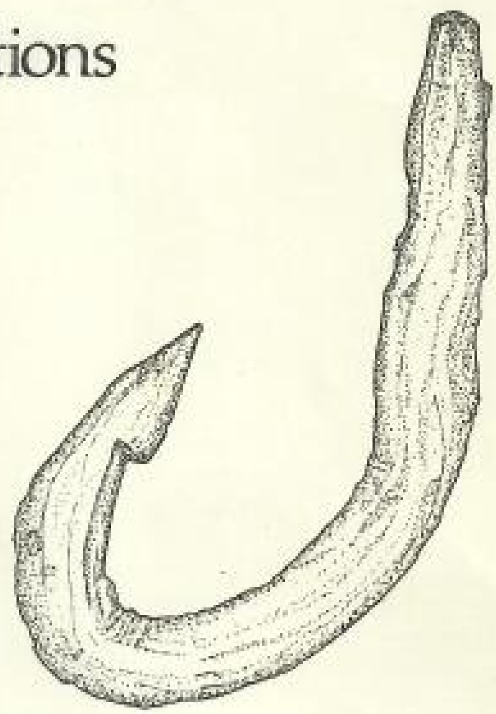
MARINE EXPLOITATION IN PREHISTORIC HAWAI'I

Archaeological Investigations at Kalāhuipua'a, Hawai'i Island



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PREFACE

Recognition of the societal values of archaeological resources is increasing in Hawai'i and throughout the United States (Lipe 1974). Conscientious management of these cultural resources is seen as important not only for "pure" archaeological research, but in terms of such general societal values as public education and the establishment of strong ethnic identities. In Hawai'i, some emphasis has also been placed on the importance of archaeological resources in the tourist industry, the economic mainstay of the State. The research value of these resources has been established, both for documenting culture history and for the potential contributions to general anthropological theory. Such attention to the significance of archaeological resources has been reinforced by a spate of national, state, and local legislation, aimed at the effective management of cultural resources in general.

The investigations reported below, undertaken in 1973 and 1975, were part of the Bishop Museum's program in Hawaiian Cultural Resources Management. Kalāhuipua'a and adjoining land in Waikoloa and Lālāmilo (a total of roughly 4000 acres on the Island of Hawai'i) constitute the geographical focus. In the Kālahuipua'a project it was fortunate that cooperation between archaeologist, planner, land developer, and the County of Hawai'i Planning Department began early in the planning process. Thus subsequent land use decisions were made with a knowledge of the range and distribution of archaeological resources in the development area.

In accordance with contemporary concepts in cultural resource management (Lipe 1974), emphasis was placed on preservation of a wide range of sites, representative of the extent of archaeological resources at Kalāhuipua'a. Two "archaeological preserves," incorporating more than 30 sites, have thus been established. Preserve A, with an area of 22.4 acres, is located inland of the fishpond area, and incorporates several shelter caves, petroglyphs, C-shaped and other structures, a shrine, and a large burial cave. The burial cave (Site E2-56) was sealed in 1975 after recording and osteological study. Preserve B, with 3.1 acres, is a complex of structural features, centered around an aboriginal steppingstone trail. Other sites will also be preserved as part of a general coastal setback for the resort development.

The archaeological research itself, both survey (1973) and excavation (1975), was structured around two over-riding aims. First, if the Kalāhuipua'a investigations were to contribute to knowledge of Hawaiian prehistory, they had to center on a major research problem with certain implications for more general theory. In this case, Kalāhuipua'a was utilized as a "laboratory" for the study of certain major problems in Hawaiian marine adaptation and exploitation. Secondly, it was recognized that archaeologists in cultural resource management have an obligation to record as extensively as possible all types of data, not only that material immediately relevant to their particular research orientations. Only in this manner can an effective record of these cultural resources be provided as a data base for future investigations of as yet undefined problems.

The present monograph thus seeks to combine the two aims of providing both a definitive and exhaustive record of the cultural resources of Kalāhuipua'a, and of addressing a more general theoretical problem, specifically the nature of prehistoric Hawaiian marine adaptation.

P. V. Kirch
January 1976

INTRODUCTION

Polynesian culture is inextricably bound to the sea, and exploitation of marine resources formed a significant component of Polynesian economies. As Reinman (1967:108) noted, ". . . the prehistoric Oceanian peoples found the sea one of the most stable and reliable food sources." The structure and complexity of indigenous Oceanic folk taxonomies of fish and other marine life (e.g., Titcomb 1952) reflect an intense familiarity with these marine fauna. Recent archaeology has only begun to reveal the antiquity and development of Oceanic fishing techniques; the material evidence of a sophisticated angling technology has been unearthed in a southwestern Pacific site (Anuta) dating from the early first millennium B.C. (Kirch and Rosendahl 1973), and yet older finds are to be anticipated.

This monograph presents the results of several seasons of intensive archaeological research at Kalāhuipua'a,* an area on the western coast of Hawai'i Island (Fig. 1). A complex of large and productive fishponds comprises the focal point of Kalāhuipua'a. Inland of the ponds, the terrain stretches away in a vast series of barren, arid lava flows spewed by 13,000-ft Mauna Loa. The fishponds, however, and sheltered Makaīwa Bay fronting Kalāhuipua'a (see Fig. 7), are anything but sterile. They abound in marine life and it was clearly this marine-species diversity and productivity that attracted prehistoric Hawaiian settlement into the area.

The research reported herein was undertaken primarily through two contracts with Mauna Loa Land, Inc., the owners of the area, in an effort to assess and preserve the cultural resources of Kalāhuipua'a. The project was part of an ongoing contract program of Cultural Resource Management at the Bernice P. Bishop Museum (Rosendahl Ms.). From the project's commencement an attempt has been made to produce more than an inventory of sites and artifacts, and to utilize this opportunity of privately funded research to investigate the nature of prehistoric Hawaiian adaptation to and exploitation of the marine environment.

ARCHAEOLOGICAL RESEARCH IN THE KALĀHUIPUA'A REGION

Initial Investigations (1955-1964)

Kenneth P. Emory of the B. P. Bishop Museum conducted the first archaeological investigations at Kalāhuipua'a in 1955, as part of a five-year program of Hawaiian archaeology (Spoehr 1956). This work consisted of a brief examination of sites in the vicinity of the Kalāhuipua'a fishponds and test excavation in a large shelter cave site (HA-E1-342), to which Emory assigned the site number H100. At the same time Emory excavated Site H101, a cave shelter at Paniau, approximately 1500 meters NE of Pauoa Bay (see Fig. 7). Results of these excavations were not published, although the fishhooks from these two sites were incorporated in Emory, Bonk, and Sinoto's island-wide analysis of prehistoric Hawaiian fishing gear (1959); field records

*The placename Kalāhuipua'a, a combination of three morphemes (*ka-lāhui-pua'a*), may be translated "the family of pigs" (Pukui and Elbert 1966:8).

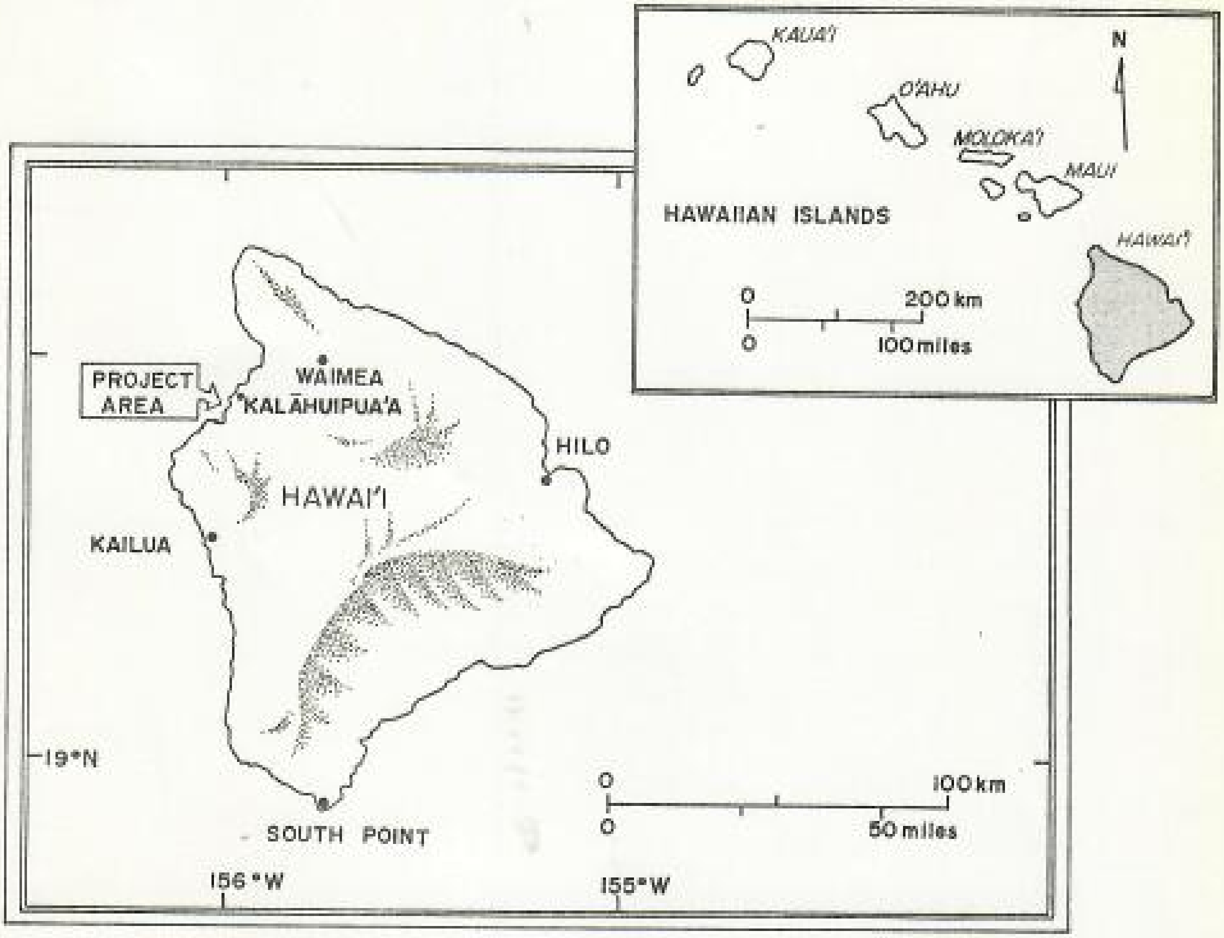

Fig. 1. MAP OF HAWAI'I ISLAND, SHOWING LOCATION OF THE KALĀHUIPUA'A PROJECT AREA.

from these excavations are on file in the Department of Anthropology of the Bishop Museum (Emory Ms.).

In 1964 the Bishop Museum undertook a comprehensive study of the extensive Puakō petroglyph fields, Site E1-5 (Bishop Museum Department of Anthropology 1964; Cox with Stasack 1970), at the request of the Board of Land and Natural Resources of the State of Hawai'i. Cox has estimated that the site includes c.3,000 glyph units. These were mapped by the Museum team at 1:20 on 29 sheets.

In 1962 and 1963 the Bishop Museum also conducted limited excavations at a coastal midden site, H22 (HA-E3-2), at Puakō Bay (see Fig. 7). The excavation, which yielded 29 portable artifacts and a quantity of faunal remains, was reported by Smart (1964). Unfortunately, no age determinations were ever obtained from this midden deposit.

Several archaeological sites along the inland periphery of the survey area were recorded during initial survey (Ching 1971) and subsequent salvage (Rosendahl 1972b) of the Kawaihae-Kailua highway corridor.

Intensive Survey (1973)

From June 25 to July 26, 1973, the Bishop Museum undertook a comprehensive survey of archaeological sites on c.3,841 acres in the *ahupua'a* of Kalāhuipua'a, Waikoloa, and Lālāmilo, on property recently acquired by Mauna Loa Land, Inc. (then Orchid Island Resorts Corp.). The survey, aimed at assessing the cultural resources of this region, resulted in the location of 179 archaeological sites, incorporating a total of 449 separate features (Kirch Ms.a). Sites were plotted on a set of base maps with the aid of aerial photos, and descriptions were prepared for all sites. In addition, sites were given a significance evaluation (Kirch Ms.a, table 2) based on potential for further research and/or public interpretation.

Interim Investigations (1973-1975)

Following the intensive survey, several additional field examinations of located sites were made in order to determine more precise locations and evaluate in more detail any sites that might be adversely affected by the proposed resort development. In 1974, 52 sites at Kalāhuipua'a were marked for aerial survey in conjunction with personnel from Belt, Collins, & Associates, Ltd., and R. M. Towill, Inc. (Kirch Ms.b). Using photogrammetric methods, these sites were then plotted by R. M. Towill surveyors on a detailed (1:2400) base map. In 1975 a set of specific recommendations was prepared regarding 27 sites within the area of the first increment of the proposed development (Kirch Ms.c, d). Recommendations were made to preserve certain unique sites, to relocate a series of petroglyphs from several sites, and to conduct salvage excavations at several cave shelter sites; it was also recommended that the large number of burials at Site E2-56 be thoroughly examined by a physical anthropologist and that the cave subsequently be sealed. A proposal to implement these recommendations was submitted to Mauna Loa Land, Inc. and accepted on June 2, 1975.

Intensive Survey and Excavations (1975)

The scope of work for the intensive Phase II program at Kalāhuipua'a included: (1) detailed recording of several petroglyph sites; (2) detailed recording and sampling of several surface midden sites; (3) removal and reinterment of burials in Sites E1-321 and -329; (4) stratigraphic excavation of midden deposits in eight shelter cave sites; (5) an osteological study of the burial population in Site E2-56; and (6) preparation of a comprehensive report on the results of these field investigations. Phase II fieldwork was conducted from June 29 through August 7, 1975, under the author's direction; a brief preliminary report was prepared after completion of fieldwork (Kirch Ms.e).

This monograph presents the results of the 1973 survey, interim investigations, and the 1975 investigations. In addition, an attempt has been made to incorporate the previously unpublished results of Emory's earlier work (see Appendix B).

RESEARCH DESIGN AND OBJECTIVES (1975)

Although several aspects of the Kalāhuipua'a investigation were structured by the contract nature of the project, an attempt was made to formulate a more specific research design, centering on the problem of prehistoric Hawaiian adaptation to and exploitation of the marine environment. The 1973 survey clearly demonstrated that a major portion of the prehistoric remains of human occupation at Kalāhuipua'a were related to exploitation of the sea. Interestingly, while ethnohistoric sources indicated the importance of marine exploitation in indigenous Hawaiian economy, and despite the archaeological importance of fishing gear in establishing culture-historical sequences (Emory, Bonk, and Sinoto 1959), little attention has been paid to the topic of prehistoric adaptation to the marine environment. Newman's Lapakahi study (n.d.) is an exception, although he relied more on ethnohistoric evidence for reconstruction of fishing techniques than on direct archaeological evidence. Other recent archaeological research has concentrated on the definition of terrestrial settlement patterns and agricultural systems (e.g., Rosendahl 1972a; Kirch and Kelly 1975; Tuggle and Griffin 1973).

One of the central questions concerning Hawaiian marine exploitation is that of stability versus change in exploitation techniques and technologies. Although typological change in fishhooks has been demonstrated (Emory, Bonk, and Sinoto 1959; Sinoto 1962), it is unclear whether such technological changes were purely stylistic modifications of form, or functional innovations related to changes in exploitation technique. A solution to this question will almost certainly depend upon concomitant analyses of both artifactual and midden remains, to determine whether significant correlations exist between patterns of technological change and of dietary composition.

In order to implement this general research design, certain specific objectives were formulated:

1. To obtain sufficient dating materials to allow for relatively precise temporal control of both excavated deposits and open-site midden scatters. The radiocarbon method, with its inherent probabilistic basis, does not provide sufficiently precise temporal control; therefore, the recently developed hydration-rind method of dating basaltic-glass artifacts was utilized (Barrera and Kirch 1973; Morgenstein and Riley 1974).

2. To recover a sizeable sample of marine exploitation gear, from a variety of sites and site types.

3. To recover samples of faunal and floral material from all excavated sites, as well as from open midden scatters.* Concurrent analyses of fishing gear and of midden materials were expected to provide data relating to: (a) spatial variation between site assemblages; (b) temporal variation in marine exploitation patterns; and (c) correlation or covariation between patterns of midden dumping and of fishing technology.

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*Midden, derived from the Scandinavian (cf. Danish *mødding*), originally meaning "dungheap," refers here to the accumulation of refuse about a dwelling place.

An additional research objective, indirectly related to the above, was to approach the osteological analysis of the E2-56 burial cave population so as to determine as closely as possible certain demographic characteristics of the prehistoric human population at Kalāhuipua'a (age-sex structure), as well as to assess variation in burial patterns in terms of rank or social stratification.

FIELD AND LABORATORY METHODS

Survey

Twenty-four days (1,152 man hours) were spent in field survey of c. 3,841 acres in 1973. Survey procedure involved traversing a predetermined area, with the field team spreading out over a given distance (dependent upon terrain and vegetation) and moving along a specified azimuth. When a site was located, either the field director or one of the two field supervisors recorded the site in his field notebook, noted general site description, measurements, and presence of artifacts and/or midden, and made a preliminary assessment of the site's potential for further research. Sites were located on topographic maps at a scale of 1:2400, with the aid of color aerial photographs. In 1974, as noted above, 52 sites were photogrammetrically plotted on the Kalāhuipua'a base map by R. M. Towill, Inc. personnel.

Sites are numbered according to the Bishop Museum system, in which 50-HA- (50 = Hawai'i State; HA = Hawai'i Island) precedes all numbers. The letter E refers to the district of South Kohala, followed by numbers that refer to the *ahupua'a*, or traditional land section (1 = Kalāhuipua'a and 'Anaeho'omalu; 2 = Waikoloa; 3 = Lālāmilo). Specific site numbers, the final digits, are consecutive in the order of recording.

In 1975 a number of sites were rechecked, to ensure a complete photographic and descriptive record, and to procure surface samples of midden and basaltic glass. Basaltic glass from six open sites was subsequently dated.

Excavation

Ten sites, all shelter-caves with midden deposits, were excavated in 1975. Sites were first mapped and a metric grid imposed over the excavation area. Since all deposits were composed of relatively homogeneous midden (predominantly shellfish remains) mixed with rubble and aeolian dust, excavation proceeded by 10-cm arbitrary levels. An exception was made in the case of Square E9, Site E1-355, which was excavated in 5-cm levels for finer control. Results of hydration-rind dating (see Age Determinations, p. 109 ff.) independently confirm that the use of arbitrary levels within these homogeneous deposits did not result in any stratigraphic inversions or irregularities; conversely, it appears that the deposits accumulated steadily over time.

Artifacts found in situ were recorded three-dimensionally. All excavated material was screened through 0.25-inch mesh; artifacts found in the screens were bagged by level. The contents of at least 1 square meter (usually more) in each site were reserved for quantitative faunal and floral analyses. Furthermore, the contents of all features (hearths, etc.) were screened through 0.12-inch mesh and all midden was retained for analysis. All bone material recovered in the 0.25-inch screens from the entire excavated area of each site was reserved for faunal analysis. Although the radiocarbon age determination method was not utilized, charcoal samples were collected (HRC-295 to -298) and are available should radiometric analysis be desired in the future.

Artifacts are cataloged by an extension of the site numbering system, which also specifies grid provenience. For example, a pig-tooth ornament from Site E1-324 is cataloged as HA-E1-324-F6-88, indicating the 88th artifact recorded from Square F6 of that site.

Field records for the excavated sites have been deposited in the archives of the Department of Anthropology, Bishop Museum (Project No. 133); photographs have roll numbers HA(a)213-233 (35-mm) and HA(b)146-168 (120 roll film). Faunal and floral remains and carbon samples have been assigned Bishop Museum Accession No. 1976.113. Artifacts are stored at Bishop Museum with extended loan status (EL-1976.01).

Sampling

The question of sample size and sampling procedure has assumed increasing significance in archaeology with the recognition of the effect of sample size on reliability of analyses, interpretations, and conclusions; a few remarks on sampling at Kalāhuipua'a are thus in order. With regard to the survey, sample size is not a factor, for the entire universe of sites within the c. 3,841 acres covered was surveyed. The 1973 survey revealed that cave shelters were the only site type containing significant deposits of midden and artifacts; they thus contained the bulk of the archaeological sample of refuse and detritus representing past human behavior in the area. A total of 40 shelter caves were situated in the survey area; of these, 14 contained midden deposits ("deposit" indicating some stratigraphic depth, and not merely a light surface scatter of shellfish remains). Ten of the 14 caves (71%) were systematically excavated.* Furthermore, these excavated site locations include coastal and "inland" shelters, and sites relatively close to, as well as removed from, the fishponds; both large and small caves are included in the sample. In sum, there is every reason to believe that the size of the excavated sample of archaeological deposits at Kalāhuipua'a is fully representative of the total universe of existing sites. Questions of size of midden samples, and of the effect of screen-mesh diameter on collection of midden samples, are considered further below (see Faunal Analyses, p. 117 ff.).

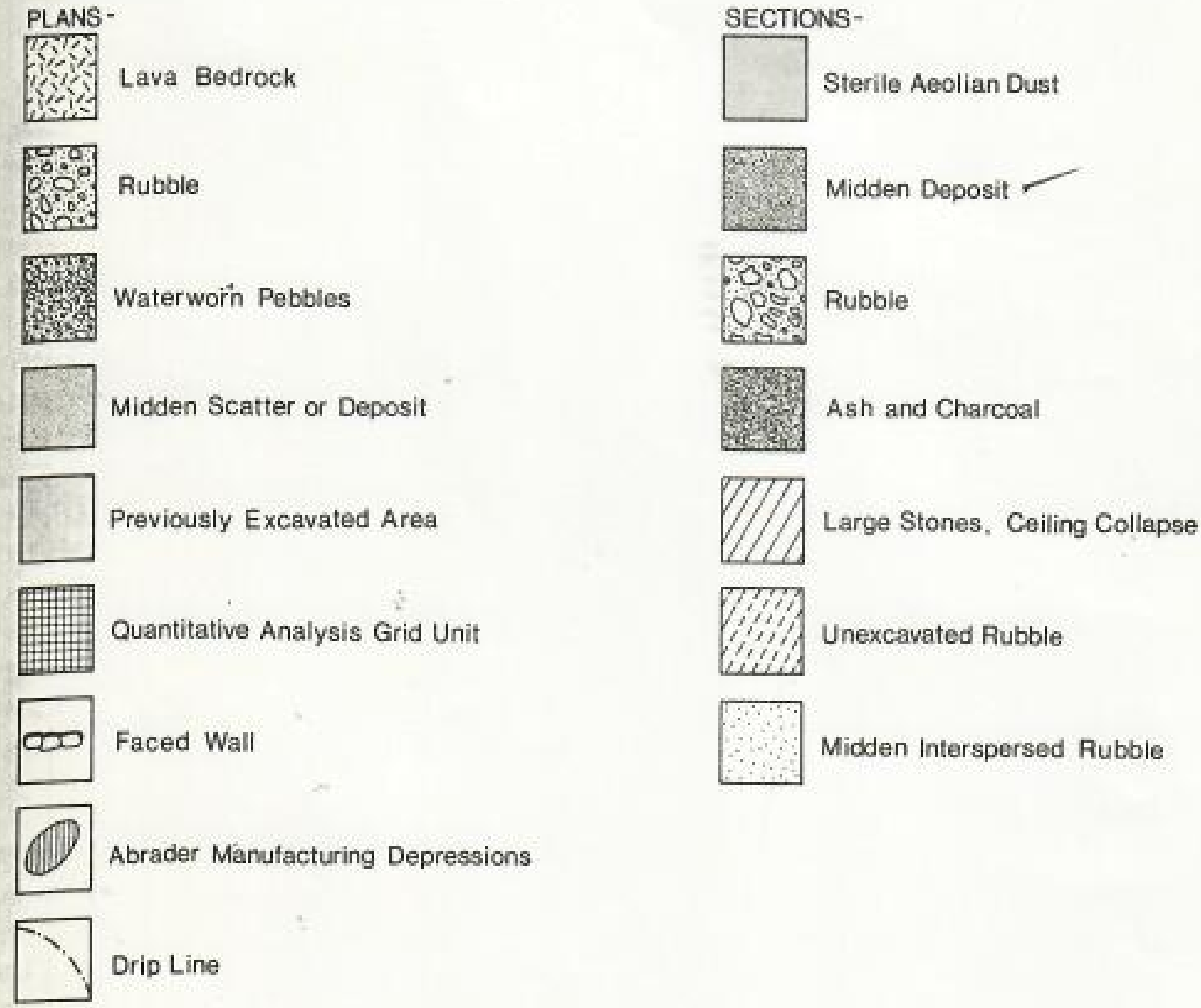
PLAN OF REPORT PRESENTATION

The primary aim of this monograph is to present the comprehensive data base from the Kalāhuipua'a investigations in a form enabling other researchers access to the material, in as much

*Site number E1-350 comprises two separate shelter caves, designated E1-350E and -350W. Thus, the ten excavated shelters are associated with nine site numbers.

detail as publication pragmatics allow. Data derived from both the 1973 survey and the 1975 excavations have been combined here into a single final report. Survey results are described first, in two parts: (1) a summary of the major kinds of sites and their distributions; and (2) detailed site descriptions. The ten excavated sites are reported next, using a standard format for all sites to facilitate comparison. Following the excavation descriptions are analyses of age determination results, portable artifacts, and floral and faunal remains. Finally, some preliminary conclusions are offered, especially concerning marine exploitation and the position of Kalāhuipua'a in the prehistory of the West Hawai'i region.

KALĀHUIPUA'A: Illustration Symbols



THE NATURAL ENVIRONMENT

The contrast between land and sea could hardly be more pronounced than at Kalāhuipua'a. Biotically impoverished, the barren lava fields of the terrestrial environment are the antithesis of the anchialine,* littoral, and marine biotopes that are characterized by variable substrate and high species diversity. Barrera's portrayal of nearby 'Anaeho'omalu as an "oasis" (1971a) is an apt metaphor equally applicable to Kalāhuipua'a. Unquestionably, these rich marine resources were the attraction which led to the prehistoric Hawaiian exploitation and occupation of Kalāhuipua'a.

TERRESTRIAL ENVIRONMENT

Geologically, Kalāhuipua'a comprises basaltic lava flows belonging to the Prehistoric Member of the Ka'ū Volcanic Series, deriving from Mauna Loa (Stearns and Macdonald 1946, Plate 1). The area extending inland from the major fishponds is older, weathered pahoehoe, while immediately to the S of the ponds, separating Kalāhuipua'a from 'Anaeho'omalu, is the massive Kanikū aa lava flow. This flow, which rises some 10 to 15 meters above the surrounding pahoehoe, is sometimes mistakenly identified as historic in age; the flow is, however, clearly prehistoric, with precontact Hawaiian sites constructed on it. The lavas in the immediate environs of Kalāhuipua'a are vesicular and hence not exploitable as material for adzes, or for other prehistoric tools requiring a fine-grained texture. These scoriaceous lavas were, however, extensively used for abraders, and literally thousands of manmade depressions in the pahoehoe are the result of abrader manufacture (see Survey, p. 18).

The climate of Kalāhuipua'a is hot and arid, with rainfall averaging less than 10 inches annually (Stearns and Macdonald 1946, fig. 36). Consequently, there has been no hydraulic erosion in the area; streams or watercourses are entirely lacking. The annual temperature is estimated to average about 78°F (based on the Māhukona average, 77.6°F; Stearns and Macdonald 1946:210).

Vegetation in the area is xerophytic and restricted in number of species. Vegetative cover is, moreover, largely restricted to the older pahoehoe substrate; the Kanikū flow is almost entirely bare of plants. Scattered over the pahoehoe inland of the fishponds, the dominants comprise a few species of low grass, *Sida fallax* Walp. (*'ilima*), and some creeping weeds. Interspersed are stunted *Prosopis pallida* (Humb. and Bonpl. ex Willd.) HBK (*kiawe*), giving the area a parkland or savanna appearance. Vegetation is considerably denser in the vicinity of the ponds,

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*"Anchialine": shoreline ponds with no connection to the sea (from Greek, *anchialos*, near the sea), after Holthius (1973).

which are rimmed with coconut (*Cocos nucifera* L.) and *Thespesia populnea* (L.) Sol. (*milo*). Sedges (Cyperaceae spp.) and grasses grow at the water's edge. In this area one also finds two economically important plants, *Morinda citrifolia* L. (*noni*) and *Pandanus* sp. Along the strand are found *Ipomoea pes-caprae* (L.) Sweet (*pohuehue*) and *Scaevola sericea* Vahl (*naupaka*).

Aside from insects and rock-dwelling lizards, the contemporary terrestrial fauna is restricted to pheasant (*Phasianus colchicus mongolicus* J. H. Brandt), quail (*Lophortyx californicus vallicola* Ridgway), mongoose (*Herpestes auropunctatus auropunctatus* [Hodgson]), native rats (*Rattus exulans hawaiiensis* Stone), and a large population of feral goats (*Capra hircus hircus* L.).

FISHPONDS (Figs. 2 and 3)

There are four major fishponds at Kalāhuipua'a--two open to the sea (Lāhuipua'a and Waipuhi Ponds), and two closed (Manoku and Hopeaia Ponds)--in addition to more than 20 smaller ponds or water-filled caves and crevasses between Pauoa Bay and the edge of the Kanikū Flow. Holthius (1973) termed the closed type of pond "anchialine," and noted that these fragile pond ecosystems are characterized by a highly distinctive fauna of which perhaps the most striking example is the minute, red, endemic atyid shrimp (*Halocharadia rubra* Holthius). The two large, open ponds are separated from Makaīwa Bay by artificial walls built on low sand spits, and have gateway structures (*mākāhā*) permitting regular tidal flow between the ponds and the ocean (Kikuchi and Belshé 1971). Consequently, these open ponds have greater salinity than the closed ponds and a greater species diversity.

Several distinctive features characterize both anchialine and open ponds (Maciolek and Brock 1974): (1) they have rocky basins formed by depressions in the lava; (2) they are lined with biogenic sediments; (3) pond waters are mixohaline, with salinity averaging about 7°/oo; and (4) pond levels are subject to tidal fluctuation. Pond flora largely comprises encrusting algal communities, with colonies of the vascular aquatic pondweed *Ruppia maritima* L. where biogenic sediments are present. Kikuchi and Belshé (1971:B65) have remarked concerning Manoku Pond: "The water is murky and some filamentous algae and perhaps phytoplankton can be seen in it. The bottom shows benthic algae and some flocculent matting."

Pond fauna includes several edible species of molluscs, crustacea, and fish. Diversity of fish species is considerably greater in the open ponds; the populations of edible brackish-water molluscs are higher toward the inland portions of these open ponds where freshwater outflow is greatest. Large populations of the edible gastropod *Theodoxus cariosus* (Wood) (Edmondson 1946:166; Brock and Brock 1974; Maciolek and Brock 1974:68) and of the bivalve *Isognomon (Melina) californicum* (Conrad) (Edmondson 1946:193) are found around the pond margins (Fig. 4) and were heavily exploited by the prehistoric human occupants of Kalāhuipua'a (see Faunal Analysis, p. 121). Also exploited was the smaller bivalve *Brachidontes cerebristriatus* (Conrad) (Edmondson 1946:191). The ponds breed large numbers of edible shrimp, *Macrobrachium grandimanus* Randall.

(BPBM Neg. No. HA(a)217-10)

Fig. 2. VIEW OF FISHPONDS AT KALĀHUIPUA'A (facing W).

In the larger of the closed ponds are found four species of fish: mullet (*Mugil cephalus* L.), milkfish or *awa* (*Chanos chanos* [Forskål]), *papio* (*Caranx ignobilis* [Forskål]), and *aholehole* (*Kuhlia sandvicensis* [Steindachner]) (Gosline and Brock 1960:97, 154, 159, 176-177). In addition to these species, the open ponds contain convict tang or *manini* (*Acanthurus triostegus sandvicensis* Randall), barracuda or *kaku* (*Sphyraena barracuda* [Walbaum]), a species of moray eel, and others (Gosline and Brock 1960:153, 245-246).

MARINE ENVIRONMENT

Littoral and marine habitats vary considerably in the Kalāhuipua'a area, from sandy beach with limited fringing reef offshore around Pauoa Bay and along Keanapukalua Point, to sheltered Makaīwa Bay with its well-developed reef ecosystem, to the jutting lava headlands of Wa'awa'a Point. The reef ecosystem of Makaīwa Bay is built from corals of the genera *Montipora*, *Pocillopora*, and *Porites*, and has sizeable bottom-dwelling populations of sea urchins (Fig. 5) (*Echinothrix calamaris* [Pallas], *Echinometra mathaei* [Blainville], *Heterocentrotus mammillatus* [L.], and *Colobocentrotus atratus* [L.]), sea cucumbers (*Actinopyga mauritiana* [Quoy and Gaimard] and *Holothuria atra* Jager), spiny lobster (*Panulirus penicillatus* [De Siebold]), octopus (*Polypus* sp.), and molluscs. Brock and Brock (1974, Appendix D) have itemized and roughly quantified 92

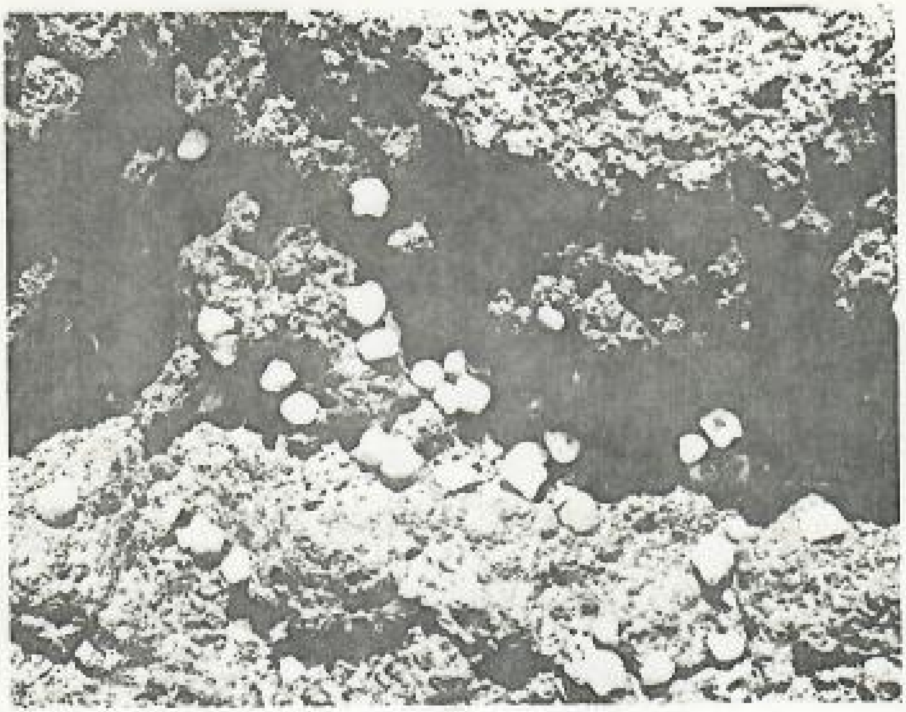
(BPBM Neg. No. HA(a)216-20)
Fig. 3. VIEW OF FISHPONDS AT KALĀHUIPUA'A (facing S).

species of fish noted during a faunistic survey of Makaīwa Bay. The rocky littoral habitats, particularly in the region of Wa'awa'a Point, support large numbers of certain gatropods that were heavily exploited in prehistoric times: *Nerita picea* Recluz, *Drupa ricina* L., *Cypraea caputserpentis* L., *Cypraea mauritiana* L., and *Cypraea maculifera* Schilder (Edmondson 1946:133, 145-148, 166).

MAJOR BIOTOPES

The importance of microenvironmental variation for prehistoric human adaptation to and exploitation of the environment has long been noted (Coe and Flannery 1964). The Kalāhuipua'a region can be segmented and classified into six biotopes, or microenvironmental zones, on the basis of differences in substrate and biota. Each biotope has particular and distinctive features with regard to prehistoric Hawaiian adaptation.

Biotope I. Open Sea. The offshore or pelagic region of deep water, the habitat of larger fish (e.g., *ulua*, Family Carangidae, *aku*, *Katuwonis pelamis*, and *ahi*, *Neothunnus* sp.), exploitable by trolling and other fishing methods.



(BPBM Neg. No. HA(a)216-36)

Fig. 4. *THEODOXUS CARIOSUS* SNAILS, AN IMPORTANT PREHISTORIC FOOD RESOURCE, ALONG THE MARGINS OF WAIPUHI FISHPOND.

(BPBM Neg. No. HA(a)213-28)

Fig. 5. A DENSE POPULATION OF SEA URCHINS (*Colobocentrotus atratus* L.), AN IMPORTANT PREHISTORIC FOOD RESOURCE, ON A LAVA-ROCK SHELF IN THE SURGE ZONE NEAR SITE E1-324.

Biotope II. The inshore or benthic region, primarily the coral reef ecosystem of Makaīwa Bay, with a diverse number of reef fish, echinoderms, octopus, lobster and other crustaceans, and bottom-dwelling molluscs. Exploitable by angling, netting, spearing, and octopus luring.

Biotope III. Littoral fringe. The lava rock substrate forms a habitat for numerous edible sea urchins, molluscs, and seaweed species, which are easily gathered at low tide.

Biotope IV. The fishponds, including three sub-biotopes: IV(A), the ponds proper, with their fish populations; IV(B), the littoral fringes with mollusc populations, particularly of *Theodoxus cariosus* and *Isognomon californicum*; IV(C), the vegetated riparian margins of the ponds, dominated by coconut palms and *milo*.

Biotope V. The biotically impoverished, older-pahoehoe lava flats inland of the fishponds. Caves were available for shelter and habitation, and scoriaceous lava for abraders.

Biotope VI. The barren aa Kanikū Flow, an entirely negative region with regard to human exploitation.

Ethnohistoric data (see Buck 1957; Reinman 1967) indicate a variety of prehistoric Hawaiian marine exploitation methods, with specialized equipment and facilities. Table 1 indicates which of these methods would have been applicable in each of the four marine biotopes.

Table 1.

CORRELATION OF ETHNOHISTORICALLY DOCUMENTED* METHODS OF MARINE EXPLOITATION WITH KALĀHUIPUA'A BIOTOPES

	Biotope			
Exploitation Technique	I Pelagic	II Benthic	III Littoral	IV Fishponds
Gathering			X	X
Fish traps		X		X
Netting				
Hand nets		X	X	X
Seine nets		X		X
Spearing		X		X
Octopus lure method		X		
Angling				
Small hooks		X		?
Shark hooks	X			
Trolling	X	?		

*Buck 1957; Reinman 1967.

ENVIRONMENTAL DYNAMICS

In assessing the nature of the Kalāhuipua'a environment with regard to prehistoric Hawaiian occupation, it is extremely important to avoid the facile assumption that the natural ecosystem has remained relatively static during the term of such occupation. The introduction of foreign plants and animals has obviously resulted in considerable modification in the past two centuries. Far more significant, however, is the evidence (Apple and Macdonald 1966) that the shoreline has subsided by as much as 1.6 meters since c. A.D. 1200. Independent confirmation of such shoreline subsidence was obtained during the present investigation, and will be discussed below. The implication that the shallow anchialine and even the deeper open ponds may not have been in existence, or were considerably smaller during the period of Hawaiian occupation, must be accounted for in any interpretation of human adaptation to the Kalāhuipua'a area.

SURVEY

SUMMARY OF ARCHAEOLOGICAL SITES

A total of 179 archaeological sites, both prehistoric and historic, were recorded during the field survey--105 sites were found in Kalāhuipua'a-'Anaeho'omalu, 15 sites in Lālāmilo, and 59 sites in Waikoloa. In addition, several sites had been previously recorded during initial survey (Ching 1971) and subsequent salvage (Rosendahl 1972b) of the Kawaihae-Kailua Highway corridor.

Some sites contain only a single feature (e.g., an isolated petroglyph) whereas others include a complex of features (e.g., a cluster of several C-shaped structures around a shelter cave). Of greater significance for archaeological interpretation, therefore, is the distribution of features, by formal or functional category. Table 2 gives a breakdown of all 449 archaeological features recorded during the survey according to 21 feature categories or types.

Table 2.

DISTRIBUTION OF FEATURES BY *AHUPUA'A* AND CATEGORY

Feature Category	Kalāhuipua'a-'Anaeho'omalu E1*		Waikoloa E2*		Lālāmilo E3*		Totals	
	N	%	N	%	N	%	N	%
Shelter Caves	29	14	17	<8	1	3	47	10
Surface-Midden Scatter	2	1	1	<1			3	1
C-shaped Shelters	81	38	105	51	23	77	209	47
Platforms	5	2	2	1	1	3	8	2
Rectangular Enclosures	5	2					5	1
Circular Enclosures	31	15	4	2	1	3	36	8
Cairns	6	3	57	27			63	14
Petroglyphs	9	4	1	<1	1**	3	11	2
Papamu	3	1					3	1
Shrine	1	<1					1	<1
Steppingstone Trails	3	1					3	1
Aa Clinker Trails	3	1	1	<1			4	1
Abrader Manufacture Areas	15	7	13	6			28	6
Ponds	2	1					2	<1
Fishpond Wall	1	<1					1	<1
Burial Caves	4	2	5	2			9	1
Burial Cist	1	<1					1	<1
Misc. Structural Features	11	5					11	2
Māmalahoa Trail			1	<1			1	<1
Historic Cemetery					1	3	1	<1
Historic Pen Walls					2	7	2	<1
TOTALS	212		207		30		449	

*E = District of South Kohala; number stands for designated *ahupua'a*.

**Puako petroglyph fields (E3-1), including c.3,000 units.

The following paragraphs summarize the major feature categories listed in Table 2, with particular reference to the attributes of such features within the survey area. Some comparative remarks relating these features to those surveyed in adjoining regions are also made.

Shelter Caves

Geologically, much of the region inland from the Kalāhuipua'a fishponds is composed of pahoehoe lava, distinguished by its smooth or ropy surface. Lava draining out from beneath the surface of the flow often leaves lava tubes (Stearns and Macdonald 1946). When portions of the tube roof collapse, forming sinks, the tube may be exposed; these opened chambers formed convenient habitation places for the aboriginal Hawaiians. Forty-seven of these shelter caves, containing midden material, were located during the survey. The midden is generally composed of shellfish, animal and fish bone, and plant material that accumulated as a result of prehistoric activity in the caves. Many of the shelter caves in the survey area have deep deposits. Some of the caves also contain structural modifications, especially low walls, terraces, or cleared areas.

Surface Midden Scatters

Midden material and/or artifacts may simply be distributed over the ground surface, testifying to previous human activity in the area.

C-shaped Shelters

These stone structures have been widely reported throughout the Hawaiian Islands, particularly in the drier leeward regions. They are small, walled structures with a ground plan resembling a "C," usually open on the seaward side. Some, such as those at inland Lapakahi (Rosendahl 1972a), contain midden deposits and indicate use over a considerable time span. Others, especially those at 'Anaeho'omalu (Barrera 1971a) and in the present survey area, are simple, crude affairs, often built directly on the lava flow, with little or no associated midden. These apparently served as temporary shelters, and are closely associated with trails and abrader manufacturing areas.

Platforms

These are raised stone structures, often paved with waterworn pebbles or gravel (*'ili'ili*). In many cases they were foundations for perishable house structures. Others may contain burials. Until excavation demonstrates specific functions for individual sites, this general formal category is used.

Rectangular Enclosures

These rectangular stone-walled structures generally functioned as habitation sites, the superstructure again being perishable. The floors are sometimes paved with waterworn pebbles. At least one example in the survey area (Site E1-381) contains a stone-lined hearth.

Circular Enclosures

Crudely built, circular-walled enclosures, usually less than 2 meters in diameter, are plentiful in the survey area, where they are often found directly on the aa lava flow. Generally only sparse midden is associated. There may be a small amount of waterworn-pebble paving on the floor. In function, they are analogous to the C-shaped structures.

Cairns

Low cairns of piled lava were found throughout the survey area and probably served as markers for various purposes. A cluster of c. 50 cairns (Site E2-83) was found on either side of a trail (Site E2-82) across the Kanikū lava flow. This cluster may represent a prehistoric boundary.

Petroglyphs

These rock carvings were found, usually in clusters and rarely as isolated examples, in the survey area from Puakō to Kalāhuipua'a. Hawaiian petroglyphs, including many of those in the survey area, have been analyzed in detail by J. Halley Cox with Edward Stasack (1970). One of the largest and best-known clusters of petroglyphs in the Hawaiian Islands, those at Paniau and Kaeo (Puakō) are included within the survey area. This site, E3-1, containing c. 3,000 petroglyph units, was mapped in detail by the Bishop Museum in 1964. Another cluster, at Kalāhuipua'a (Site E1-5), was mapped during the 1973 survey (Kirch Ms.a). Petroglyphs may be considered from both artistic and anthropological viewpoints and represent a wealth of information on prehistoric and early contact-period Hawaiian culture. All petroglyph sites in the survey area have been assigned the highest category for preservation.

Papamū

A kind of petroglyph, these are rectangular grids of small holes pecked into the pahoehoe lava, used as the playing board for *kōnane*, a traditional Hawaiian game (Cox with Stasack 1970: 34; Buck 1957:369).

Shrine

One site (E1-334) within the survey area--a shelter cave--has been interpreted as a shrine. The distinguishing attribute is a raised platform on which is situated a waterworn elongate cobble in upright position. Such waterworn cobbles were widely used in precontact Hawaii as representations of "family" or local social-group deities (*'aumakua*) (Buck 1957:495-496). Similar shrines are known elsewhere in the islands.

Steppingstone Trails

Three trails of this type were recorded within the survey area, all on the rough Kanikū flow. Apple (1965:1-30) refers to these as "Type A" trails, formed by placing waterworn cobbles as steppingstones. Such trails were used extensively in prehistoric times. The three trails in our survey area, connecting a number of prehistoric sites, were certainly constructed in precontact times, although they were probably used well into the historic period.

Aa Clinker Trails

This is another variant of Apple's "Type A" trail, marked by use-worn aa clinker rather than by waterworn-cobble steppingstones. Fissures in the lava flow that are crossed by the trails have sometimes been filled. These trails are generally only wide enough for foot traffic. One such trail (Site E2-82), however, had apparently been widened for horse traffic in historic times; several rusted horseshoes were noted along its course. These modified trails are included in Apple's "Type AB" (1965:65).

Abrader Manufacturing Areas (Fig. 6)

One of the major tool types used by the prehistoric Hawaiians to manufacture bone artifacts (especially fishhooks) is the lava abrader. These abraders were made by grinding down blocks of the vesicular, scoriaceous pahoehoe lava to a desired shape. Areas in which such abraders were prepared are marked by numerous, shallow, smooth depressions on the pahoehoe surface, worn down through the action of grinding. Scattered around these manufacturing areas are finished and unfinished lava abraders. Such abrader manufacturing areas have been investigated by Barrera (1971a), Ching (1971), and Rosendahl (1972b).

(BPBM Neg. No. HA(a)225-3)

Fig. 6. ABRADER MANUFACTURING DEPRESSION.

Ponds

Aside from the large, well known ponds of Kalāhuipua'a, the survey also recorded two smaller ponds, both containing brackish, but probably potable, water. Steppingstone trails leading to the sites evidence that they were used in prehistoric times.

Fishpond Wall

In recent years, all of the functional fishpond walls at Kalāhuipua'a have been reconstructed using concrete; thus it is difficult to determine their original structure and function. One submerged wall foundation was located, however, and is described below (Site El-374).

Burial Caves

Nine burial caves were discovered during the survey. Most of these contain single burials. One large cavern complex (E2-56), however, contains 30 individuals, as well as canoe segments and other artifacts. This cave, similar to those recorded by Barrera (1971a: 78) at 'Anaeho'omalu, was probably the sepulcher of single social group. The majority of the burials found during the survey are probably of prehistoric age.

Burial Cist

One burial cist, on a high aa clinker hill overlooking Honoka'ope Bay, was located (Site El-401). This cist, containing at least three individuals, is described below.

SITE DESCRIPTIONS

The following section presents the essential results of the survey, providing detailed descriptions of individual sites. Presentation order is numerical; sites are located on the survey area maps (Figs. 7 to 11). Figure 7 is a master map of the entire survey area, and shows the locations of the four detailed location maps, Figures 8-11.

Table 3 provides a numerical listing of all sites recorded during the survey and their status ratings.

El-5 Petroglyphs

This site, assigned this number by Cox with Stasack (1970:85) is identical with Site El-342, to which the reader should refer.

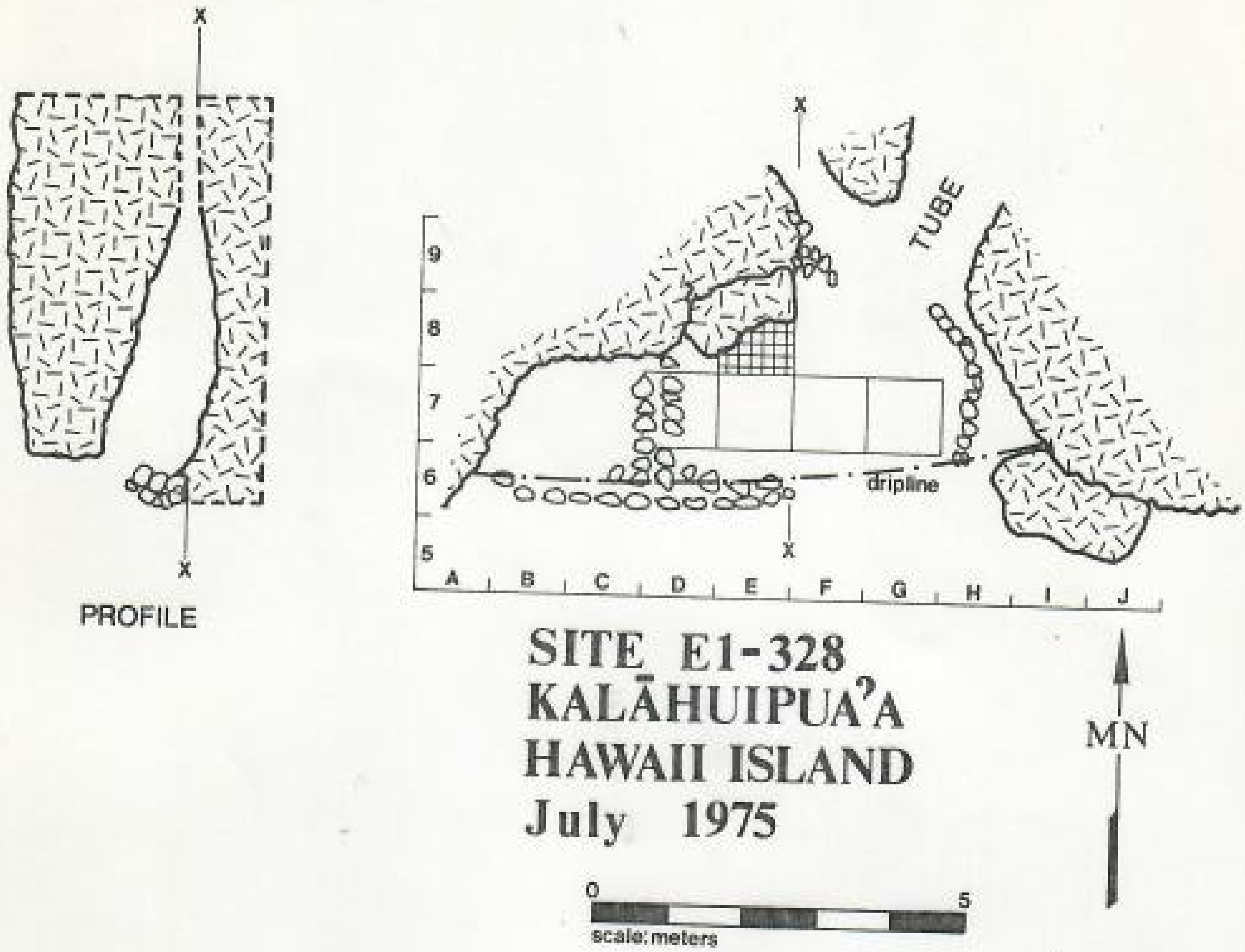


Fig. 36. PLAN AND PROFILE OF SHELTER CAVE SITE EI-328, SHOWING EXCAVATION GRID.

midden, of which 94.36% is shellfish remains. Two basaltic-glass flakes, dated with hydration-rind technique, indicate a temporal span of c. A.D. 1650-1725, although use of the site was probably restricted to a single, short-term event (as with Site E1-327).

SITE E1-342

Description

Site E1-342 is a large, airy, lava-tube shelter cave, opening inland to a collapsed sink. The site is relatively close to Hopeaia Fishpond. On the outside surface of the smooth pahoehoe that forms the cave roof are numerous petroglyphs, originally given site number E1-5 (Cox with Stasack 1970:85). In 1973 we recorded this petroglyph complex at 1:25 (Figs. 37, 38). A second, smaller group of figures is situated on the opposite side of the sink, and was also recorded in 1973 (Fig. 39). There are numerous, and often deep, abrader manufacturing depressions in the area.

Fig. 37 VIEW OF PETROGLYPHS ABOVE SITE E1-342.

A plan view of the shelter cave is shown in Figure 40. The outer area of the shelter, where the major cultural deposit is located, measures roughly 17 meters wide and 10 meters deep; in the center of this area the ceiling is slightly more than 2 meters above the top of the cultural deposit. A low wall of lava rubble separates the outer chamber from a lower, narrower lava tube which bifurcates in two directions, to the S and to the W.

A unique find was made in the W lava tube, in a high, narrow chamber, reached by crawling through a constricted part of the tube where the ceiling is only 30 to 50 cm high. The find was a cache of 16 wooden fishhooks, of varying sizes and forms, and in several stages of manufacture. Several of these are evidently shark hooks (Buck 1957:338-342). The hooks lay directly on the lava bedrock floor of the chamber (Fig. 41), and are in a relatively good state of preservation; they are described in the Artifacts section (p. 157 ff). The cache presumably represents a "kit" belonging to a single individual.

Previous Investigations (1955)

Site E1-342 was test excavated in July 1955 by a Bishop Museum field party under the direction of K. P. Emory (assisted by Y. Sinoto, W. Bonk, and V. Kobayashi). They assigned the site number H100, and dubbed it "Kulia Cave," after Julia Brown (a relative of the previous land owner). On two separate days, Emory's crew excavated seven 3-by-3-ft pits (see Fig. 40). From these, 89 artifacts were recovered; midden and basaltic glass apparently were not saved. The artifacts were primarily abraders (78 specimens, of echinoid spine, coral, and scoriaceous lava), but also included a wooden fire plow, a bone two-piece fishhook point, and a small basalt adz.

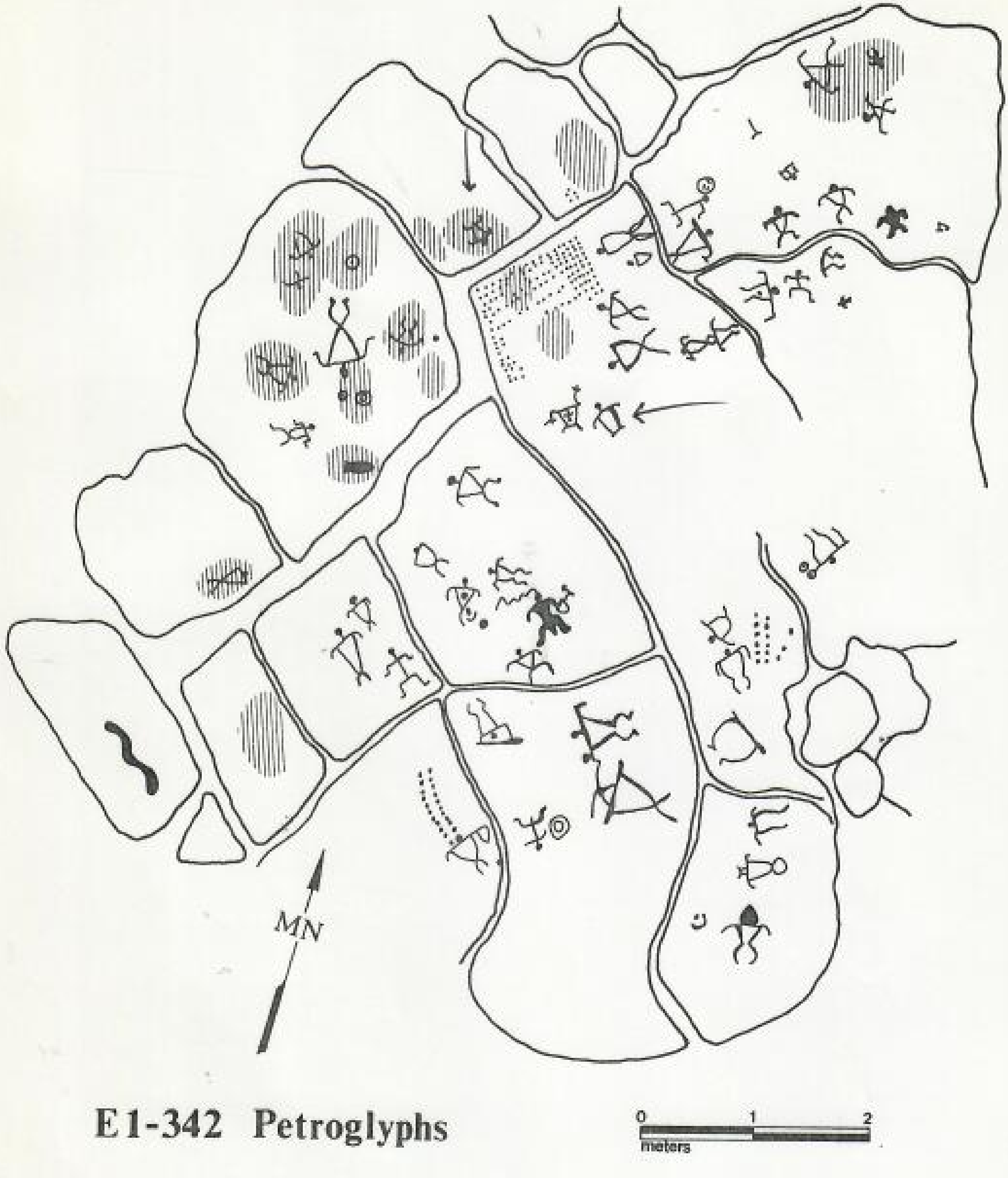


Fig. 38. PETROGLYPHS ABOVE SITE E1-342.

available for reference. In Table 9, both the measured rind thicknesses (range and mean) and the calculated ages are given. The ± factor is based on range of rind thickness and on instrument error (microscope resolution) and represents the total range for the age determination; it is not a statistical standard deviation.

In Figure 60, the results as reported in Table 9 have been graphed by site, showing mean age determinations and ranges.

These results are analyzed briefly below, with regard to the five specific objectives listed above; further consideration of these age determinations and their importance in an areal chronology for the West Hawai'i region is presented in the Concluding Discussion.

1. The approximate date for initial occupation and/or utilization of the Kalāhuipua'a area can be fixed by the earliest age determinations for Sites E1-355 and -342. These samples (HIG-655, -656, and -663) indicate that the two sites were first occupied in the early 1200s. Both sites are ideal cave shelters for temporary occupation, are close to the fishponds, and could be expected to have been among the first sites occupied.

2. Abandonment of Kalāhuipua'a by the indigenous Hawaiian population seems to have occurred during the 1700s, and to have been fully accomplished by the beginning of the 19th century. There is some evidence, however, at Sites E1-324, -368, and -342, that depopulation, or decreasing use of the area, may have begun as early as A.D. 1650. In the case of Site E1-324 this may be attributed to flooding of the cave due to shoreline subsidence, but this natural cause cannot explain the other instances. Thus the Kalāhuipua'a data tentatively confirm Barrera's conclusions regarding late prehistoric depopulation (1971a:107-108; Barrera and Kelly 1974:62). Potential causes are considered in the Concluding Discussion.

3. Temporal ranges of occupation for the nine excavated sites have been determined fairly precisely (see Fig. 60). Sites E1-355 and -342 were occupied first, and longest. The remaining sites were all occupied after A.D. 1400, and most during the period A.D. 1500-1700. The majority of the sites thus are pene-contemporaneous, i.e. their contemporaneity has been demonstrated within the degree of accuracy allowed by the hydration-rind method.

4. The correlation between stratigraphic depth and age estimates from excavated sites, particularly from Site E1-355, indicate steady rates of midden accumulation, and support the thesis that the more-or-less amorphous deposits are horizontally stratified (see p. 97). Specific rates of accumulation vary, but appear to have been fairly slow and regular within each site (e.g. 17 years per cm in Site E1-355).

5. Age determinations of surface-collected glass from open sites (E1-315, -347, -376, -380, -381, and -393) demonstrated a late prehistoric (c. A.D. 1500-1750) time range. Clearly, the majority of settlement pattern components at Kalāhuipua'a can be assigned to the late prehistoric period, specifically after A.D. 1500 but prior to major European contact.

ANALYSIS OF FAUNAL AND FLORAL MATERIAL

AIMS

As noted in the Introduction, the 1975 investigations at Kalāhuipua'a were designed to incorporate extensive analysis of midden deposits, in order to address certain problems of prehistoric Hawaiian marine exploitation. Midden analysis was directed to five specific aims:

1. To quantitatively sample each of the excavated cave-shelter midden sites so as to provide a record of midden content as part of the data base for each site.

2. To examine midden content with the objective of reconstructing as closely as possible dietary and consumption patterns.

3. To determine whether there were significant temporal changes in patterns of marine exploitation and diet, and if so, whether or not these might correlate with natural changes in the marine environment at Kalāhuipua'a.

4. To compare the results of midden analysis with the results of analysis of artifact assemblages in terms of general patterns of human adaptation to the marine ecosystem at Kalāhuipua'a.

5. To obtain data that could be utilized in estimating the size of the prehistoric populations which occupied the Kalāhuipua'a cave shelters.

The following pages present a summary of the methods used in analysis of the Kalāhuipua'a midden, and the basic results. Results are discussed in terms of major taxonomic categories of faunal and floral material. Further discussion and interpretation of these results in terms of diet, population, and adaptive change in marine exploitation are given in the Discussion.

METHODS

A midden is a complex entity, the result of a series of natural and cultural phenomena and processes. Archaeologists have only begun to recognize that analysis and interpretation of midden deposits requires that certain assumptions concerning the structure and formation of the midden be made explicit. Further, since it is rarely feasible to excavate a midden in its entirety, sampling methods must be devised and tested which will allow interpolation of total midden content with a minimum of sampling error.

The major phenomena and processes resulting in a midden deposit are outlined in the accompanying diagram (Fig. 61; see also Kirch and Rosendahl 1973:91). Essentially, we are concerned with the transformation of objects from what Schiffer (1972:157) has termed systemic context, in which the objects are participating in a behavioral system, to archaeological context, in which the objects are the subject of archaeological investigation. In the case of faunal materials, this involves, first, the cultural selection or exploitation of a set of natural species populations, second, the differential transport and deposition of these faunal entities by humans, and third, the effects of natural processes of decay and dispersion which act on the materials once they have been deposited in a site. The first two kinds of transformations listed above have been termed c-transforms (cultural), and the latter n-transforms (natural)(Schiffer and Rathje 1973; Schiffer 1975). It is necessary to further consider the effects of sampling, which may skew the patterning of an archaeological context as it is reconstructed, and interpreted, by the archaeologist.

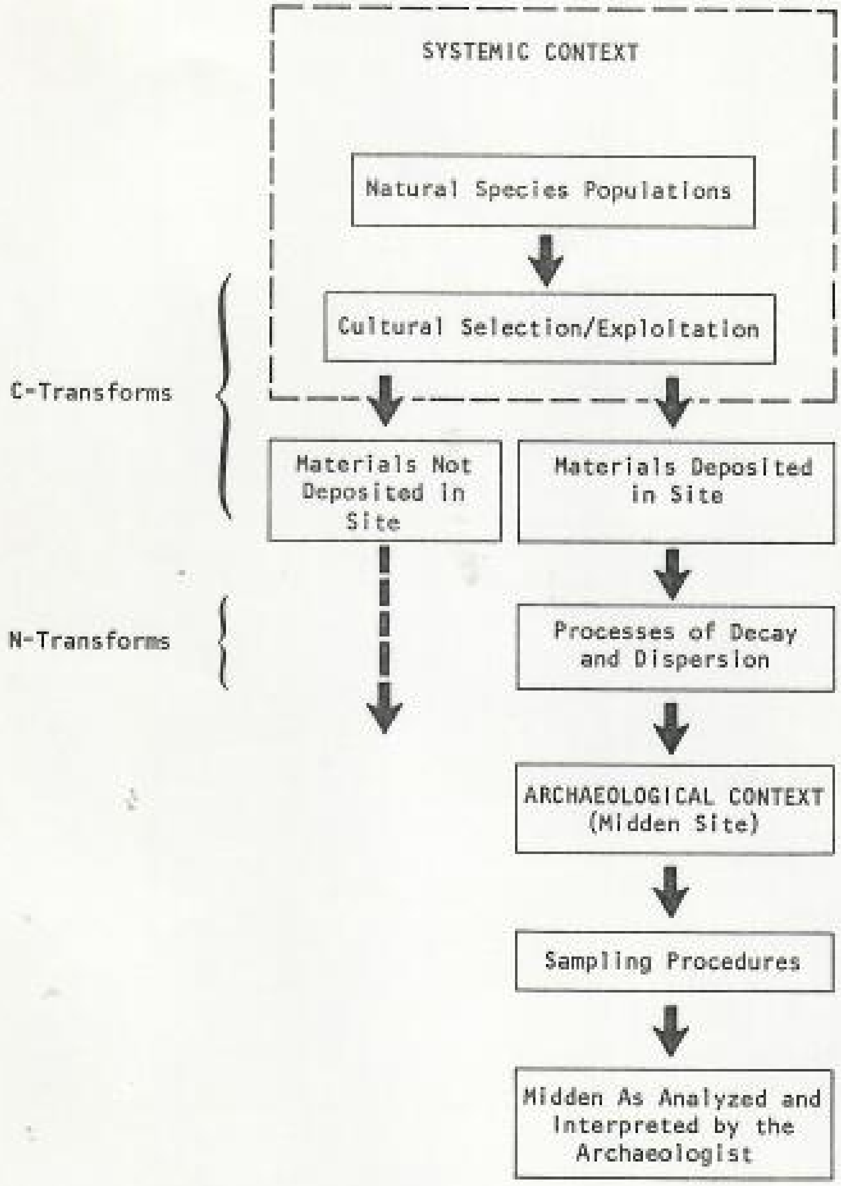


Fig. 61. DIAGRAM OF PROCESS OF MIDDEN FORMATION, INDICATING FACTORS THAT SKEW THE REPRESENTATION OF PAST BEHAVIORS.

The nature of prehistoric c-transforms is the most important problem for the interpretation of the Kalāhuipua'a cave-shelter middens. The literature of Polynesian ethnography, as well as as this author's personal experience in several Polynesian societies (Anuta, Futuna, Uvea), indicate that faunal materials are not uniformly deposited in occupation sites. For example, shellfish are frequently consumed and discarded on the reef, while fish may be cleaned and prepared at temporary camp sites. Thus, it is uncritical to assume that relative frequencies of midden materials in a site will accurately represent the relative consumption or utilization of these species by the prehistoric human population that occupied that area. Indeed, there is reason to hypothesize that fish are under-represented in the Kalāhuipua'a middens, since fish may have been transported to upland dwelling sites for consumption. Such consumption of fish in upland sites has been documented by Rosendahl for Lapakahi (1972a:424-426). For present purposes, it is important to maintain an awareness that c-transforms may have had important effects in skewing the sample of archaeological remains at Kalāhuipua'a.

The problem of n-transforms appears to be less critical at Kalāhuipua'a. It is important to note that the Kalāhuipua'a cave-shelter middens are of the concentrated variety and that they are finite and bounded (with important sampling implications). They are also protected by the nature of their bounding bedrock walls. Further, the hot arid climate of West Hawai'i favors preservation of faunal and floral remains rather than disintegration. Selective decay of materials, a common problem on open sites (particularly in humid areas with acidic soils), is not therefore a major consideration in the interpretation of the Kalāhuipua'a sites. We are probably justified in assuming that once materials were deposited in the cave middens, they were not significantly disturbed or alterred, except by the rearranging actions caused by human occupants themselves.

The finite, bounded, and concentrated nature of the Kalāhuipua'a cave-shelter middens simplifies archaeological sampling, alleviating several problems encountered in open sites (Ambrose 1967). During the 1975 excavation, two sampling procedures were utilized. Molluscan remains, which composed the bulk of all deposits (usually more than 90% by weight), were sampled by retaining the contents of at least one square meter in each site, and screening the deposit through 0.25-inch mesh. This procedure yielded samples ranging from c.20% to c.80% of the total universe of each cave midden. While the sheer quantity of molluscan remains necessarily required the above sampling design, a different procedure was used for bone and plant remains. These were quantitatively retained from all excavated units of each site. The sample size of bone and plant materials is thus equal to the size of the excavated sample of these materials for the entire site.

Screen size itself induces a sampling bias, and has been the subject of considerable methodological controversy. In order to test the effects of the 0.25-inch mesh used in the Kalāhuipua'a excavations, 200-gram samples of screened residue from each of three sites (E1-342, -355, and -368) were further analyzed in the laboratory in order to determine the quantity and nature of the materials which were not retained in the 0.25-inch mesh screens. A similar test had been applied to screened deposit residue at site HA-D4-51 at Kahalu'u (Kirch 1973a:24, Table 3). The 200-gram samples were sifted through a set of five nesting screens, with mesh diameters of 5, 3, 2, 1, and 0.5 mm. Results are presented in Table 10, indicating that only the fractions retained in the 5-mm and 3-mm screens were identifiable. On the whole, this experiment indicated that less than 5% of the total molluscan and bone materials passed through the 0.25-inch mesh screen, confirming expectations based on previous results (Kirch 1973a:24). Screen mesh size is thus discounted as significant skewing factor in the sampling of the Kalāhuipua'a middens.

Table 10

RESULTS OF FINE-SCREENING OF SIFTED SOIL SAMPLES FROM THREE EXCAVATED SITES*

Category of Identifiable Material	Weight of Residue (gm) by Site and by Screen Mesh Diameter (mm)																	
	Site El-342						Site El-355						Site El-368					
	5	3	2	1	0.5	Pan	5	3	2	1	0.5	Pan	5	3	2	1	0.5	Pan
Rock	9.1	22.0					8.5	21.0					6.6	20.9				
Coral		+					+	+					+	+				
Shell	1.7	3.7					1.2	5.1					1.8	3.0				
Echinoderm	0.3	1.8					0.3	4.9					0.2	3.9				
Crustacea														+				
Fish Bone	+	+	+	+	+		+	0.2		+			+	+	+	+		
Charcoal	+	+						+						+				
Unsortable Fraction			17.2	24.6	20.3	97.0			20.3	27.8	18.9	89.0			22.1	34.3	22.1	82.9
Total Weight	11.5	27.5	17.2	24.6	20.3	97.0	10.5	32.2	20.3	27.8	18.9	89.0	8.8	28.8	22.1	34.3	22.1	82.9

+ = Trace present, ≤0.1 gram.

*All samples 200 grams.

ANALYSIS OF QUANTITATIVE SQUARES

The complete contents of a 1-square-meter excavation unit, as retained by the 0.25-inch-mesh screens, were analyzed for each of the following sites: E1-324, -327, -328, -342, -350E, -355, -368, and E2-51. Composition of these samples, by weight, is indicated in Tables 11 through 18, following a standard format to facilitate comparison. The data for all sites are summarized in Table 19 as percentage composition, by weight of major midden categories. In all cases, molluscan remains constituted the majority of the midden, ranging from 87.46% (E1-324) to 97.59% (E2-51) of the total midden weight. Bone, whether of mammal (dog, pig, rat), fish, or bird, usually comprised less than 0.1% of the total quantitative sample weight.

In addition to the excavated samples, quantitative samples of surface midden were analyzed from Sites E1-381, E1-343, and E1-404d (.25 square meter each), and from two locations at Site E3-21 (quads I and II, 1 square meter each). Sites for the surface midden analysis were selected on the basis of their ecological settings, with the object of trying to encompass as much variation as possible. Site E3-21 is situated above Puakō Bay, an area with exposed basalt rocks at the shoreline, and shallow, muddy, or sandy bay. Site E1-343, a cave shelter, lies inland of the Kalāhuipua'a fishponds, with their unique populations of brackish-water fauna, particularly the gastropod *Theodoxus cariosus*. Site E1-381, a rectangular habitation enclosure, commands easy access to the rocky shore at Wa'awa'a Point and Ili'ilinaehehe Bay. Site E1-404d is situated on a rocky point next to the sand beach at Honokaʻope Bay. Results of surface midden sample analyses are presented in Table 20.

It is evident from the data in Table 20 that the surface midden samples do directly reflect the immediate coastal resources adjacent to the particular sites. The gastropods are especially good indicators. Large numbers of *Theodoxus cariosus*, which thrive in the brackish-water fishponds, were found at Site E1-343. Site E1-381 has a high percentage of gastropods with a rocky surge-zone habitat (*Cypraea* spp., *Drupa* sp.), conforming to the coastal environment adjacent to E1-381. The bivalve *Periglypta reticulata* at Site E3-21 is indicative of the nearby shallow-bay ecology at Puakō.

MOLLUSCS AND OTHER INVERTEBRATES

Mollusca

As noted above, molluscs generally compose more than 90% of the total weight of midden at the Kalāhuipua'a cave-shelter sites. Table 21 indicates the number of gastropod and pelecypod species at each site. The dominance of gastropods (80.2% of all mollusc species) reflects the relative composition of the Hawaiian molluscan fauna in general (Kay 1967, table 1), and not a selective preference on the part of the prehistoric human population.

Five genera of molluscs (*Nerita*, *Theodoxus*, *Cypraea*, *Brachidontes*, and *Isognomon*) constitute nearly 90% of the total weight of molluscan midden, and were evidently the major shellfish contributors to the diet of the persons residing in the Kalāhuipua'a caves. These are listed in Table 22, with their relative percentage composition by site. Included also in Table 22 is *Cellana* (synonym *Helcioniscus*), a genus that was often a major contributor to the prehistoric Hawaiian diet, and is still of commercial value (Kay and Magruder 1975). As indicated in Table 22, *Cellana* is represented only in minor quantitities in the Kalāhuipua'a sites.

Table 11

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM

SQUARE F6, SITE E1-324

Material	Weight (gm) per Depth Increment		
	0-10 cm	10-20 cm	20-30 cm
SHELL			
<u>Gastropoda</u>			
Cellana spp.	7.2	13.5	8.0
Conus spp.	9.9	16.3	1.7
Cymatium spp.	1.7		
Cyprasa caputserpentis L.	305.9	259.7	276.7
Cyprasa maculifera Schilder	14.9	65.4	--
Cyprasa spp.	--	--	16.8
Drupa morum Röding	--	2.5	4.2
Drupa ricina L.	8.1	10.2	11.0
Littorina pintado (Wood)	0.4	--	1.2
Melampus semiplicatus Pease	0.3	0.6	0.4
Morula spp.	1.7	0.8	3.0
Nerita polita L.	13.5	8.6	8.0
Nerita spp.	120.3	77.1	118.7
Opercula	--	--	0.4
Strombus maculatus Sowerby	5.0	11.3	5.0
Theodoxus sp.	91.1	126.0	109.7
Trochus histrio Reeve	--	--	1.1
Unidentified shell	11.1	20.4	17.0
<u>Pelecypoda</u>			
Brachidontes cerebristriatus (Conrad)	0.1	0.1	0.1
Isognomon sp.	55.8	42.8	38.9
Periglypta reticulata (L.)	--	1.0	1.7
Tellina (Quidnipagus) palatam (Iredale)	8.6	12.6	19.7
TOTAL SHELL	655.6	668.9	643.3
ECHINODERMATA			
Heterocentrotus mammillatus (L.)	3.4	5.7	9.5
Unidentified	4.5	1.6	1.9
BONE			
Mammal	--	--	0.5
Fish	1.3	1.6	4.3
MISCELLANEOUS			
Coral	18.7	29.8	23.1
Charcoal	1.0	0.1	0.9
GRAND TOTAL	684.90	707.70	683.50

Table 12

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM SQUARE E14, SITE E1-327

Material	Weight (gm) per Depth Increment	
	0-10 cm	10-20 cm
SHELL		
Gastropoda		
Cellana spp.	0.4	1.5
Conus spp.	0.9	1.2
Cymatium spp.	0.1	--
Cypraea caputserpentis L.	121.8	75.9
Cypraea maculifera Schilder	14.7	13.1
Drupa morum Röding	--	1.4
Drupa ricina L.	--	8.8
Littorina pintado (Wood)	0.3	--
Mitra sp.	--	0.4
Morula sp.	0.2	--
Nerita picea Recluz/*Theodoxus neglectus* (Pease)	7.0	3.7
Nerita polita L.	0.3	--
Strombus maculatus Sowerby	2.3	0.1
Thais harpa (Conrad)	--	0.3
Theodoxus cariosus (Wood)	61.0	144.2
Unidentified shell	3.7	5.0
Pelecypoda		
Brachidontes cerebristriatus (Conrad)	0.1	--
Isognomon californicum (Conrad)	11.8	19.4
Periglypta reticulata (L.)	0.7	--
TOTAL SHELL	225.3	275.0
ECHINODERMATA		
Heterocentrotus mammillatus (L.)	3.2	--
Unidentified	0.1	0.4
CRUSTACEA	1.0	--
BONE		
Fish	0.1	0.1
Bird	0.1	0.3
MISCELLANEOUS		
Coral	9.0	0.3
Candlenut	0.6	1.9
GRAND TOTAL	239.4	278.0

Table 13

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM

SQUARE E8, SITE E1-328

Material	Weight (gm) per Depth Increment	
	0-10 cm	10-20 cm
SHELL		
Gastropoda		
Cellana spp.	--	0.2
Cypraea caputserpentis L.	53.2	112.1
Drupa morum Röding	1.5	--
Drupa ricina L.	1.0	8.5
Nerita picea Recluz/*Theodoxus neglectus* (Pease)	2.3	4.1
Theodoxus cariosus (Wood)	37.0	81.0
Unidentified shell	2.9	1.8
Pelecypoda		
Brachidontes cerebristriatus (Conrad)	--	0.1 (1 piece)
Isognomon californicum (Conrad)	2.4	9.5
Periglypta reticulata (L.)	--	0.5 (1 piece)
TOTAL SHELL	100.3	217.8
ECHINODERMATA		
Heterocentrotus mammillatus (L.)	4.5 (1 piece)	--
Unidentified	0.1	--
BONE		
Mammal	12.7	1.3
Bird	0.1	--
MISCELLANEOUS		
Coral	0.3 (1 piece)	--
GRAND TOTAL	118.0	219.1

Table 14.

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM SQUARE H10, SITE E1-342

Material	Weight (gm) per Depth Increment 0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60-70 cm
SHELL							
Gastropoda							
Cellana spp.	8.5	--	0.4	0.4	0.1	--	--
Conus spp.	9.0	2.6	--	1.1	2.1	--	0.7
Cypraea caputserpentis L.	432.3	76.5	111.6	60.9	31.0	17.5	52.1
Cypraea maculifera Schilder	6.9	3.8	--	4.1	--	--	--
Cypraea mauritiana L.	3.0	--	--	--	--	--	--
Cypraea spp.	14.3	0.1	--	--	--	--	--
Drupa morum Röding	21.9	--	8.0	--	2.8	--	--
Drupa ricina L.	36.6	15.9	12.1	10.4	1.1	3.6	1.2
Hipponyx pilosus imbricatus Gould	--	0.1	0.2	--	--	--	--
Littorina pintado (Wood)	0.1	--	0.2	--	0.4	--	--
Morula sp.	1.7	--	0.1	--	--	--	--
Nerita picea Reclus/*Theodoxus neglectus* (Pease)	51.6	14.9	19.9	16.8	10.7	7.2	9.3
Nerita polita L.	6.7	1.5	0.3	2.0	--	--	--
Opercula	--	--	0.1	0.3	0.1	--	--
Strombus maculatus Sowerby	4.0	4.4	2.1	0.3	0.2	--	0.7
Thais aperta Blainvile	--	--	--	--	--	--	2.7
Thais harpa (Conrad)	0.1	--	0.1	0.2	--	--	--
Theodoxus cariosus (Wood)	--	--	--	--	39.7	22.8	23.1
Theodoxus sp.	162.8	68.7	98.6	65.4	--	--	--
Trochus histrio Reeve	--	0.6	0.8	4.3	2.1	--	0.1
Unidentified shell	37.1	10.0	10.3	2.3	2.2	2.3	1.1
Pelecypoda							
Brachidontes crebristriatus (Conrad)	3.0	2.5	2.4	1.4	0.7	0.5	1.1
Isognomon spp.	63.1	37.2	18.7	16.0	7.6	3.9	3.6
Periglypta reticulata (L.)	1.1	0.6	0.7				
Tellina (Quidnipagus) palatam (Iredale)	9.0	6.7	6.2	0.3	2.8	0.3	0.2
TOTAL SHELL	862.8	246.1	292.8	186.2	103.6	58.1	95.9
ECHINODERMATA							
Colobocentrotus atratus (L.)	--	0.2	0.6	--	--	--	--
Echinometra mathaei (Blainville)	0.1	0.3	--	--	<0.1	--	0.1
Heterocentrotus mammillatus (L.)	4.9	0.2	0.3	--	0.6	0.1	--
Unidentified	9.0	5.6	3.1	4.0	0.9	0.5	0.6
CRUSTACEA	0.3	0.1	0.2	0.1	0.1	--	--
BONE							
Fish	1.8	--	1.0	0.3	<0.1	<0.1	1.4
Bird, Feather	<0.1	--	<0.1	--	--	--	--
MISCELLANEOUS							
Coral	8.6	4.7	5.1	7.1	1.3	0.1	2.0
Candlenut	2.0	--	0.2	1.1	--	--	--
Charcoal	4.8	--	5.2	1.2	1.2	0.8	0.9
Coconut	2.9	--	--	0.5	--	--	0.4
Gourd	1.2	0.1	1.1	0.2	0.1	<0.1	--
Wood	3.6	1.0	4.5	2.0	0.1	0.6	0.1
GRAND TOTAL	902.1	258.4	314.2	202.7	108.1	60.4	101.4

TOTAL Square = 1,947.3

Table 15.

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM SQUARE G6, SITE E1-350 EAST

Material	Weight (gm) per Depth Increment	
	0-10 cm	10-20 cm
SHELL		
Gastropoda		
Cellana spp.	2.8	8.6
Conus spp.	13.7	1.6
Cypraea caputserpentis L.	327.2	181.0
Cypraea maculifera Schilder	7.9	6.3
Cypraea mauritiana L.	7.2	--
Drupa morum Röding	--	2.7
Drupa ricina L.	7.5	8.9
Littorina pintado (Wood)	1.9	1.5
Morula sp.	0.2	0.2
Nerita picea Recluz/ *Theodoxus neglectus* (Pease)	130.5	77.2
Nerita polita L.	--	0.5
Opercula	0.1	0.1
Strombus maculatus Sowerby	0.1	0.4
Terebra sp.	--	0.1
Thais harpa (Conrad)	0.1	0.1
Theodoxus cariosus (Wood)	22.5	23.2
Unidentified shell	15.1	5.6
Pelecypoda		
Brachidontes cerebristriatus (Conrad)	0.1	0.1
Isognomon sp.	29.4	28.1
Tellina (Quidnapagus) palatam (Iredale)	--	0.1
TOTAL SHELL	566.3	346.3
ECHINODERMATA		
Heterocentrotus mammillatus (L.)	1.2	0.9
Unidentified	3.5	5.7
CRUSTACEA	0.5	0.1
BONE		
Mammal	4.4	2.0
Fish	0.6	1.0
Bird	0.3	--
MISCELLANEOUS		
Coral	6.0	43.6
Charcoal	0.3	5.0
Candlenut	4.4	3.9
Glass	0.4	--
GRAND TOTAL	587.9	408.5

Table 16.

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM SQUARE E9, SITE E1-355

Taxa	Weight (gm) per Depth Increment					
	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
SHELL						
Gastropoda						
Cellana exarata (Reeve)/*sandwicensis* (Pease)	29.85	--	--	--	--	--
Cellana spp.	4.00	76.5	84.7	42.0	51.9	--
Conus catus Hwass in Bruguière	5.50	--	--	--	--	--
Conus chaldaeus Röding	8.70	--	--	--	--	--
Conus distans Hwass in Bruguière	49.40	--	--	--	--	--
Conus ebraeus L.	4.70	--	--	--	--	--
Conus spp.	16.95	88.6	34.5	31.8	16.3	38.4
Conus textile L.	0.85	--	--	--	--	--
Cymatium spp.	1.30	4.0	0.7	--	--	0.8
Cypraea caputserpentis L.	1261.00	1903.8	1625.0	945.9	678.6	1017.0
Cypraea isabella L.	--	--	--	--	2.0	--
Cypraea maculifera Schilder	187.30	214.8	153.0	111.8	74.3	16.3
Cypraea mauritiana L.	61.35	14.6	--	--	--	1.3
Cypraea mauritiana (immature?)	--	6.4	4.2	4.0	0.2	--
Cypraea spp.	0.40	--	--	--	4.6	3.1
Drupa morum (Röding)	24.60	77.1	39.0	45.0	84.3	71.6
Drupa ricina L.	68.80	110.1	104.5	113.1	130.3	177.2
Hipponyx pilosus imbricatus Gould	--	--	--	--	0.2	0.1
Littorina pintado (Wood)	2.40	4.6	6.9	4.7	12.0	18.5
Littorina spp.	0.50	--	--	--	--	--
Morula granulata (Duclos)	1.50	--	--	--	--	--
Melampus semiplicatus Pease	--	0.3	0.3	--	0.2	0.2
Morula sp.	--	--	--	2.5	0.9	--
Morula tuberculata	--	--	--	--	--	4.6
Morula uva (Bolten)	1.90	--	--	--	--	--
Natica gualteriana Recluz	--	1.0	--	2.5	--	--
Nerita picea Recluz/*Theodoxus neglectus* (Pease)	184.85	397.3	404.9	342.2	366.5	581.6
Nerita polita L.	8.65	15.7	8.2	7.7	15.1	33.9
Opercula	--	3.6	23.7	3.6	3.6	4.7
Planaxis labiosa A. Adams	--	0.5	0.3	0.1	--	0.1
Strombus maculatus Sowerby	20.80	44.4	43.5	16.5	9.3	11.0
Thais aperta Blainville	--	--	--	--	--	15.7
Thais harpa (Conrad)	--	0.2	0.4	--	3.6	--
Thais intermedia Kiener	--	--	--	--	9.7	--
Theodoxus cariosus (Wood)	621.80	1247.4	1131.5	678.0	551.8	744.6
Tritonaria tritonus (L.)	--	--	--	6.4	--	--
Trochus histrio Reeve	3.30	10.8	4.1	7.0	2.5	0.9
Waterworn *Conus* spp.	3.00	--	--	--	--	--
Identifiable Gastropoda	--	6.9	4.0	--	--	--
Unidentified Gastropoda	20.00	--	--	--	--	--
Unidentified shell	--	127.4	121.2	44.0	38.7	80.0
Pelecypoda						
Brachidontes cerebristriatus (Conrad)	115.60	486.7	818.9	400.9	171.3	255.5
Isognomon californicum (Conrad)	--	299.7	274.6	251.8	210.7	370.5
Isognomon spp.	112.75	50.8	58.2	39.6	37.1	30.7
Lamellibrach/*Isognomon* (?)	19.10	--	--	--	--	--
Pectinidae	--	--	--	--	0.4	0.4
Periglypta reticulata (L.)	--	4.7	4.4	9.5	5.3	1.0
Tellina (Arcopagia) elizabethae (Pilsbry)	--	0.5	--	0.3	--	--
Tellina (Quidnipagus) palatam (Iredale, 1929)	--	2.9	0.9	8.5	0.9	4.0
Unidentified bivalves	2.10	--	--	--	--	--
Unidentified mollusca	37.20	--	--	--	--	--
TOTAL SHELL	2881.95	5201.3	4956.8	3119.40	2482.3	3483.7
ECHINODERMATA						
Colobocentrotus atratus (L.)	0.4	1.2	1.6	2.6	2.8	4.4
Echinometra mathaei (Blainville)	--	0.5	2.8		0.1	0.1
Echinothrix calamaris (Pallas)	0.4	1.9	2.5	0.3	0.7	1.0
Heterocentrotus mammillatus (L.)	5.3	22.5	4.9	6.7	5.5	8.4
Unidentified	31.6	122.7	189.2	80.7	60.7	129.5
CRUSTACEA						
Crab	--	2.5	3.2	7.5	4.5	9.7
ARTHROPODA						
Orthamalus hembeli (?)	1.00	--	--	--	--	--
Unidentified	--	--	5.2	13.9	10.0	5.2
BONE						
Mammal	--	1.2	1.2	0.9	0.6	2.0
dog teeth	1.60	--	--	--	--	--
rat	0.3	--	--	--	--	--
Fish	4.0	14.7	16.9	9.1	8.2	16.4
Bird	2.29	1.7	0.9	1.2	0.5	1.9
MISCELLANEOUS						
Coral	15.20	90.6	18.0	83.7	8.5	31.5
Charcoal	6.45	17.0	17.3	8.6	10.6	4.6
Fibrous material		0.2				
Candlenut	8.70	20.8	16.1	15.2	16.6	14.4
Coconut	28.25	33.6	--	--	--	13.6
Gourd	1.35	5.8	6.3	2.9	0.2	0.6
Wood	3.00	6.3	9.7	3.4	0.8	2.3
GRAND TOTAL	2991.89	5544.00	5248.50	3359.00	2612.90	3729.30

Table 17.

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM SQUARE N10, SITE E1-368

Material	Weight (gm) per Depth Increment	
	0-10 cm	10-20 cm
SHELL		
Gastropoda		
Cellana spp.	33.4	17.5
Conus spp.	133.5	28.0
Coralliophila bulbiformis Conrad		0.8
Cymatium sp.	0.9	2.2
Cypraea caputserpentis L.	520.0	263.7
Cypraea maculifera Schilder	102.3	41.6
Cypraea mauritiana L.	3.5	
Drupa morum Röding	9.6	3.1
Drupa ricina L.	15.1	28.0
Hipponyx pilosus imbricatus Gould	0.2	
Littorina pintado (Wood)	3.8	18.8
Morula sp.		1.3
Nerita picea Recluz/ *Theodoxus neglectus* (Pease)	105.1	176.3
Nerita polita L.	3.1	3.3
Opercula	1.2	3.8
Peresternia chlorostoma Sowerby	0.4	
Strombus maculatus Sowerby	3.6	40.9
Thais aperta Blainville	13.1	
Thais harpa (Conrad)	1.3	
Thais intermedia Kiener	11.8	
Theodoxus sp.	467.7	873.1
Trochus histrio Reeve	0.1	
Unidentified shell	43.6	80.3
Pelecypoda		
Brachidontes cerebristriatus (Conrad)	4.1	13.3
Isognomon spp.	334.0	891.3
Periglypta reticulata (L.)		0.7
Tellina (Quidnapagus) palatam (Iredale)	1.5	0.8
TOTAL SHELL	1812.9	2488.8
ECHINODERMATA		
Colobocentrotus atratus (L.)	0.4	0.4
Heterocentratus mammillatus (L.)	14.3	13.4
Unidentified	23.7	27.4
CRUSTACEA	9.8	9.8
BONE		
Mammal	4.2	1.2
Dog tooth		0.2
Fish	13.8	20.2
Bird	0.2	
MISCELLANEOUS		
Coral	52.5	33.8
Candlenut	7.4	2.1
Charcoal	4.3	1.8
Coconut	5.4	2.9
Gourd		0.2
Wood	7.6	3.2
GRAND TOTAL	1956.5	2605.4

Table 18.

QUANTITATIVE ANALYSIS OF MIDDEN MATERIAL FROM

SQUARE G10, SITE E2-51

Material	Weight (gm) per Depth Increment
	0-10 cm
SHELL	
Gastropoda	
Cellana spp.	26.4
Conus spp.	9.9
Cymatium sp.	0.4 (1 piece)
Cypraea caputserpentis L.	368.7
Cypraea maculifera Schilder	1.7
Cypraea sp.	0.7 (1 piece)
Drupa morum Röding	38.0
Drupa ricina L.	88.1
Littorina pintado (Wood)	3.9
Nerita picea Recluz/*Theodoxus neglectus* (Pease)	203.0
Opercula	17.8
Strombus maculatus Sowerby	14.9
Theodoxus sp.	422.0
Trocus histrio Reeve	1.5
Unidentified shell	22.3
Pelecypoda	
Brachidontes cerebristriatus (Conrad)	14.2
Isognomon californicum (Conrad)	544.1
Pectinidae ?	2.7
Periglypta reticulata (L.)	0.8
Tellina (Arcopagia) elizabethae (Pilsbry)	3.7
Tellina (Quidnipagus) palatam (Iredale)	1.4
TOTAL SHELL	1786.2
ECHINODERMATA	
Colobocentrotus atratus (L.)	3.1
Echinometra mathaei (Blainville)	0.1 (1 piece)
Echinothrix calamaris (Pallas)	0.2
Heterocentrotus mammillatus (L.)	7.1
Unidentified	3.1
CRUSTACEA	0.2
BONE	
Mammal	3.0
Fish	5.2
Bird	0.8
MISCELLANEOUS	
Coral	6.9
Candlenut	4.2
Charcoal	8.5
Coconut	0.4
Gourd	0.4
Wood	0.8
GRAND TOTAL	1830.2

Table 19.

PERCENTAGE COMPOSITION OF QUANTITATIVE MIDDEN SAMPLES BY SITE*

SITE	MIDDEN CATEGORY						
	Mollusca	Echinodermata	Crustacea	Bone			Miscellaneous
				Mammal	Fish	Bird	
E1-324	87.46	1.18	0.02	0.02	0.28	----	11.04
-327	96.69	0.71	0.19	----	0.04	0.08	2.29
-328	94.36	1.36	----	4.15	----	0.03	0.10
-342	94.77	1.60	0.04	----	0.17	0.01	3.41
-350E	91.59	1.05	0.06	0.64	0.16	0.03	6.47
-355	94.21	2.94	0.12	0.04	0.29	0.04	2.36
-368	94.29	1.74	0.43	0.12	0.74	0.01	2.67
E2-51	97.59	0.74	0.01	0.16	0.28	0.04	1.18

*Percent of total midden in 1 square meter by weight.

Table 20.

QUANTITATIVE ANALYSIS OF SURFACE MIDDEN SAMPLES FROM FOUR SITES IN KALĀHUIPUA'A AND LĀLĀMILO

Material	Weight (gm) per Site				
	E1-981	E1-343	E1-404d	E3-21(I)	E3-21(II)
SHELL					
Gastropoda					
Cellana exarata (Nuttall)	1	1	2	--	1
Conus catus Hwass in Bruguière	4	2	1	1	1
Conus ebraeus L.	0.5	--	--	2	2
Conus imperialis L.	--	23	--	--	--
Conus sp.	1	--	0.5	--	--
Cypraea caputserpentis L.	116	96	63	120	97
Cypraea maculifera Schilder	10	3	6	19	--
Cypraea mauritiana L.	--	--	--	--	10
Cypraea spp.	--	--	--	0.5	--
Drupa morum Röding	12	--	--	--	--
Drupa ricina L.	12	6	4	4	2
Littorina pintado (Wood)	1	--	0.5	--	--
Melanella thaanumi (Pilsbry)	--	--	--	--	2
Morula tuberculata Blainville	0.5	--	2	3	1
Nerita picea Recluz	19	53	26	25	7
Strombus maculatus Sowerby	--	--	0.5	--	--
Terebra sp.	1	--	--	--	--
Thais aperta Blainville	--	21	--	--	--
Theodoxus cariosus (Wood)	4	22	3	1	--
Pelecypoda					
Brachidontes cerebristriatus (Conrad)	--	1	--	--	--
Isognomon californicum (Conrad)	--	10	--	1	--
Periglypta reticulata (L.)	1	1	--	8	--
Pinctada galtsoffi Bartsch	--	1	--	--	--
ECHINODERMATA					
Colobocentrotus atratus (L.)	0.5	0.5	3	--	--
Echinothrix calamaris (Pallas)	--	1	2	0.5	0.5
Heterocentrotus mammillatus (L.)	5	2	6	1	2
CRUSTACEA					
Crab (unidentified)	--	0.5	--	--	--
BONE					
Bird	--	0.5	--	--	--
MISCELLANEOUS					
Candlenut	--	5	--	--	--
Coral	1	1	6	--	12
TOTALS	189.5	249.5	125.5	186.0	137.5

Table 21.

DISTRIBUTION OF MOLLUSCAN SPECIES BY SITE

Site	Number of Species		Total Number of Molluscan Species
	Gastropods	Pelecypods	
E1-324	15	4	19
-327	16	3	19
-328	7	3	10
-342	18	4	22
-350E	16	3	19
-355	30	7	37
-368	22	4	26
E2-51	14	6	20
	$\bar{x}$ = 17.25	$\bar{x}$ = 4.25	$\bar{x}$ = 21.5
	σ = 6.65	σ = 1.49	σ = 7.7
	(80.2%)	(19.8%)	(100.0%)

Table 22.

Perçentage Composition of Major Molluscan Genera by Site*

Site	Major Molluscan Genera					
	Theodoxus	*Nerita*	*Isognomon*	*Brachidontes*	*Cypraea*	*Cellana*
E1-324	16.6	16.1	6.9	0.01	47.7	1.5
-327	41.0	2.1	6.2	0.02	45.1	0.4
-328	37.1	2.0	3.7	0.03	52.0	0.06
-342	26.1	7.1	8.1	0.6	43.3	0.5
-350E	5.0	22.7	6.3	0.02	58.0	1.2
-355	22.3	10.8	7.2	9.5	33.3	1.3
-368	31.2	6.5	28.5	0.4	21.6	1.2
E2-51	23.0	11.1	29.7	0.8	20.3	1.4
$\bar{x}$ =	25.3	9.8	12.1	1.4	40.2	0.9
σ =	11.48	7.04	10.59	3.28	13.81	0.54

*Percent of total weight of molluscan midden.

Of the five dominant genera, three (*Theodoxus*, *Isognomon*, and *Brachidontes*) are primarily brackish-water dwelling. Each of these is represented by a single species at Kalāhuipua'a: *T. cariosus*, *I. californicum*, and *B. cerebristriatus*. Large populations of these species occur on the margin of the fishponds (see p. 9 ff. and Figs. 2, 3, & 4). The genera *Theodoxus*, *Nerita*, and *Cyprasea* occupy the surge-zone and tidal pool marine habitats and are represented by two species, *N. picea* and *T. neglectus*, while *Cyprasea* includes *C. caputserpentis* (the dominant species at Kalāhuipua'a) and the larger *C. maculifera* and *C. mauritiana*.

Table 23 gives the percentage composition of these five dominant molluscan genera by 10-cm depth increment in Square E9, in Site E1-355. These figures suggest a slight decline over time in the relative exploitation of *Nerita*, and concomitant increase in the exploitation of *Cyprasea*. There is an increase, followed by subsequent decline, in *Brachidontes*, while *Theodoxus* and *Isognomon* remain relatively constant. Whether these temporal trends are reflective of environmental changes in the Kalāhuipua'a area (i.e., in the habitats of these genera), or of changes in human exploitation patterns, is uncertain. The relative stability of *Theodoxus* and *Isognomon*, brackish-water dwellers, would suggest that the area of brackish-water habitat at Kalāhuipua'a has not altered drastically over the period of human occupation. This does not, however, preclude a shift in shoreline position (see p. 14).

Table 23.

PERCENTAGE COMPOSITION OF MAJOR MOLLUSCAN GENERA
IN SQUARE E9, SITE E1-355, BY DEPTH

Genera	%* per Depth Increment					
	0-5 cm**	5-10 cm	10-15 cm	15-20 cm	20-25 cm	25-30 cm
Theodoxus	22	24	23	22	22	21
Nerita	6	8	8	11	15	17
Cyprasea	44	37	33	30	27	29
Isognomon	4	6	6	8	8	11
Brachidontes	4	9	17	13	7	7

*Percent of total weight of molluscan genera.

**Depth below surface.

Figure 62 provides data on size and weight of archaeological populations of four dominant molluscan species, from the 10 to 15 cm level of Square E9, Site E1-355. *Cyprasea* was excluded because these shells were nearly always smashed to facilitate meat extraction. All samples indicate relatively normal distributions, suggestive of harvesting without selective preference for a particular size range. Unfortunately, we are lacking good comparative data on natural populations of these genera. More studies, such as that of Kay and Magruder (1975) on the biology of *Cellana*, are desirable in order to compare archaeological and natural populations of shellfish species. A few comparative studies of this sort have been undertaken in New Zealand (Terrell 1967; Shawcross 1967; Coutts 1971).

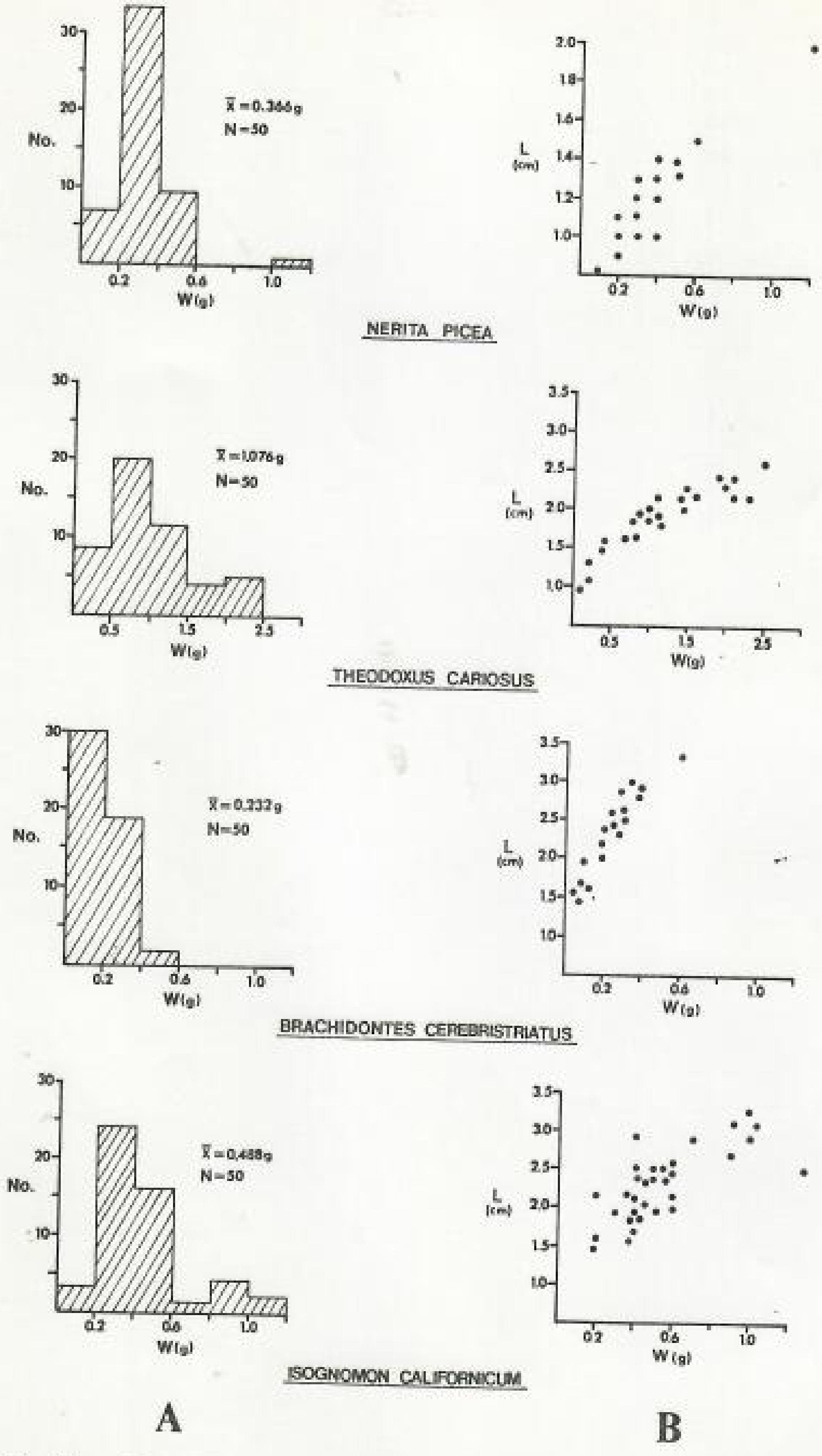


Fig. 62. SIZE AND WEIGHT RELATIONSHIPS OF ARCHAEOLOGICAL POPULATIONS OF FOUR DOMINANT SHELLFISH GENERA FROM SITE E1-355.

Data on individual shellfish weight may be further applied to estimating the average number of individual shellfish represented in Site El-355, as in Table 24. While the estimated total numbers of individuals of each species for the entire site is quite large, the estimated average number of individuals collected per year (based on a 500-year span for the occupation of the site) is surprisingly small. Further calculations of estimated edible meat are given in the Discussion (below), but for the present we may posit two important conclusions on the strength of the data in Table 24. First, on an annual basis, the level of shellfish exploitation at Kalāhuipua'a was quite low, probably at a level which would not significantly affect the reproductive fitness and recovery rate of the molluscan species. Continuous but intermittent exploitation of only a few hundred, or even thousand, individuals per year can hardly be expected to have had a significant impact on the population structures of the shellfish species themselves. Second, the data in Table 24 are suggestive of intermittent, rather than permanent, occupation of Site El-355, since the meat value represented is well below that to be anticipated if the midden had resulted from continuous and permanent occupation.

Table 24.

ESTIMATES OF INDIVIDUAL NUMBERS OF MAJOR SHELLFISH SPECIES REPRESENTED IN SITE El-355

Species	Average Weight of One Individual* ($\bar{x}$)	Total Weight Square E9**	No. of Individuals		
			Square E9	Total Site†	Per Year††
Nerita picea	0.366	2277.35 g	6,222	130,662	261.32
Theodoxus cariosus	1.076	4975.1	4,624	97,104	194.21
Brachidontes cerebristriatus	0.232	2248.9	9,693	203,553	407.11
Isognomon californicum	0.488	1520.05	3,115	65,415	130.83

*See Fig. 62.

**See Table 16.

†Number in Square E9 multiplied by 21 meters (total area of deposit).

††Number of individuals in total site divided by 500 years.

Echinodermata

Four species of sea urchins are represented in the Kalāhuipua'a middens: *Echinometra mathaei* (Blainville), *Echinothrix calamaris* (Pallas), *Colobocentrotus atratus* (L.), and *Heterocentrotus mammillatus* (L.). All are edible, but *H. mammillatus* was also exploited for its abrasive spines, used in bone artifact manufacture (see Portable Artifacts, p. 167 ff.). *Echinometra mathaei* and *C. atratus* frequent the tidal pools and surge zone, while *E. calamaris* and *H. mammillatus* are generally found in slightly deeper water on the reef platform. A contemporary population of *C. atratus*, on the surge-zone lava platform seaward of Site El-324, is illustrated in Figure 5.

Crustacea

Samples of crustacea from Square E9 of Site E1-355 were identified by Dr. Dennis Devaney, Invertebrate Zoologist, Bishop Museum. Three families of the Order Decapoda are represented: Calappidae, Xanthidae, and Grapsidae. Calappidae is represented by *Calappa gallus* (Herbst), found in sandy bottom areas (from the 15 to 20 cm level of E9). Xanthid remains were present in all excavation levels, the only identifiable species being *Carpilius maculatus* (Linnaeus), "found under stones on the reef, or more frequently in crevices of porous rocks" (Edmondson 1946:284). Grapsid fragments were noted from the 25 to 30 cm level of Square E9; these are possibly *Grapsus grapsus tenuicrustatus* (Herbst) which, as Edmondson (1946:304) notes: "is commonly seen clambering about on the rocks near the water's edge." All of these crab remains are undoubtedly food refuse.

FISH

Gross representation, in terms of weight, of fish bone in the Kalāhuipua'a middens has been discussed above (Table 19). Unfortunately, further identification of fish bone to lower-order taxa is a difficult task, complicated by a neglect of osteology in standard ichthyological studies. Although methods have progressed on the analysis of certain North American fish bones (Casteel 1972), Fowler's monograph on Fijian fish bones (1955) remains the only serious study of the subject for the central Pacific. Thus analyses of fish in Oceanic middens (e.g. Kirch 1973b; Kirch and Rosendahl 1973) have remained largely on the level of gross identification.

Mouthparts or dental apparatus are presently the most readily identifiable of the Kalāhuipua'a fish bone midden. Identifications were made on the basis of a small comparative osteological collection in the Bishop Museum, made by A. Sinoto, and with reference to the standard taxonomic work of Gosline and Brock (1960). Fowler's (1955) monograph was also utilized. Schultz's review of the parrotfishes (1958) includes useful data and illustrations on the pharyngeal mill which allowed identification of scarid remains to the generic level.

Fish mouthparts and other identifiable bones were analyzed from all excavated sites except E1-327 and E1-350W. Of the total 504 specimens examined, it was possible to identify, to at least the family level, 409 specimens (81%), leaving 95 (19%) unidentified. Three taxa account for 320 specimens (63%): the genera *Scarus* (36%) and *Calotomus* (12%) in the family Scaridae, and the family Labridae (15%). Dominance of these taxa in the middens is almost certainly a factor of their heavy dental apparatus, which are not easily fragmented, and are easily recognized. These taxa, then, appear to have a preservation advantage with regard to the c- and n-transforms, which result in the fragmentation and decomposition of much fish bone (see Methods, p. 117).

Identifiable fish bone counts for excavated sites are given in Tables 25 through 30. Examples of identified fish mouthparts are illustrated in Figure 63.

Most of the identifiable fish bones in the Kalāhuipua'a midden derive from smaller reef species. Parrotfish (*Scarus*, *Calotomus*), pufferfish (*Diodon*), triggerfish (Balistidae), and wrasses (Labridae) frequent the inshore waters of Makaīwa Bay. These fish may be captured by spearing, angling, or netting. The larger snappers (Lutjanidae) and jacks (Carangidae) may have been taken by trolling. Sharks are known ethnographically to have been taken on special wooden hooks (Buck 1957) of which several examples were recovered at Site El-342 (see Portable Artifacts p. 157). It is interesting to note that the genus *Monotaxis*, despite its large, bony, and easily identifiable dental jaw, was not represented in the Kalāhuipua'a samples.

Considerable size variation exists among the Kalāhuipua'a fish mouthparts, and the ranges of several taxa are illustrated in Figure 64. In the future, it would be desirable to obtain data from modern fish populations regarding dental apparatus-size/body weight relationships (see Akazawa 1969; Akazawa and Watanabe 1968), in order to estimate gross body weight and size of the archaeological fish population represented at Kalāhuipua'a, or elsewhere.

Table 31 provides data on the percentage distributions of fish mouthparts by depth increment in Site El-355 (all squares). Although the sample size is limited (247 specimens), and should be interpreted with caution, several temporal trends are suggested. One of these is an increase in the frequency of parrotfish over time. A decrease in the frequency of labrids is also apparent. Whether these trends are significant, and whether they are associated with temporal changes in fishing gear technology (see pp. 162 ff.) is not certain. It would be useful to re-examine the 'Anaeho'omalu data (Barrera 1971a) in this light, to determine if similar changes occured in these nearby sites.

Table 25.

FISH BONE FROM SITE El-324

Taxon and Identified Bone	Number of Identified Bones per Depth Increment			Total
	0-10 cm	10-20 cm	20-30 cm	
Scarus sp.				
Dental Plate	1	2	2	5
Dental Jaw (R)	1			1
Dental Jaw (L)	2			2
Upper Pharyngeal Plate	2			2
Calotomus sp.				
Dental Jaw (R)		1		1
Lower Pharyngeal Plate	1			1
Labridae				
Dental Jaw	1	1	3	5
Lutjanidae				
Dental Jaw			1	1
Balistidae				
Spine	1	2		3
Unidentified	2		1	3
Totals	11	6	7	24

Table 26.

FISH BONE FROM SITE EI-342

Taxon and Identified Bone	Number of Identified Bones per Depth Increment			Total
	0-1 cm	10-20 cm	20-30+ cm	
Scarus sp.				
Dental Plate	5	2	1	8
Dental Jaw (R)	2			2
Dental Jaw (L)	1	2	1	4
Upper Pharyngeal Plate	1		1	2
Lower Pharyngeal Plate	3	1	1	5
Calotomus sp.				
Dental Jaw (R)	2			2
Dental Jaw (L)	1	1	1	3
Lower Pharyngeal Plate	1	1		2
Labridae				
Dental Jaw	2	1		3
Diodon hystrix L.	1		1	2
Lutjanidae		1		1
Balistidae (spine)			2	2
Mullidae (?)	1			1
Shark (tooth)		1		1
Unidentified	4		1	5
Totals	23	11	9	43

Table 27.

FISH BONE FROM SITE EI-343

Taxon and Identified Bone	Number of Bones Identified per Depth Increment				Total
	0-10 cm	10-20 cm	20-30 cm	30-40+ cm	
Scarus sp.					
Dental Plate	5	7	2	2	16
Dental Jaw (R)	2	2			4
Dental Jaw (L)	1			1	2
Upper Pharyngeal Plate	5	2	2	2	11
Calotomus sp.					
Dental Jaw (R)	1	2	1	1	5
Dental Jaw (L)	1	1			2
Upper Pharyngeal Plate	4	1	-	-	5
Lower Pharyngeal Plate	2	1			3
Labridae					
Dental Jaw	2	1	1	2	6
Pharyngeal Plate	2	5	2	4	13
Lutjanidae	1	2			3
Balistidae (spine)	1	2	2		5
Other spine (unident.)	1	4		1	6
Unidentified	7	8	6	4	25
Totals	35	38	16	17	106

Table 28.

FISH BONE FROM SITE EI-355

Taxon and Identified Bone	Number of Identified Bones per Depth Increment				Total
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	
Scarus sp.					
Dental Plate	19	5	5	2	31
Dental Jaw (R)	8	6	3		17
Dental Jaw (L)	9	8	2		19
Upper Pharyngeal Plate	10	4	1	1	16
Lower Pharyngeal Plate	6	2	1		9
Calotomus sp.					
Dental Jaw (R)	8	4	2	1	15
Dental Jaw (L)	13	2			15
Lower Pharyngeal Plate	5	1			6
Labridae					
Dental Jaw	5	3	7		15
Lower Pharyngeal Plate	2	9	8	4	23
Lutjanidae					
Dental Jaw	7	2	1	1	11
Balistidae (spine)	11	12	8	2	34
Diodon hystrix L.					
Dental Plate	1				1
Mullidae/Carangidae(?)					
Dental Jaw	2		2		4
Shark (teeth)	4	2			6
Unidentified	25	16	10	2	53
Totals	135	76	50	13	274

Table 29.

FISH BONE FROM SITE EI-368

Taxon and Identified Bone	Number of Identified Bones per Depth Increment		Total
	0-10 cm	10-20 cm	
Scarus sp.			
Dental Plate	1	1	2
Dental Jaw (R)	3	1	4
Dental Jaw (L)		2	2
Upper Pharyngeal Plate	3		3
Lower Pharyngeal Plate	1	1	2
Calotomus sp.			
Dental Jaw (R)	1	2	3
Dental Jaw (L)		1	1
Lower Pharyngeal Plate		2	2
Labridae			
Dental Jaw	4		4
Pharyngeal Plate	2	5	7
Balistidae (spine)	2	1	3
Other Spine (unident.)	3	1	4
Shark (teeth)		1	1
Unidentified	6	2	8
Totals	26	20	46

Table 30.

FISH BONE FROM SITES E1-328, -350E, AND E2-51

Taxon	Number of Identified Bones per Site			Total
	E1-328	E1-350E	E2-51	
Scarus sp.				
Dental Plate		1	1	2
Dental Jaw (R)		1	2	3
Lower Pharyngeal Plate			2	2
Calotomus sp.				
Lower Pharyngeal Plate			1	1
Labridae				
Dental Jaw		1		1
Balistidae	1			1
Unidentified			1	1
Totals	1	3	7	11

MAMMALS

Mammalian remains in the Kalāhuipua'a middens were restricted to pig, dog, and rat bone. A good deal of the pig and dog bone has been modified by cutting, and represents detritus of artifact manufacture, primarily of fishing gear. In virtually all sites, mammal bone composed considerably less than 1% of the total midden by weight. The rat material may be assigned to the species *Rattus exulans*, the Polynesian rat.

BIRDS

A small, but consistently represented midden component in the Kalāhuipua'a sites is bird bone. Most of this material is highly fragmented; unfortunately, it has not been possible to obtain specific identifications. The majority of the material is presumed to be of sea birds.

PLANT MATERIAL

The hot, arid climate of Kalāhuipua'a is responsible for the preservation of large amounts of plant material in the excavated cave sites. This material was examined and identified by Dr. D. E. Yen, Bishop Museum Ethnobotanist, in consultation with Dr. P. van Royen, Bishop Museum Botanist. Yen's identifications and notes on the material are given in Table 32; a selection of these plant materials is illustrated in Figure 65.

The identified plant remains are nearly all of economically important species, such as coconut (*Cocos nucifera* L.), the bottle gourd (*Lagenaria siceraria* [Molina] Standl), screw-pine (*Pandanus* sp.), and kava (*Piper methysticum* J. R. and G. Forst.). The leaf material

Table 31.

PERCENTAGE DISTRIBUTION OF FISH MOUTHPARTS BY 10-cm DEPTH INCREMENT OF SITE E1-355 (N = 247)

Taxa	Depth Increment			
	0-10 cm	10-20 cm	20-30 cm	30-40 cm
Scarus spp.	38	32	41	15
Calotomus sp.	19	9	4	7
Labridae	5	16	30	31
Lutjanidae	5	3	2	8
Balistidae	8	16	16	15
Shark	3	3	0	0
Unidentified	21	21	24	15

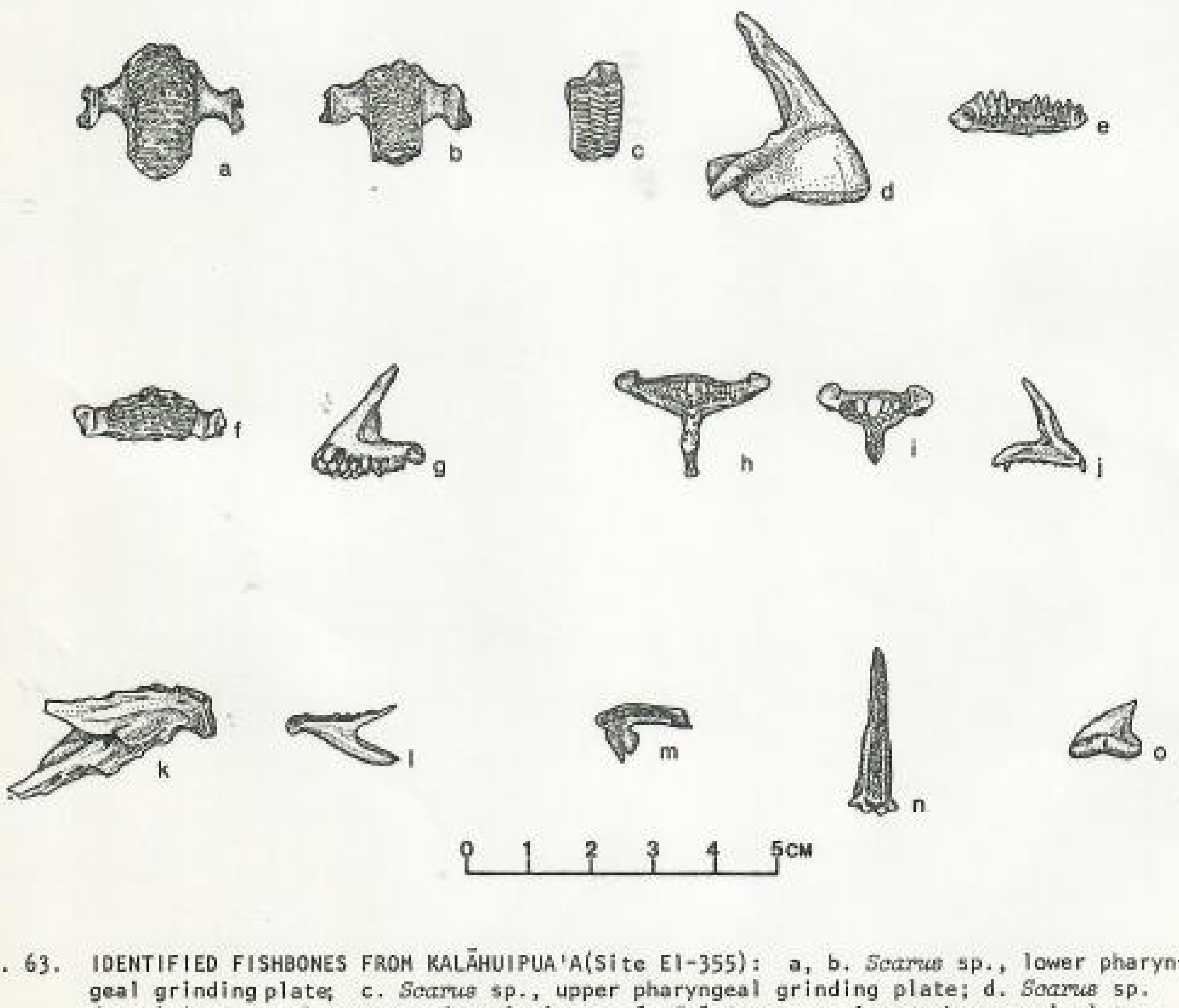


Fig. 63. IDENTIFIED FISHBONES FROM KALĀHUIPUA'A(Site E1-355): a, b. *Scarus* sp., lower pharyngeal grinding plate; c. *Scarus* sp., upper pharyngeal grinding plate; d. *Scarus* sp. dental jaw; e. *Scarus* sp. dental plate; f. *Calotomus* sp. lower pharyngeal plate; g. *Calotomus* sp. dental jaw; h, i. Labridae pharyngeal plates; j. Labridae, dental jaw; k, l. Lutjanidae, dental jaws; m. Mullidae (?) dental jaw; n. Balistidae, spine; o. shark tooth.

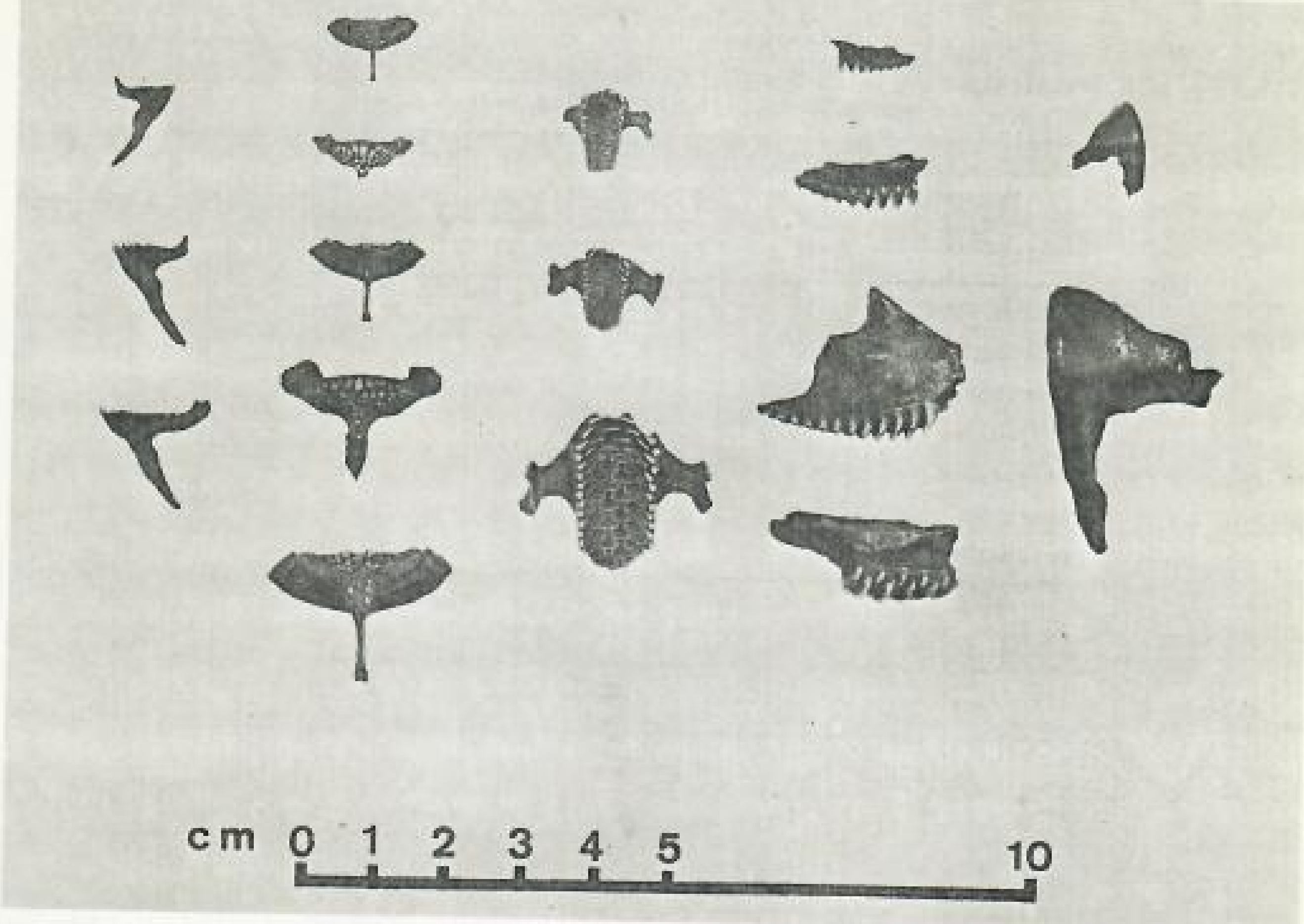


Fig. 64. VARIATION IN SIZE OF FISH MOUTH PARTS (*Scarus* and Labridae) FROM SITE E1-355.

of *Cordyline fruticosa* (L.) A. Chevalier and that of *Alpinia* (ginger) was probably used in wrapping bundles, either of food or, possibly, of medicinal plants. *Sidax fallax* Walp. of which flowers were found in Sites E1-342 and -343, is a dominant in the Kalāhuipua'a area, and its flowers are known to have been used ornamentally. *Sicyos* is a genus in the family Cucurbitaceae, with about ten native species (Neal 1965:808). The *Heteropogon* stalks are probably of *Heteropogon contortus* (L.) Beauv. (*pili* grass), a common thatching material.

Table 33 summarizes presence and absence of plant macrofossils from the surface of shelter caves. Coconut was most commonly found, and indeed, it is present all along the shoreline even today. The bottle gourd fragments were probably the remains of containers, and were likely grown either near the fishponds or in the uplands. Candlenuts (*Aleurites moluccana* Willd.) were used both as candles and as a relish to be mixed with fish and seaweed (Buck 1957:73), and were certainly imported from elsewhere as they will not grow in this arid environment. The *Thespesia populnea* (L.) Solander seeds probably came from the fishpond area where the tree is dominant. A few *Pandanus* sp. trees are also found around the ponds. Leaves of the *Pandanus* were used for matting and the keys were used as brushes.

Table 32.

PLANT REMAINS FROM KALĀHUIPUA'A SITES

(Identified by D. E. Yen)

Provenience	Plant Part	Identification	Confidence	Notes
El-342, H10				
10-20 cm	Fruit fragment	*Cocos*	Good	Small fragment
	Flower fragment	*Sicyos*	Fair-Good	
	Flower including anthers	*Sida*	Good	
8-10 cm	Flower parts	*Sicyos*		
	Endocarp	*Cocos*	Fair-Good	
	Flower	*Sida*	Fair	Small fragment
	Wood	Unidentified	Good	Worked ?
	Seed coat	Unidentified		
20-30 cm	Stalks	Gramineae (*Heteropogon*)	Fair-Good	
	Shell fragment	*Lagenaria*	Good	
30-40 cm	Flowers	*Sida*	Fair-Good	
	Flower	*Sicyos*	Fair-Good	
	Wood fragment	Gramineae (Bamboo)	Good	Shaped ?
Surface	Leaf base	*Pandanus*	Good	Good preservation
El-343, P19				
0-10 cm	Wood	*Cocos*	Fair	Shaped ?
	Flower	*Sida/Hibiscus*	Fair	Rather large
El-343, W17				
Surface	Basal stem	*Piper methysticum*	Fair	
El-355, C10				
0-10 cm	Mature fruit-shell fragments	*Lagenaria siceraria*	Good	Possibly containing *poi* (taro paste)
El-355, C10				
0-10 cm	Leaf material	*Alpinia* ?	Fair	Tied bundle, food or medicinal; probable top of original package; coarse texture
	Leaf material	*Cordyline fruticosa*	Good	Fine texture
El-355, C11				
In rubble	Wood	Unidentified		Cut when alive
El-355, D9	Leaf material	*Cordyline fruticosa* or *Alpinia*	Fair	Tied bundle; coarse texture
El-355, E1				
25-30 cm	Seed fragment	*Canarium*	Poor-Fair	Alternatives: *Terminalia* Sapotaceae Sapindaceae
El-355, F12				
5 cm	Proximal end, mature fruit	*Lagenaria siceraria*	Good	
El-368, L11				
0-10 cm	Fruit fragment	*Pandanus*	Good	
El-368, M10				
0-10 cm	Fruit fragment	*Pandanus*	Good	
El-368, N10				
0-10 cm	Fruit-shell fragment	*Cocos*	Good	
	Fruit-shell fragment	*Lagenaria*	Fair	Proximal end, immature
	Fruit fragment	*Pandanus*	Good	
El-368, O10				
0-10 cm	Fruit fragment	*Pandanus*	Good	4 fragments
El-368, O11				
0-10 cm	Fruit fragment	*Pandanus*	Good	7 fragments
El-368, P11				
0-10 cm	Fruit fragment	*Pandanus*	Good	6 fragments
El-368, Q10				
0-10 cm	Fruit shell fragment	*Cocos*	Good	
	Fiber	*Cocos*	Good	
El-368, Q11				
0-10 cm	Fruit fragment	*Pandanus*	Good	
El-368, S12				
0-10 cm	Fruit shell fragments	*Lagenaria siceraria*	Good	
	Leaf material	*Cordyline fruticosa*	Good	Fine-textured, numerous pieces
	Husk	*Cocos*	Good	

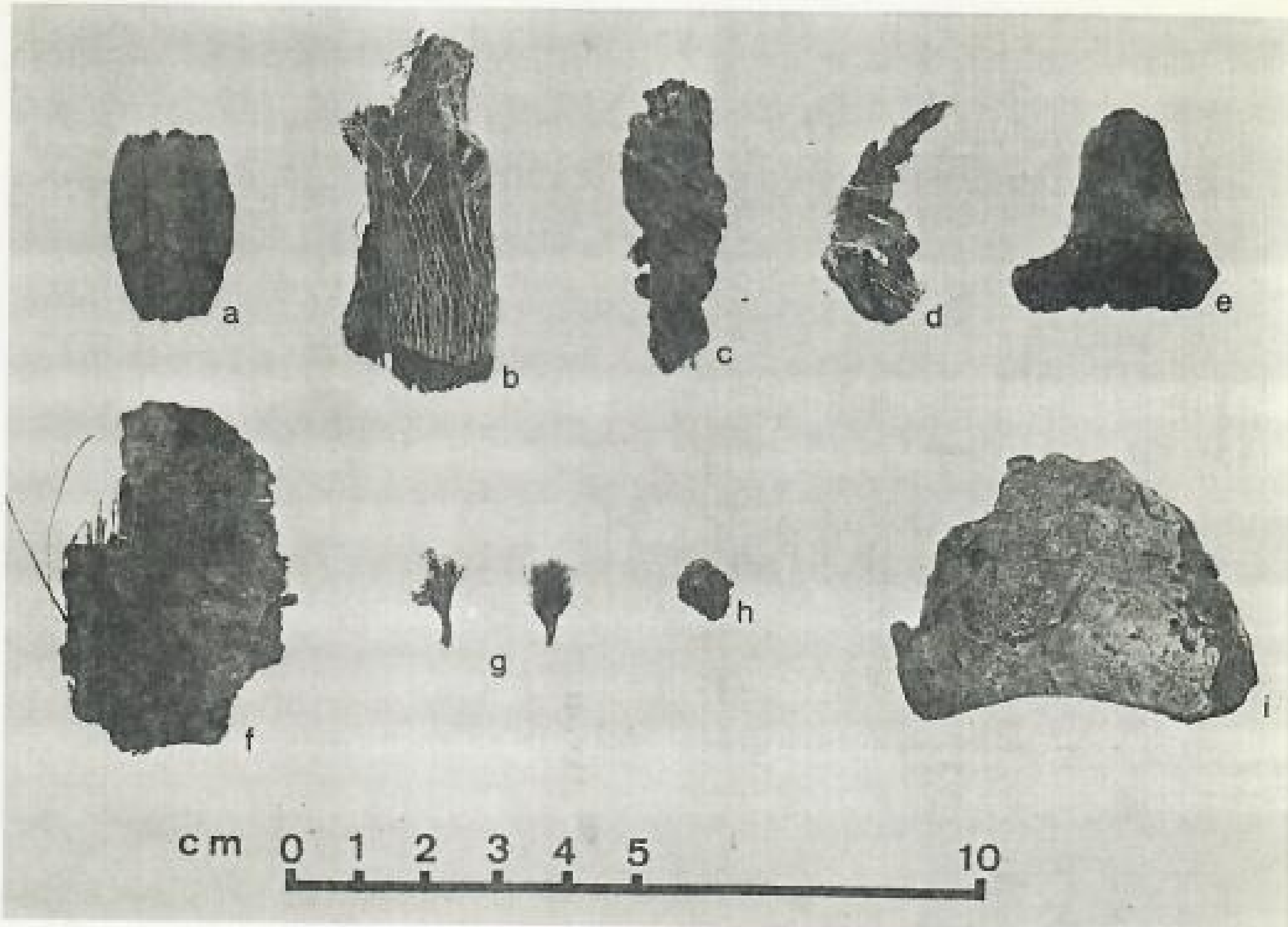


Fig. 65. IDENTIFIED PLANT REMAINS FROM KALĀHUIPUA'A SITES: a. *Pandanus* fruit; b. *Piper* stem; c, d. tied leaf fragments, probably *Cordyline*; e. *Lagenaria*, proximal end of mature fruit; f. *Pandanus* leaf fragment; g. *Sida* flowers; h. unidentified seed; i. *Cocos*, endocarp fragment.

Table 33.

SURFACE PLANT MATERIAL FROM SHELTER CAVES IN KALĀHUIPUA'A AND WAIKOLOA (1973)

Material	Kalāhuipua'a Site No. (E1-)							Waikoloa Site No. (E2-)					Total Occurrences
	334	336	343	347	350	355	368	45	46	51	66	67	
Cocos nucifera L. husk			+*					+	+				3
endocarp	+	+	+	+		+	+	+		+	+		9
Lagenaria siceraria (Molina) Standl.				+						+	+		3
Aleurites moluccana Willd.			+	+	+	+							4
Thespesia populnea (L.) Sol.									+				1
Pandanus sp. key							+						1
Grass fibers		+						+	+		+		4
Unmodified Wood									+	+	+	+	4
Charcoal			+							+			2
Total Occurrences	1	2	4	3	1	2	2	3	4	4	4	1	31

*+ = presence.

DESCRIPTION AND ANALYSIS OF PORTABLE ARTIFACTS

The 1973 survey yielded 169 portable artifacts including 29 basaltic glass flakes, while the 1975 excavations resulted in the recovery of an additional 1,221 specimens, exclusive of 10,809 flakes and cores of basaltic glass. Artifacts are catalogued by site according to the Bishop Museum system (excavated specimens are numbered by square, e.g., HA-E1-355-E9-1 is the first artifact recovered from Square E9 of Site HA-E1-355) and all specimens have been given loan designation EL-1976.01. Distribution of surface artifacts is given in Table 34, and of artifacts from excavated sites in Table 35. Artifacts are described and analyzed below, following a broadly functional outline. Further comparative descriptions of many of these artifact types may be found in Buck (1957), Emory, Bonk, and Sinoto (1959), Emory and Sinoto (1961), and Kirch (1975a).

CANOES

As might be anticipated in a region where maritime exploitation was certainly the dominant economic theme, the physical remains of canoes are well represented. The preservation of such generally perishable wooden artifacts is due to the extreme aridity of the environment, and to their protection in caves. The spreader, gunwale fragment, and paddle discussed below were taken to Bishop Museum for preservative treatment and are in storage. The canoe-hull segments themselves, associated with prehistoric human burials, have not been disturbed. However, deterioration of these valuable specimens is proceeding apace, and measures should be taken in the near future to at least stabilize their condition and prevent further deterioration. There are few extant examples of prehistoric Hawaiian canoes, since construction style and technique changed soon after European contact. This stresses the unique value of these specimens.

Hull Segments

Site E2-56, a burial cave entombing at least 30 individuals, also contains six canoe-hull segments. Each of these segments is from prow to midship at most, where they were cut in prehistoric times. These were used as "coffins" to contain some of the burials. Buck (1957:569, 573) has described such canoe burials. The hull segments all seem to have been cut with stone adzes and show no signs of other than indigenous methods of workmanship.

The measurements taken on five of the six segments are as follows:

Hull Segment (No.)	Length (meters)	Width (cm)	Depth (cm)	Remarks
1	2.30	45	30	--
3	2.36	34	30	--
4	1.72	--	--	--
5	0.94	18	--	prow only
6	0.77	--	--	prow only

The larger segments have elongate, rectangular lashing holes cut through the edge of the hull, used to lash the gunwale to the edge of the hull. The holes are c. 1 to 2 cm long and are spaced 10 to 17 cm apart.

Table 34

DISTRIBUTION OF SURFACE ARTIFACTS FROM SURVEY AREA (1973)

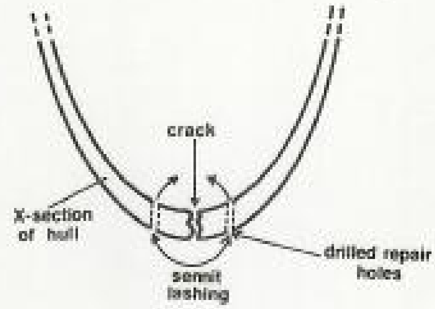
Artifact Type	Number of Specimens				
	Kalāhuipua'a-'Anaeho'omalu	Waikoloa	Lālāmilo	Category Totals	% of Total Surface Artifacts
CANOES					
Hull segments		6		6	4.3
Spreader		1		1	0.7
Gunwale fragment		1		1	0.7
Paddle		1		1	0.7
FISHING GEAR					
One-piece fishhook	1			1	0.7
Two-piece fishhook point		1		1	0.7
Octopus lures	5	1		6	4.3
Line sinkers	3			3	2.1
TOOLS					
Adzes (sections)	2	1	3	6	4.3
Adz chips	3	1	9	13	9.3
Coral abraders	13	2	2	17	12.1
Echinoid-spine abraders	16	4	1	21	15.0
Scoriaceous-lava abraders	20	18		38	27.1
Whetstone	1			1	0.7
Hammerstone			1	1	0.7
DOMESTIC IMPLEMENTS					
Cellana scraper		1		1	0.7
Pinctada scraper		1		1	0.7
Fire-plows		2		2	1.4
Coconut cup		1		1	0.7
Mortar		1		1	0.7
Pestle		1		1	0.7
Gourds		4		4	2.9
Gourd stopper		1		1	0.7
ORNAMENTS					
Cut cone shell			1	1	0.7
MISCELLANEOUS					
Wooden needle	1			1	0.7
Carrying poles	2			2	1.4
Forked sticks	2			2	1.4
Worked bone	3			3	2.1
Spear		1		1	0.7
Wooden bowl (?)		1		1	0.7
TOTALS	72	51	17	140	
BASALTIC-GLASS FLAKES	13	14	2	29	
GRAND TOTALS	85	65	19	169	

Table 35

ARTIFACTS FROM EXCAVATED SITES (1975)

Artifact Type	Number of Specimens and Sites										Category Totals	% of Total Excavated Artifacts
	E1-324	-327	-328	-342	-343	-350E	-350W	-355	-368	E2-51		
FISHING GEAR												
Tabs and unfinished hooks	4				2	1	1	16	5		29	2.4
One-piece hooks				17	1			27	1		46	3.8
Two-piece hooks	1		1	1				4	2		9	0.7
Bonito point				1							1	0.1
Octopus lures								4			4	0.3
Line sinkers								1	1		2	0.2
TOOLS												
Adzes	2								1		3	0.2
Adz flakes	12	1		3	4		1	29	26		76	6.2
Coral abraders	37		1	7	17	1	4	64	13	7	151	12.4
Lava abraders	13	9		6	2	4	1	26	13	1	75	6.1
Echinoid-spine abraders	71	1		16	32	2	6	260	48	12	448	36.7
Whetstones					1			10			11	0.9
Hammerstones							1	11	1		13	1.1
Basalt flakes	15				6			18	63	1	103	8.4
MISCELLANEOUS												
Pickers/awls					2			7	1		10	0.8
Scraper								1			1	0.1
Toggles								4			4	0.3
Drilled teeth	4							2			6	0.5
Twine/sennit					1			6		1	8	0.6
Worked bone	32			8	16	1		130	23		210	17.2
Worked pearlshell								5			5	0.4
Drilled *Theodoxus*							2				2	0.2
Worked wood									1	1	2	0.2
Historic objects								1	1		2	0.2
TOTALS	191	11	2	59	84	9	16	626	200	23	1,221	100.0
BASALTIC GLASS	233	75	0	23	1,078	133	469	8,506	22	270	10,809	
GRAND TOTALS	424	86	2	82	1,162	142	485	9,132	222	293	12,030	

The bottom of hull No. 4 had apparently cracked during use (this crack is now 57 cm long) and was repaired by drilling lashing holes opposite each other on each side of the split, c. 4 cm apart. The following sketch indicates the method of lashing.



Spreader

A canoe spreader (Buck 1957:271-274; Haddon and Hornell 1936:21-22, fig. 12) was found in a side chamber of Site E2-56, against the cave wall. The specimen is 29 cm across and 18 cm deep, with a maximum diameter of 4.7 cm. The small width of this spreader suggests that it was situated toward the prow of a canoe, where the canoe would taper. A fragment of sennit remains in the lashing hole. Figure 66 illustrates the spreader and its position and function in a canoe.

Gunwale Fragment

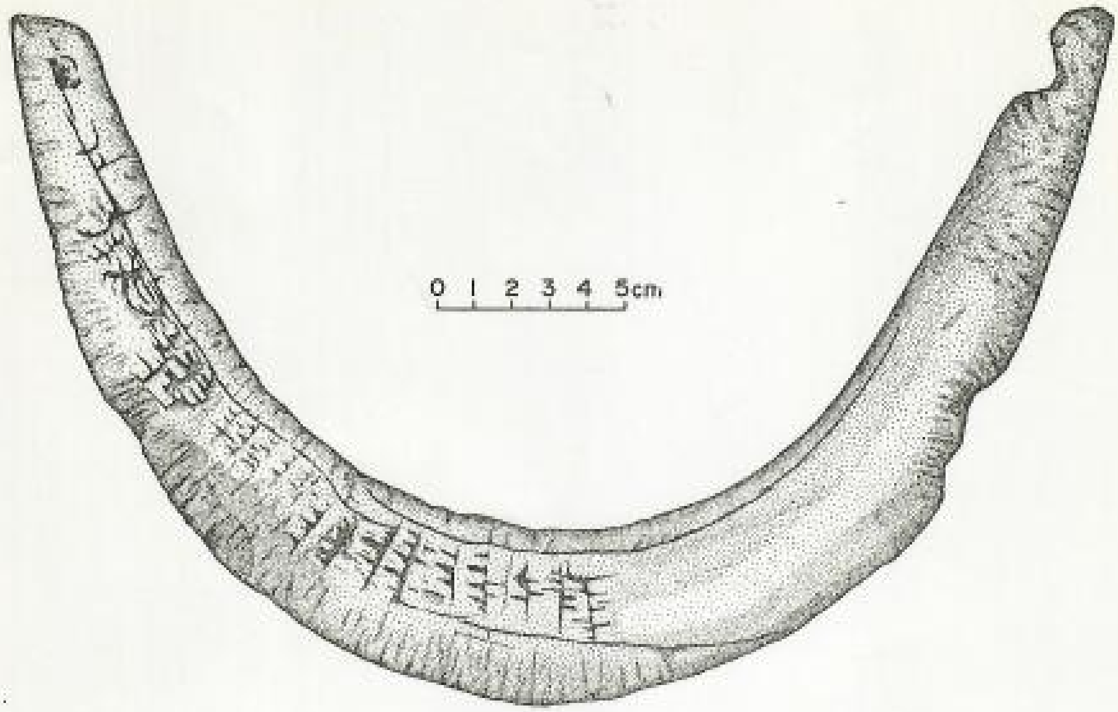
The freeboard of Hawaiian canoes was increased by lashing gunwales on to the one-piece hull (Buck 1957:295; Haddon and Hornell 1936:8-10, fig. 4). The unique, indigenous Hawaiian technique of lashing the gunwale to the hull, described by Buck (1957:260, fig. 183) is well illustrated by this example (Figs. 67, 68). This gunwale specimen is 44.5 cm long at the base, 12.5 cm high, 1.8 to 2.4 cm thick, and the basal lashing holes are c. 2 cm long and 0.8 cm wide.

Paddle

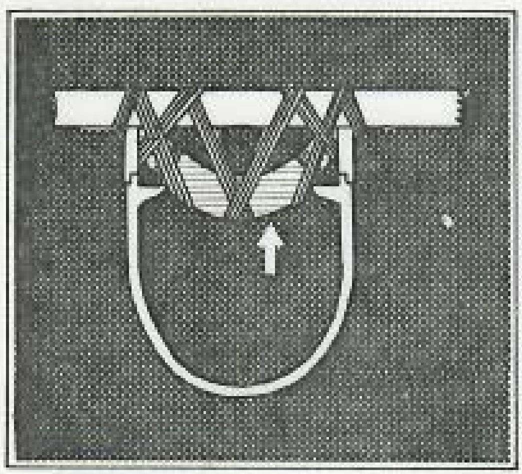
A complete paddle (Fig. 69), with only medium deterioration to the blade, came from a storage cave (E2-39). This paddle is of typical Hawaiian form, as described and illustrated by Haddon and Hornell (1936:17, fig. 11), including the short rib or thickening at the tip of one side. This specimen is 1.66 meters long, has a blade length of 72 cm, blade width of 23.5 cm, and handle diameter of 3.5 cm.

FISHING GEAR

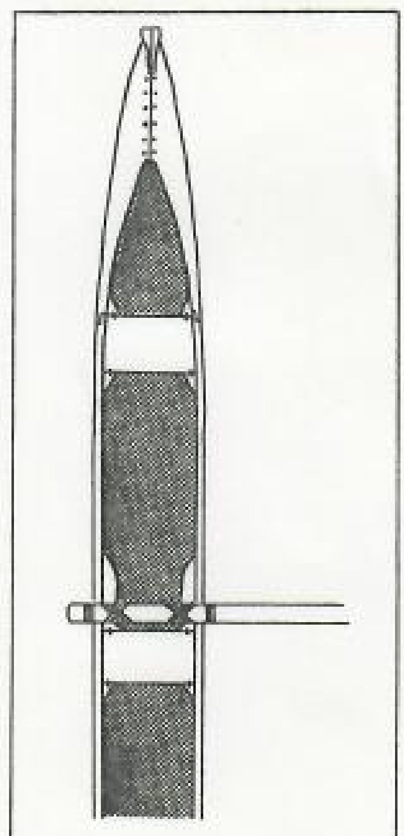
As might be anticipated, the majority of portable artifacts from Kalāhuipua'a constitute marine exploitation gear, or tools utilized in the manufacture of such gear. Analysis of fishing gear, particularly fishhooks, has played an important role in Hawaiian archaeology since the initial demonstration of chronologically meaningful change in fishhook types (Emory, Bonk, and Sinoto 1959; Sinoto 1962, 1968).



a. Spreader with sennit still in left-hand perforation

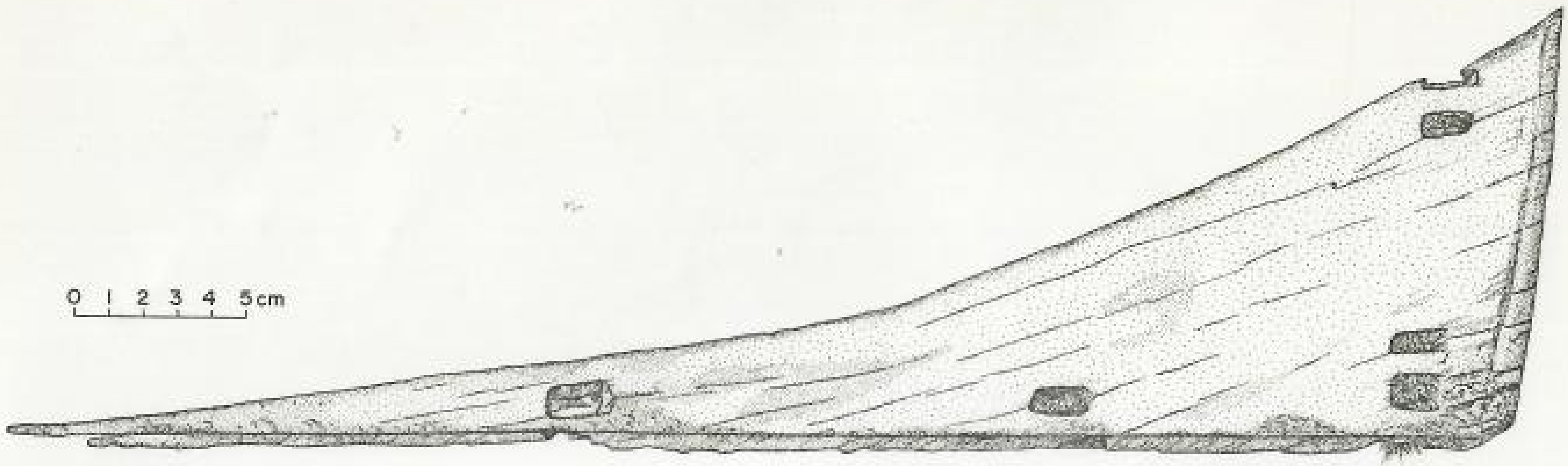


b. Position of spreader as used in canoe beneath outrigger boom

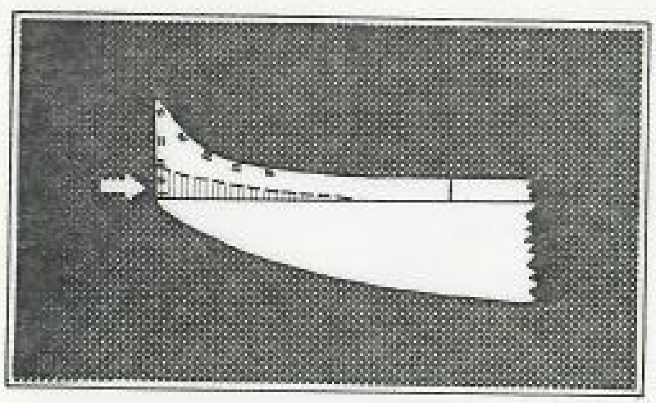


c. Plan of canoe, showing attachment of outrigger boom

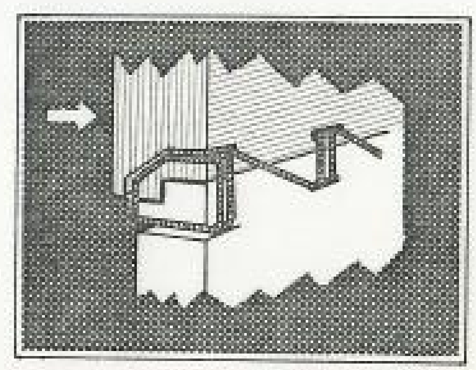
Fig. 66. CANOE SPREADER FROM SITE E2-56.



a. Inside view of gunwale fragment, showing lashing holes



b. Position of gunwale fragment in canoe



c. Detail showing method of lashing gunwale to canoe hull

Fig. 67. CANOE GUNWALE FRAGMENT FROM SITE E2-60.

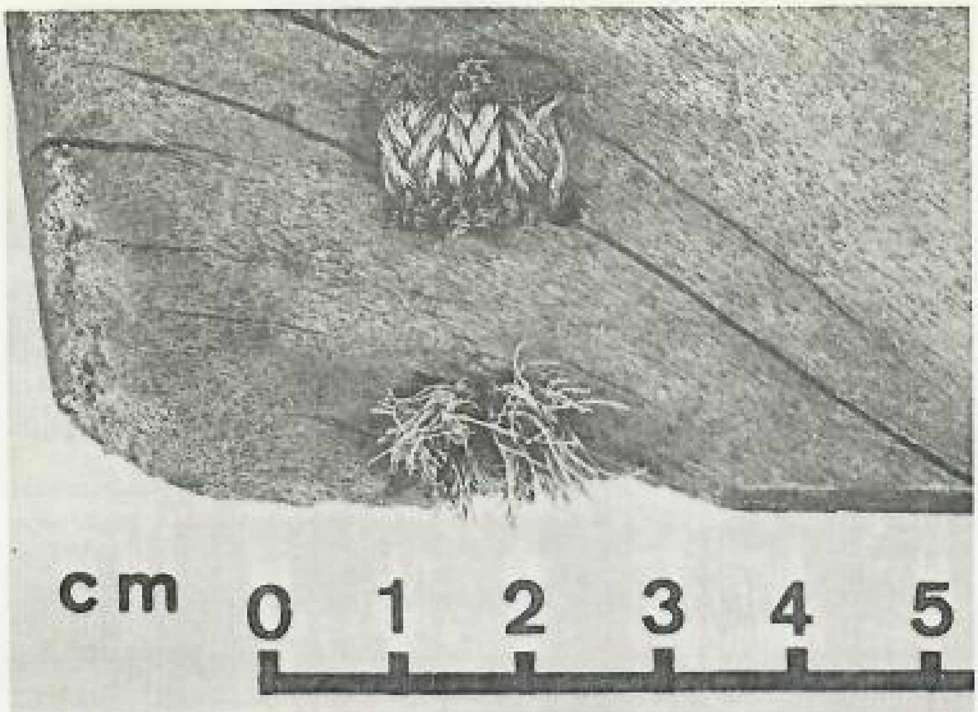


Fig. 68. DETAIL OF SENNIT LASHING IN GUNWALE FRAGMENT FROM SITE E2-60.

Fig. 69. BLADE OF CANOE PADDLE FROM SITE E2-39.

The original Hawaiian fishhook classification devised by Emory, Bonk, and Sinoto (1959:10) was revised by Soehren and Sinoto (Soehren Ms.) to allow for expansion of new types. This revised classification, with a few minor alterations, has been thoroughly discussed by Sinoto (Ms.). Sinoto (Ms.:8) also presents a revised typology of head (line-lashing device) types. Analysis of the Kalāhuipua'a fishhook assemblage follows the classification and methods described in Sinoto (Ms.).

Distribution of the 60 Kalāhuipua'a fishhooks by site is given in Table 36. Slightly more than half of the assemblage (31) was obtained from Site El-355; as noted above, the time span of this site, as well as its large yield of artifactual and midden material, make it the most important site for the analysis of prehistoric change at Kalāhuipua'a.

Table 36

DISTRIBUTION OF FISHHOOKS BY TYPE AND SITE*

SITE	HOOK TYPE							Totals
	One-Piece			Two-Piece				
	IA/B Jabbing-Rotating	IA Jabbing	IB Rotating	IIB1 Point (Slender)	IIB2 Point (Massive)	IIIA Bonito Point	Wooden Hooks	
E1-324				1				1
-328				1				1
-342	2			2		1	16	21
-343	1							1
-347	1							1
-350		1						1
-355	15	8	4	4				31
-368				1	1			2
E2-60					1			1
Totals	19	9	4	10	1	1	16	60

*Including 2 surface-collected specimens and 2 hooks excavated by Emory in 1955.

Table 37 provides descriptive data on all fishhooks from Kalāhuipua'a, excepting the 16 wooden hooks from Site El-342, which are described in Table 40. Included in Table 37 are two hooks excavated by Emory in 1955 at El-342 (H100), and two hooks recovered during the 1973 survey (from El-347 and E2-60); the remaining 40 hooks were excavated in 1975. The Hawaiian fishhook classification system is reproduced in Appendix C. A matrix of types and attributes of all bone and shell fishhooks is provided in Table 38, allowing correlation of all significant attributes. Data on the Kalāhuipua'a hook assemblage has been added to the keysort matrix-index file of Hawaiian fishhooks in the Anthropology Department of Bishop Museum (see Sinoto Ms.).

Table 37

FISHHOOKS FROM KALĀHUIPUA'A SITES

Catalog No.	Classification*	Head Type	Provenience	S.L.**	P.L.	W.	Remarks
E1-324-F7-1	IIB1A1a(1)a		F7, 0-10 cm		45		Notched
-328-E7-2	S-IIB1Bb1(1)(d)a		E7, 10-20 cm		14		
H100-F12-1	IIB1B1b1(1)a		F12, -		30		Emory 1955
H100-E9-1	S-IA/BU(1)(a,b,x)a		E9, -	31			Emory 1955
-342-G10-4	IIB1B2b1(1)a		G10, 34 cm		19		
-342-G10-5	IIIAIC(1)b		G10, 40 cm		22		Single hole
-342-G10-7	S-IA/BU(1)(a,b,c)a		G10, 0-10 cm	26			Unfinished
-343-P19-6	S-IA/BU(2)(c,d)a		P19, 0-10 cm		31		Human bone
-347-4	S-IA/BU(1)(a,b,c)	HT1a	Surface	16.5			1973 survey
-350-M10-21	S-IA1U(1)(x)a	HT1a	M10, -				Unfinished
-355-C10-18	S-IA/BU(1)(c)a		C10, 0-10 cm			15	
-355-C11-13	S-IB2U(1)(b,c)b		C11, 30 cm	27		15	Double-drilled
-355-D9-4	S-IA/BU(1)(b,c)b		D9, 17 cm			19	Massive
-355-D9-14	S-IA/BU(1)(b,c)b		D9, 35 cm			11+	
-355-D9-27	IA2V(1)a	HT1a	D9, 10-20 cm	13	9	10	
-355-D10-27	S-IA(x)a		D10, 29 cm	14			Unfinished
-355-D10-65	S-IB(d)a		D10, 10-20 cm				Massive
-355-D10-89	IA1U(1)a	HT1a	D10, 30-40 cm	13	11	7.5	
-355-D10-96	IA1U(1)a	HT1a	D10, 20-30 cm	14	10.5	6.5	
-355-D11-41	S-IA(1)(x)a	HT1a	D11, 10-20 cm	13	10.5	6.5	
-355-E9-6	S-IA/B(a,b)a	HT4a	E9, 2 cm				
-355-E9-39	IA2U(1)a	HT1a	E9, 35 cm	12	8	7	
-355-E9-82	S-IA/BU(1)(c)a		E9, 5-10 cm			18	
-355-E10-22	S-IA/B(1)(a,b)a	HT1a	E10, 23 cm	±23			
-355-E10-45	IA2U(1)a	HT?	E10, 10-20 cm	14	10	6	Unfinished
-355-E10-46	IA/BU(c,x)a		E10, 10-20 cm			14	
-355-E11-25	S-IA/BU(1)(a,b)a	HT4b	E11, 10-20 cm	±13			
-355-E11-26	S-IA/BU(1)(a,b,c)a	HT4b	E11, 0-10 cm	26			
-355-E11-27	S-IA/BU(1)(b,c)b		E11, 10-20 cm				Double-drilled
-355-E11-28	S-IA/B(1)(a,b)a	HT4b	E11, 10-20 cm	±28			
-355-E11-34	S-IA/B(1)(a,b)b	HT1a	E11, 20-30 cm				Double-drilled
-355-E12-6	IIB1B2b1(1)a		E12, 3 cm	27			
-355-E12-17	S-IA/B(1)(a,b)a	HT4b	E12, 0-10 cm	±25			
-355-E12-18	S-IA/B(1)(a,b)a	HT4b	E12, 0-10 cm				
-355-F10-5	IIB1B1b1(1)a		F10, 4 cm	±28			
-355-F11-1	S-IA/BU(1)(a,b,c)b	HT4b	F11, 2 cm	26.5			
-355-F11-11	IIB1a		F11, 6 cm	51			Aberrant
-355-F11-14	IIB1B2a(1)a		F11, 5 cm	±31			
-355-F11-16	IB1U(1)a	HT1a	F11, 8 cm	20	15	12	
-355-H9-4	IA1U(1)a	HT4b	H9, 0-10 cm	16	11	7	
-355-H10-10	IB2U(1)a	HT1a	H10, 10-20 cm	14	11	9	
-368-P10-7	IIB2B1b1(2)a		P10, 0-10 cm	50			Massive
-368-P11-15	IIB1B2b1(1)a		P11, 9 cm	49			
E2-60-1	S-IIB1B2a(1)b		Surface				1973 survey

*See Appendix C.

**S.L. = Shank length; P.L. = Point Length; W. = Width.

Table 38

HOOK TYPE AND ATTRIBUTE* MATRIX, KALĀHUIPUA'A ASSEMBLAGE

Type/Attribute	IA	IB	IA/B	IIB1	IIB2	IIIA	HT1a	HT4a	HT4b	Pearl Shell	Animal Bone	Human Bone	Point Barb	V Bend	U Bend	Notched Base	Knobbed Base
IA	9																
IB	-**	4															
IA/B	-	-	19														
IIB1	-	-	-	10													
IIB2	-	-	-	-	1												
IIIA	-	-	-	-	-	1											
HT1a	6	2	2	-	-	-	10										
HT4a	0	0	1	-	-	-	-	1									
HT4b	1	0	6	-	-	-	-	-	7								
Pearl Shell	0	1	5	1	0	1	1	0	1	8							
Animal Bone	9	3	13	9	1	0	9	1	6	-	35						
Human Bone	0	0	1	0	0	0	0	0	0	-	-	1					
Point Barb	0	0	1	0	1	0	0	0	0	0	1	1	2				
V Bend	1	0	0	-	-	-	1	0	0	0	1	0	0	1			
U Bend	6	3	13	-	-	-	6	0	4	5	16	1	1	-	22		
Notched Base	-	-	-	1	0	-	-	-	-	0	1	-	0	-	-	1	
Knobbed Base	-	-	-	8	1	-	-	-	-	1	8	-	1	-	-	-	9

*See Appendix C.

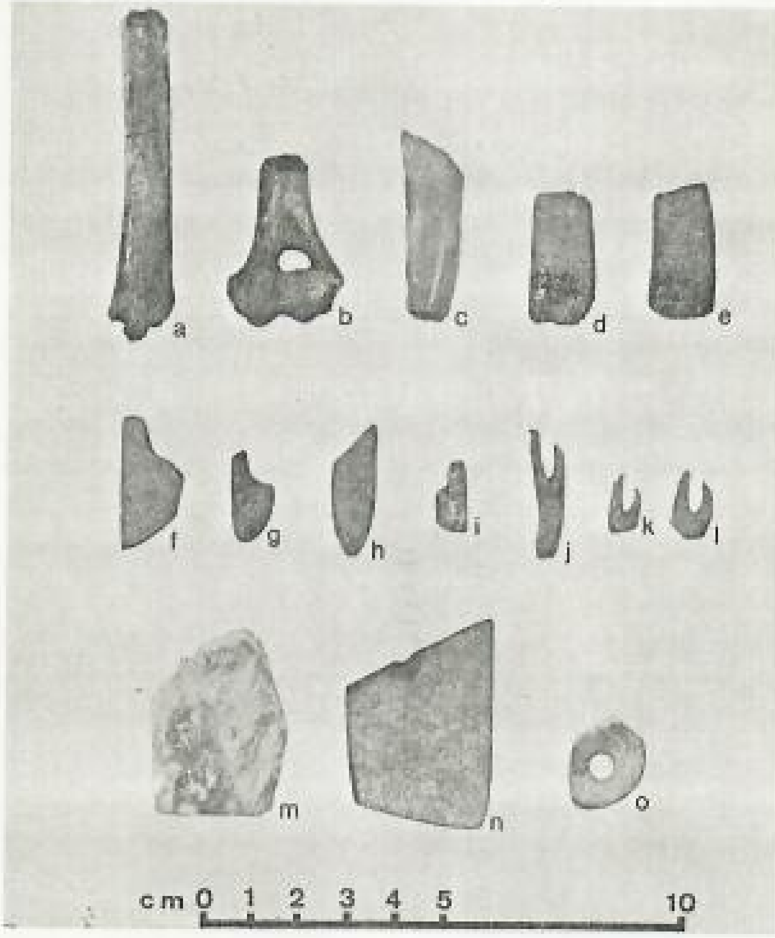
**- = Not Applicable

Materials and Manufacture

Excepting the large wooden hooks from El-342, the Kalāhuipua'a fishhooks were manufactured either from animal bone or pearl shell. Including hook tabs, unfinished hooks, and complete specimens, 86% of the assemblage is composed of animal bone, and 14% of pearl shell. A single hook from El-343 is made of human bone; other bone hooks are of dog and pig bone. A large quantity of worked bone scraps from the excavated sites comprises detritus from the process of hook manufacture.

Tools used in fishhook manufacture include coral and scoriaceous-lava abraders, and echinoid-spine abraders. These ubiquitous tools are described below.

Three categories of fishhook tabs, corresponding to manufacturing stages, were recovered in the Kalāhuipua'a sites: (1) roughed-out tabs; (2) prepared tabs that have begun to take on the outline of the eventual hook; and (3) unfinished hooks, where the tab was in the process of being shaped as a hook. Examples of these three categories are illustrated in Figures 70 and 71. Table 39 gives the distribution of fishhook tabs by site.



(BPBM Neg. No. HA(a)233-12)

Fig. 70. STAGES IN FISHHOOK MANUFACTURE: a, b, cut long bones; c-e, roughed-out tabs; f-i, prepared tabs; j-l, unfinished hooks; m-o, pearlshell tabs.

Table 39
DISTRIBUTION OF FISHHOOK TABS BY SITE

Site	Tab Category			Total
	Roughed-out Tabs	Prepared Tabs	Unfinished Hooks	
E1-324	1	1	1	3
-343		2		2
-350			2	2
-355	8	4	4	16
-368	3	2		5
-386	1			1
Total	13	9	7	29

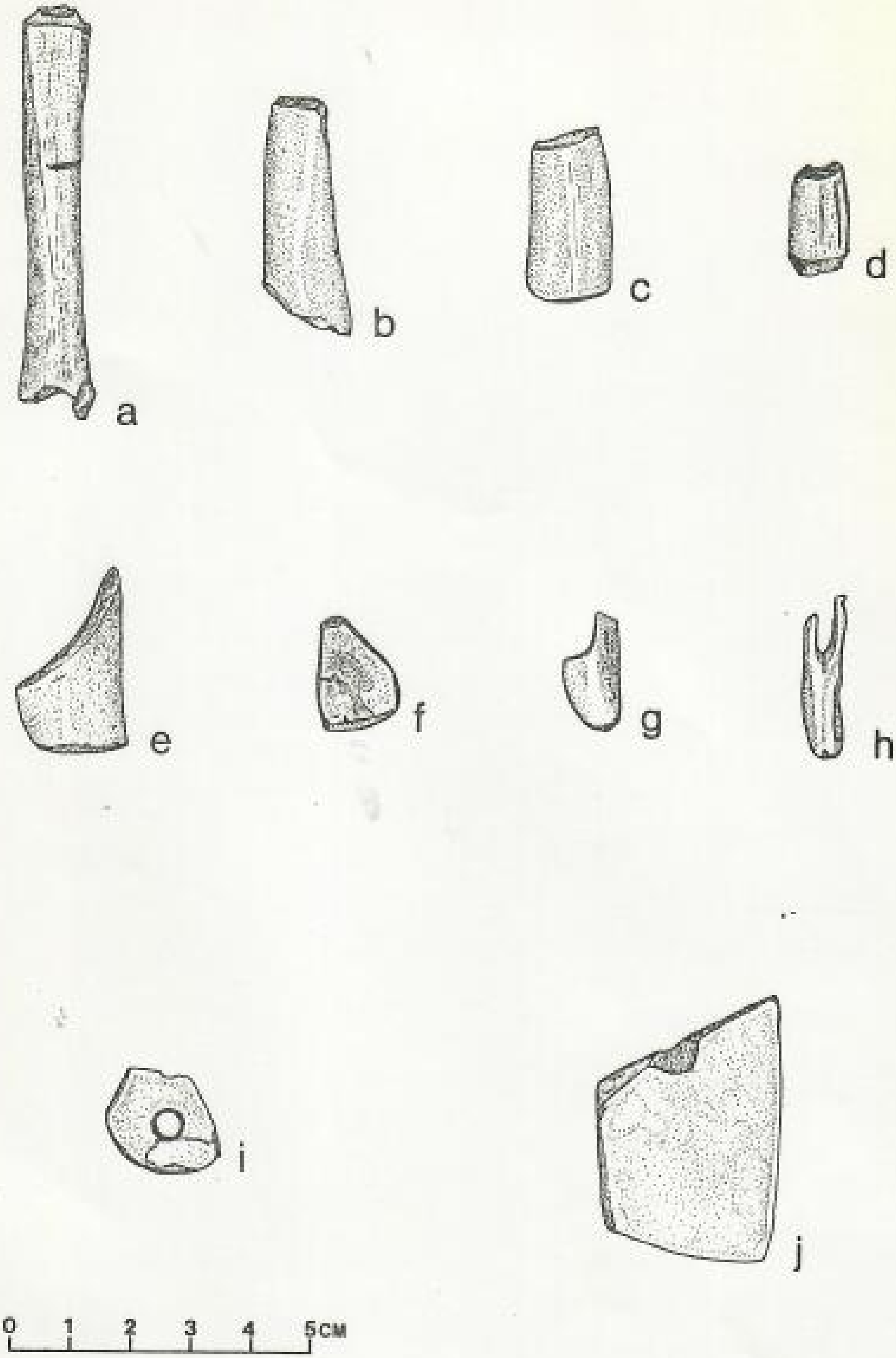


Fig. 71. CUT BONE AND UNFINISHED FISHHOOKS FROM KALĀHUIPUA'A: a, cut long-bone segment; b-d, roughed-out tabs; e-g, prepared tabs; h, unfinished hook; i-j, pearlshell tabs.

Three different methods of hook manufacture are evidenced in the Kalāhuipua'a material. In the simple drilling method (Sinoto 1967:352, fig. 6c, d), which seems to have been used primarily for rotating hooks, a perforation was made in the prepared tab. In the double-drilling method (Sinoto 1967:352, fig. 6e, f), two holes were drilled, often allowing for inner point or shank barbs. This method was evidenced on the shanks of several nearly completed pearl-shell hooks, and was apparently used in making the human bone hook from El-343. The notching and filing method (Sinoto 1967:352, fig. 6a), where a notch was cut downward into the prepared tab, was used particularly for the smaller jabbing hooks. Of the seven unfinished hooks, five show evidence of simple drilling, and two hooks evidence notching and filing.

One-Piece Fishhooks

The numerically largest hook class from Kalāhuipua'a is that of one-piece hooks, including both jabbing and rotating varieties. As Sinoto (Ms.:5, fig. 4) has remarked, this jabbing-rotating distinction subsumes important kinetic and functional, as well as formal, differences (also see Reinman 1970). With a jabbing hook, an upward force or pull applied to the line results in a concomitant upward thrust of the point, whereas in a rotating hook a pull on the line results in an inward rotation of the point. Sinoto has noted that in inshore waters with considerable coral growth, jabbing hooks become ensnared in coral branches much more frequently than do rotating hooks (Sinoto, pers. comm., 10/75). Nine jabbing and four rotating hooks were excavated, in addition to 19 one-piece fragments, not further classifiable. The complete jabbing and rotating hooks are illustrated in Figure 72, and the fragmentary one-piece hooks in Figure 73. Although the total sample size is restricted (N=20), an analysis of shank length on one-piece hooks (Fig. 74a) confirmed an impression of bimodality in hook size. The smaller component comprises a group of bone jabbing hooks (Fig. 72). Histograms of point length and hook width are provided in Figure 74. Only one hook, the human bone specimen from El-343, has a prominent barb.

Three line-lashing devices or head types (see Appendix C) are present in the Kalāhuipua'a sample. Most frequent (10 examples) is HT1a, in which the shank end is more-or-less flat, with a notch filed on the outer side of the shank. Type HT4a is represented by a single example; the shank end is beveled with a notch on the outer side of the shank. Type HT4b, represented by seven examples, has been notched on the shank end and outer side of the shank, to produce a distinct knob (Sinoto Ms.: fig. 5).

Wooden Hooks. The cache of 16 wooden one-piece fishhooks in a rear chamber of Site El-342 was a particularly unique and significant find, since wooden hooks are known mainly from ethnographic collections, and are only rarely encountered in archaeological contexts. This cache seems to represent the hook "kit" of a single individual, and its deposition in the cave, the result of a single event. Descriptive and metrical data on these hooks are provided in Table 40, and examples are illustrated in Figure 75. There is considerable size range among these hooks; shank lengths range from 114 mm to 315 mm. Likewise, the intended functions probably varied considerably. Some of the smaller specimens closely resemble a wooden hook illustrated and described by Buck (1957:330, fig. 226) and identified as a *makau ulua*, or hook for *ulua* (Carangidae family, esp. *Carangoides* spp.). The larger specimens, however, closely match the shark hooks (*makau mano*) described by Buck (1957:338-342). Four specimens have point limbs faceted for attachment of a bone point; one hook (Fig. 75b) has an inner point barb, similar to that illustrated by Buck (1957, fig. 234b). Two hooks have notched line-lashing devices of Type HT2a, similar to that described by Buck (1957:339-340) for the peculiar snood lashings of shark hooks. Remnants of bark still adhere to some hooks, and it appears that most were still in the final stages of manufacture.

distinct mode at 10 to 15 mm in shank length, whereas in the wider Hawaiian sample the mode correlates closely with the mean at c. 19 mm. This would suggest an emphasis, at Kalāhuipua'a, on inshore angling for smaller fish, such as wrasses. Although Barrera (1971a) unfortunately did not analyze the 'Anaeho'omalu hook assemblage, an examination of these specimens in Bishop Museum revealed a similarly large proportion of small jabbing hooks.

It would be instructive to compare hook sizes from varying Hawaiian archaeological assemblages with data on fish midden (and reconstructed fish size, from jaw measurements; see Akazawa 1969; Akazawa and Watanabe 1968). Unfortunately, the dearth of midden analyses from excavated sites renders this task impossible for the present.

DIET AND ECONOMY

The midden analyses presented earlier provide data relevant to certain major questions of relative exploitation of various marine animals, and of the energy values represented by the midden remains. The following interpretation must, however, be viewed with caution, considering both the infantile status of faunal analysis in Hawaiian archaeology, and the possible sources of error that may be introduced in various calculations. As discussed earlier, the whole problem of c- and n-transforms and their skewing effects on midden analyses are as yet largely unexplored.

Figure 97a is a ternary plot of relative percent (by weight) of three major shellfish genera (*Theodoxus*, *Cypraea*, and *Isognomon*) for eight sites. These three genera were selected not only because they composed a substantial proportion of the midden (more than 75%, see Table 22), but because they are indicators of brackish (*Theodoxus*, *Isognomon*) and salt-water (*Cypraea*) habitats. As can be seen in the figure, there is a fair degree of consistency among a cluster of five sites (E1-324, -327, -328, -342, and -355); however, the divergent patterns of Sites E1-350E, -368, and E2-51 must be noted. There does not appear to be any correlation between spatial proximity to fishponds (habitat for *Theodoxus* and *Isognomon*) and relative exploitation of brackish-water species. Site E1-324, farthest from the large ponds, falls into the same cluster with E1-355, while Site E1-350E, adjacent to Waipuhi Fishpond, had the highest percentage of *Cypraea*.

Evidence from Site E1-324, as well as previous study by Apple and MacDonald (1966), documents gradual subsidence of the West Hawai'i coastline. It was hypothesized that such subsidence could have had a serious effect on the area of brackish-water habitat at Kalāhuipua'a within the span of human occupation; if so, one might anticipate a temporal change in relative exploitation of brackish and marine shellfish. However, a ternary plot (Fig. 97b) of relative percentage composition of *Theodoxus*, *Cypraea*, and *Isognomon* by 5-cm levels in Site E1-355 did not indicate more than a very gradual decrease in *Cypraea* exploitation and concomitant increase in *Theodoxus*/*Isognomon* exploitation. In fact, it is rather the remarkable consistency in relative species exploitation over the 500-year span represented by Site E1-355 that seems more significant. In sum, shoreline subsidence at Kalāhuipua'a does not appear to have had any significant effect on availability or exploitation of major shellfish genera.

Relative exploitation of fish taxa by site (based on identified bone counts) is plotted in Figure 98a. The high percentage of scarids is evident, although as I have noted this may be a factor of differential bone preservation (n-transforms) rather than an accurate representation of relative exploitation. In Figure 98b, the percentage composition of fish taxa in Site E1-355 is plotted by 10-cm levels. A trend toward decreasing representation of labrids and increasing representation of scarids is evident, although the 20 to 30 cm level (No. 3 on Figure 98b) is somewhat aberrant in this pattern. It would be interesting to test this apparent trend against the as yet unanalyzed fish remains from 'Anaeho'omalu sites.

The evidence for increasing population at Kalāhuipua'a has been noted above (see p. 184 ff.). It is interesting to contrast this pattern of population increase with the total midden contents, by 5-cm level, of Site E1-355 (Square E9), as plotted in Figure 99. The significant increase in midden weight in the 10 to 15 and 5 to 10 cm levels would suggest, if not population increase, certainly intensification of marine exploitation (assuming a regular rate of deposition, verified by hydration-rind age determinations). The most recent level (0 to 5 cm) indicates a return to initial exploitation levels.

Finally, we may address the problem of the energy values represented by the Kalāhuipua'a middens, both in terms of (1) the relative contribution of fish and shellfish, and (2) the size of the human population that could be supported on the energy represented in these middens. Thermodynamic models of this sort have been presented for two New Zealand middens by Shawcross (1967, 1972); to date, however, the analysis of prehistoric Hawaiian middens has not proceeded beyond the level of gross mensuration. This is unfortunate, for although thermodynamic analysis of prehistoric middens is fraught with numerous difficulties and sources of error, the results are nevertheless of great potential value both in contrasting various sites in differing ecological situations and in addressing the question of temporal change. The following calculations, based on the material from Site E1-355, are preliminary and tentative; hopefully, they may stimulate further analyses of this sort in Hawaiian archaeology.

Table 52 presents data on the relative and total meat and caloric values of fish and shellfish in the E1-355 midden (total site). The values for usable meat per individual are, of course, rough estimates based on presently available data; they could be improved by studies of contemporary species populations. Nevertheless, as "ballpark" indicators, the resulting calculations are of some interest, with shellfish representing more than 90% of the total meat and energy value of the midden. To what extent this figure is an accurate reflection of actual dietary consumption is unknown. For example, it is possible that a large percentage of the fish taken at Kalāhuipua'a may have been dried for consumption in upland sites (see Settlement Patterns, above).

Whether or not the caloric values of fish and shellfish at E1-355 are accurate reflections of dietary consumption patterns, they are of some value for comparison with other midden sites in differing ecological situations. At Site Mo-A1-3 in Hālawa Valley, Moloka'i (Kirch 1975a and unpublished data in Bishop Museum), fish are estimated to account for 25% of the usable meat and shellfish for 62%. Dog and pig, virtually absent at Kalāhuipua'a, account for 13% of the

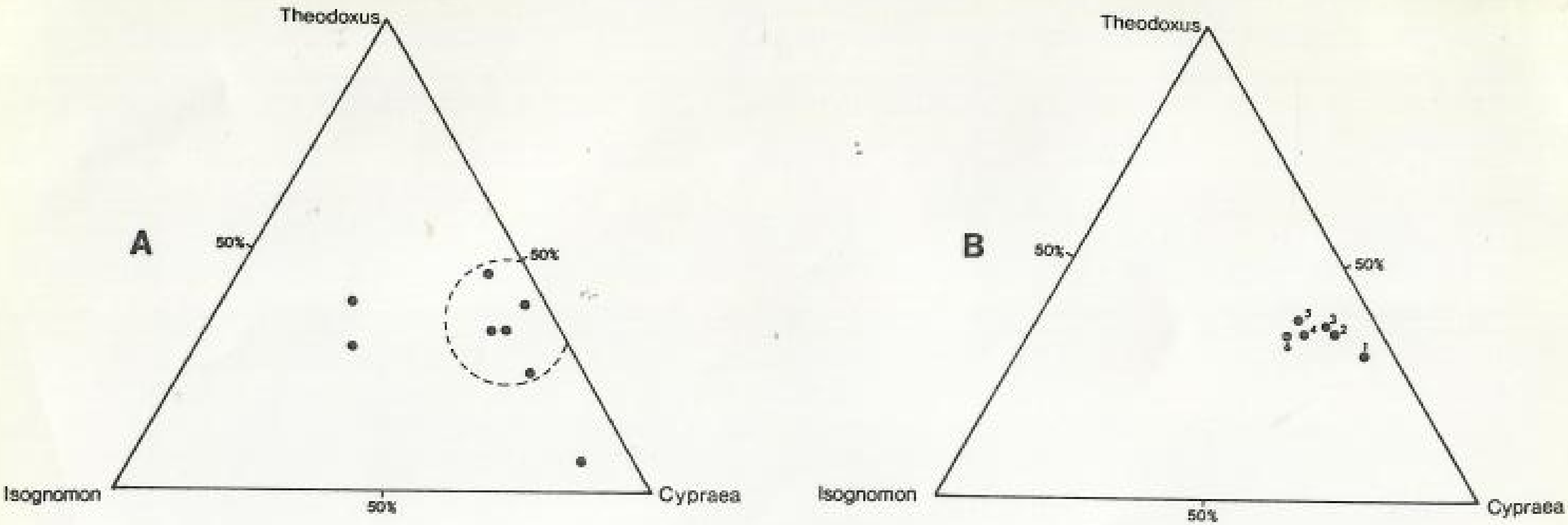


Fig. 97. TERNARY PLOTS OF MAJOR SHELLFISH GENERA IN KALĀHUIPUA'A MIDDEN SITES.

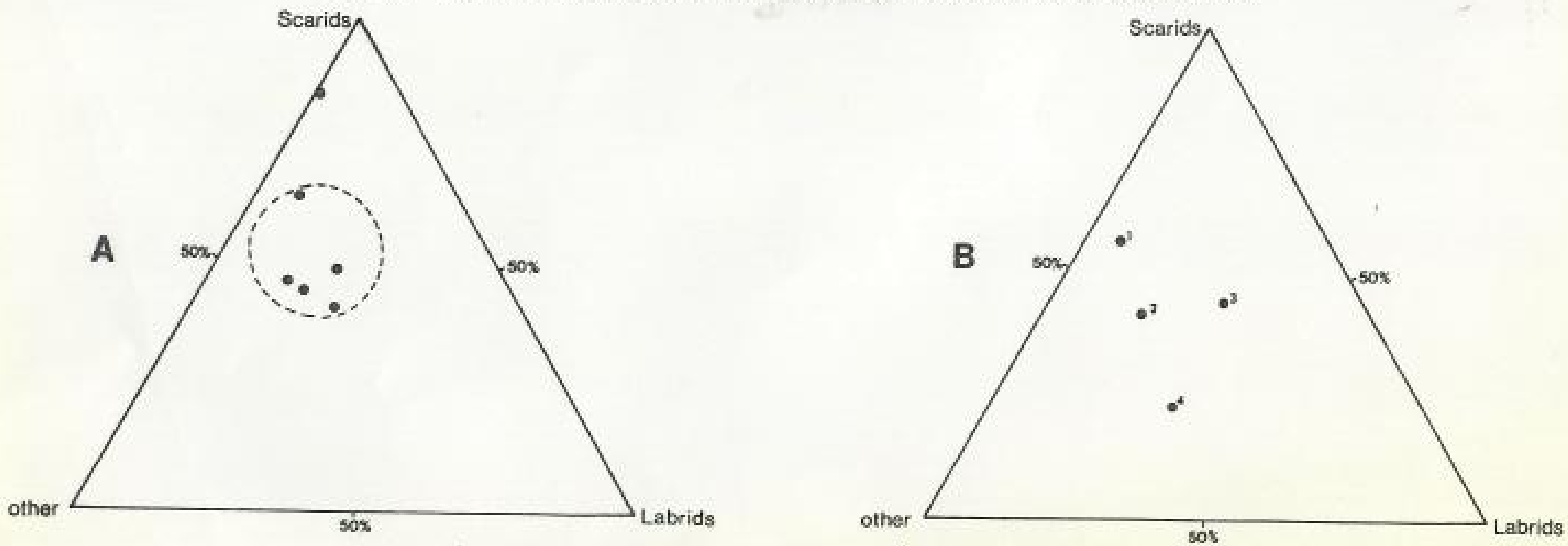


Fig. 98. TERNARY PLOTS OF FISH BONE IN KALĀHUIPUA'A MIDDEN SITES.

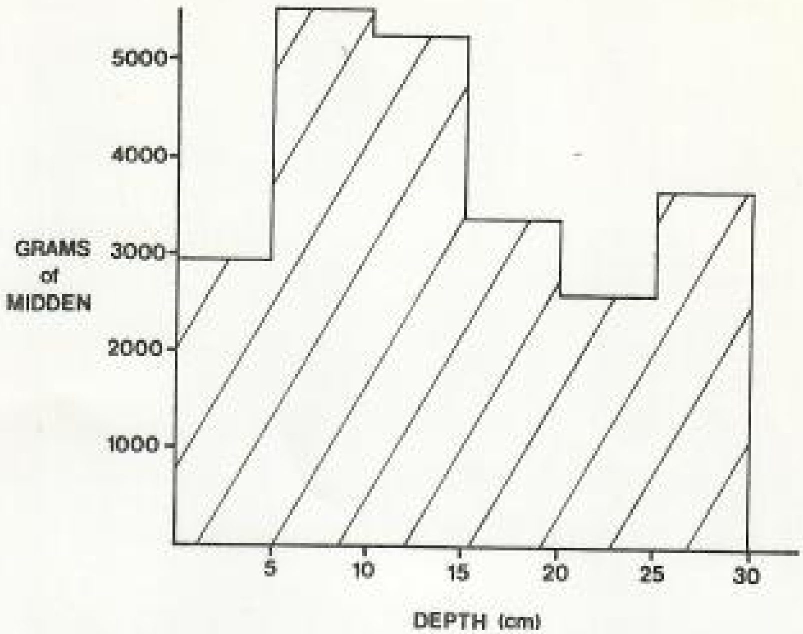


Fig. 99. GROSS WEIGHT OF MIDDEN IN SQUARE E9, SITE E1-355, BY DEPTH INCREMENT.

Table 52

USABLE MEAT AND ENERGY VALUE OF THE SITE E1-355 MIDDEN

Parameter	Fish	Shellfish	Total
Total Meat Value	31.6 kg (5%)	555 kg (95%)	581.6 kg
Calories per kg	950	700	
Total Caloric Value (kcal)	30,020 (7.2%)	388,500 (92.8%)	418,520

usable meat in the Hālawa midden. The contrast between Sites E1-355 and A1-3 is considerable and significant, and can be seen as reflecting the differences between a temporary marine exploitation site and a permanent agricultural settlement. Farther afield, the E1-355 data may be compared with the energy values of the Galatea Bay midden in New Zealand (Shawcross 1967, 1972; Terrell 1967). At Galatea Bay, a seasonally occupied marine-exploitation site, shellfish account for 92.3% of the kcal energy value, fish for 5.8%, and mammals for 1.8%. Thus, both the Kalāhuipua'a and Galatea Bay marine exploitation sites are quite similar in relative compositions of total energy value, and contrast significantly with the Hālawa settlement site.

The total estimated energy value of the E1-355 midden (418,520 kcal) also provides some basis for assessing the size of the human population that could be supported by it. Such assessments are, of course, crude estimates only, dependent upon a range of assumptions and error sources. In my view, however, they are exceedingly better than no estimate at all.

Furthermore, such estimates are of considerable value for comparative purposes. Table 53 provides several calculations of man-days and man-years represented by the El-355 midden at varying levels of individual caloric intake per day. A range of caloric intake values is given, and represents hypothetical situations; in all cases it is assumed that some proportion of the daily caloric intake was provided by vegetable foods, not represented in the midden. Considering that a c. 500-year occupation span has been documented for Site El-355, the 2.3 man-years maximum estimate of the midden's energy value is somewhat striking. To me, this is strong evidence that the site was occupied only intermittently. Of course, such an interpretation would be negated if it were shown that a large amount of food remains consumed by persons residing at El-355 was discarded elsewhere; at present, however, we have no evidence for such a pattern.

Table 53

ESTIMATES FOR CONSUMPTION TIME OF El-355 MIDDEN*

Protein (Calories) Consumption/day	Number of Man-Days Represented	Number of Man-Years Represented
500 calories	837	2.3
1000 "	418	1.1
1500 "	279	0.8
2000 "	209	0.6

*Total 418,520 calories

P. 198-228 MISSING

APPENDIX B.

NOTES ON THE EXCAVATION OF SITE H101, PANIAU SHELTER

by
P. V. Kirch

Site H101, a lava tube shelter cave, is located a few meters inland of the coast at Paniau, between Puakō Bay and Kalāhuipua'a, in the vicinity of the E3-1 petroglyphs. This midden-bearing shelter site was excavated intermittently from June through August, 1955, under the direction of K. P. Emory, whose notes are on file in the Anthropology Department of Bishop Museum. The excavation of Site H101, along with the testing of Site H100 (E1-342), was one part of a Hawaiian archaeological program with the major aim of recovering artifact assemblages, particularly fishhooks, in order to establish a cultural chronology for the Hawaiian islands (Spoehr 1956). Unfortunately, by contemporary standards, excavation records for H101 are minimal; no information exists on midden content. Because it is probable that no final excavation report for H101 will be forthcoming, a few notes on the excavation, compiled from Emory's field records, are provided here. Our present interest in H101 lies in the small (10 specimens) but interesting collection of fishing gear, which may be compared with that from nearby Kalāhuipua'a.

The H101 cave has internal dimensions of approximately 5 by 7 meters (c. 25 to 30 square meters). The 1955 excavations opened up 20 units, each measuring 3 by 3 feet. Stratigraphic records are limited to a cross section of the NW faces of Squares E7 and F7. The following stratigraphy was revealed: Layer I, fine aeolian dust (1-2 inches); Layer II, midden deposit (11 inches thick); and Layer III, bedrock or rubble floor of the cave.

Three features were recorded: Feature 1, a stone-lined hearth in Square E7 (surface exposure), composed of seven upright slabs in a circular arrangement, c. 1.5 feet in diameter; Feature 2, a partially stone-lined hearth with three upright slabs, extending from 8 to 18 inches below the surface in Square F8; and Feature 3, an ash lens, about 1 foot in diameter, from 12 to 15 inches below surface. No radiocarbon age determinations were obtained from any of these features.

A total of 54 portable artifacts was recovered, of which 32 are abraders (24 echinoid-spine, seven coral, and one scoriaceous-lava). In addition to nine one-piece fishhooks and one hook blank, the site yielded two sinkers (one basalt, one coral), cut bone (one), cut pearl shell (one), one hammerstone, one basalt flake, three drilled neritid shells, two fragments of sennit, and a pointed length of wood interpreted by Emory as a gorge for eel fishing.

The fishhook assemblage from Site H101 is described in Table 64, and certain specimens are illustrated in Figure 105. Excepting the possible eel gorge, all are one-piece hooks. One specimen (H101-F8-3) is dog tooth, one (H101-F7-1) is pearl shell, and the remainder are bone. Of the complete hooks, five are rotating, and one is jabbing. Line-lashing devices include three examples of HT1a and four of HT4b, suggesting that the site was occupied rather late in the prehistoric period.

Table 64

FISHHOOKS FROM SITE H101

Catalog No.	Characteristics*		S.L.**	P.L.**	W.**	Remarks
H101-D8-1	IB2U(1)a	HT4b	18	9	11	
-F7-1	IB2U(1)b	HT4b	25	16	17	
-F8-2	IB2U(1)a	HT4b	16	10	12.5	
-F8-3	IA1U(1)i	HT1a	10	5	6.5	Tooth
-F8-4	IB2V(1)a	HT4b	23	13	9	Bend very angular
-F8-6	S-IA2U(1)(c,d)a		--	8	7	
-F10-1	S-IB1(1)(d)a		--	--	--	
-G10-1	S-IA/B(a,b)a	HT1a	--	--	--	
-G10-7	IB2U(1)a	HT1a	12.5	9	7	

*See Appendix C.
**S.L. = Shank length; P.L. = Point length; W. = Width; all measurements in millimeters.

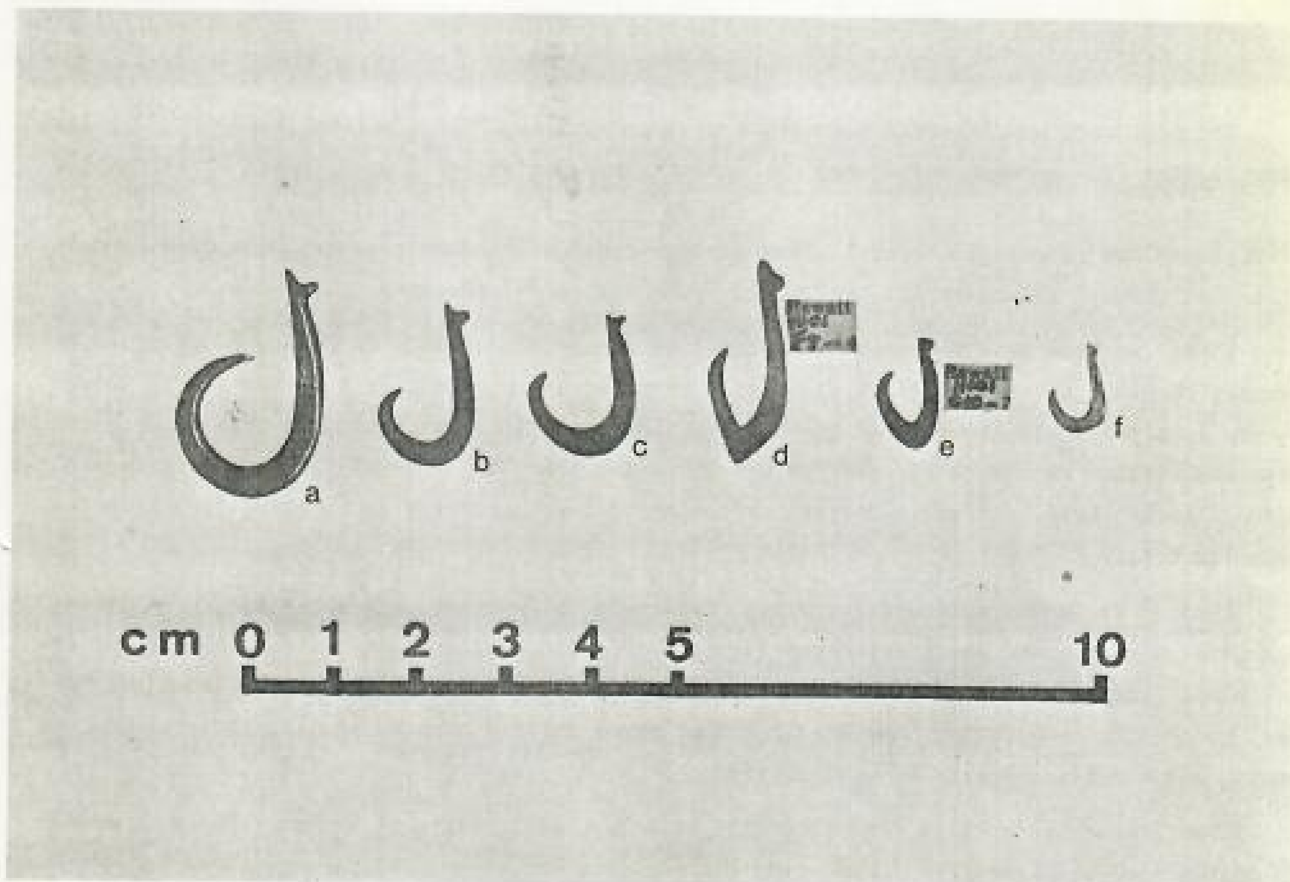


Fig. 105. COMPLETE FISHHOOKS FROM SITE H101, PANIAU SHELTER.

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4 *Makaha Valley Historical Project: Interim Rept. No. 1.* Roger C. Green, Editor. 1969. 101 pp; 3 tables; 32 figs.; glossary. (Out of Print)

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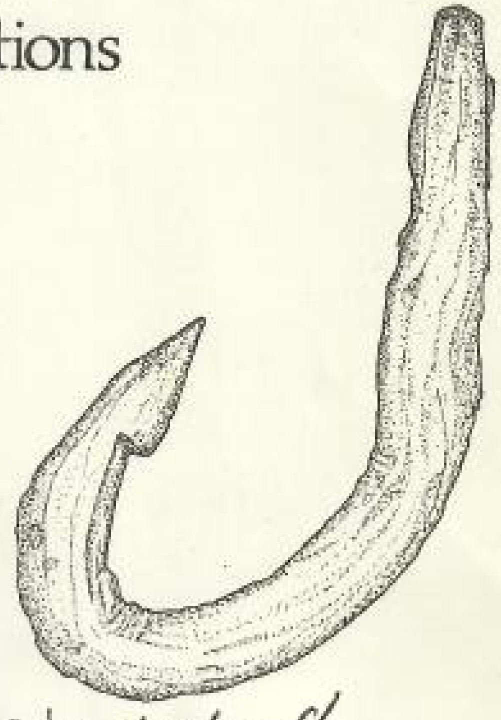

PATRICK VINTON KIRCH

P. 194 .. "dog and pig virtually absent"

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