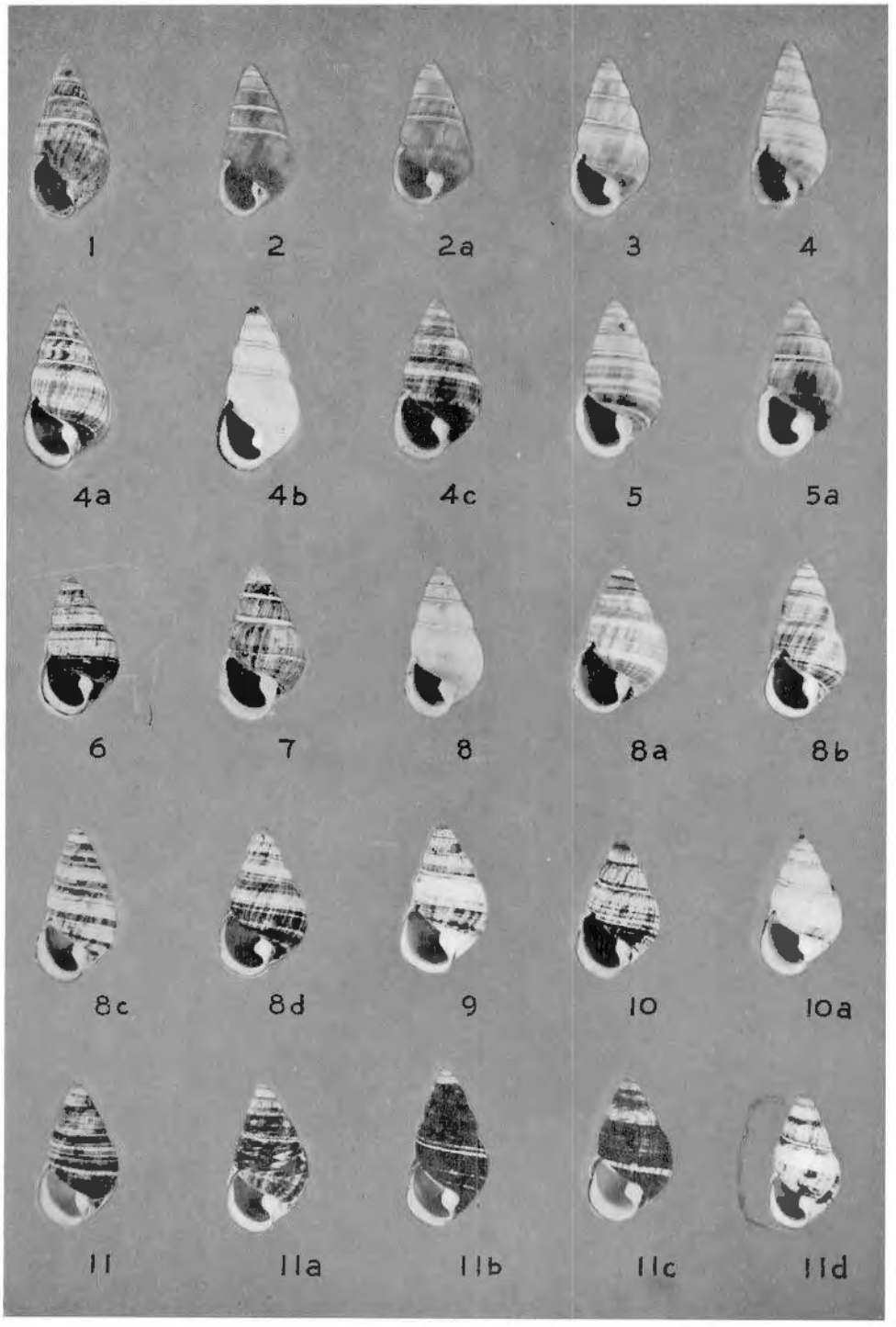
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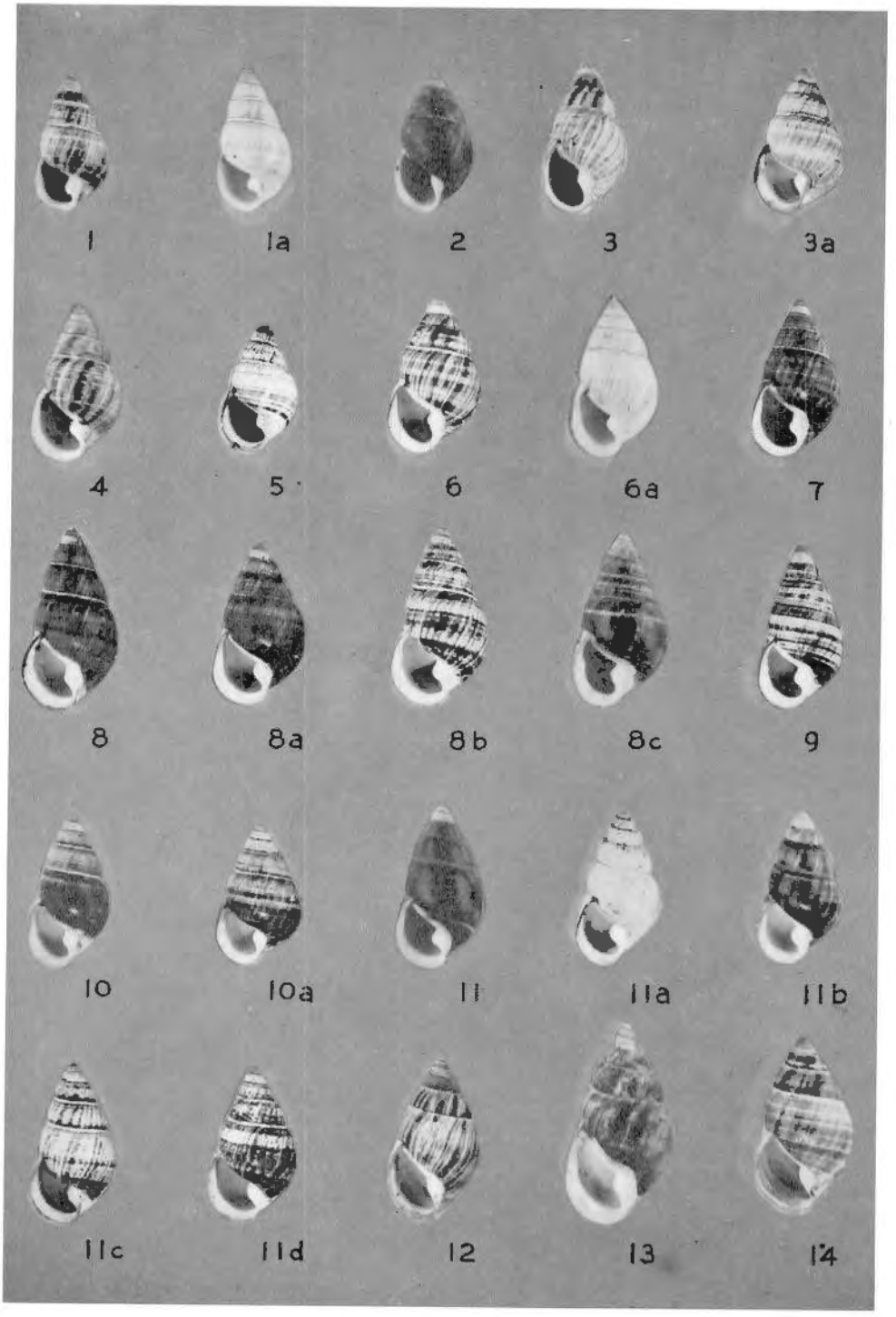
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