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Review of Archaeological and Historical Data Concerning Reef Fishing in Hawaii and American Samoa

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Executive Summary

This review of reef fishing in Hawaii and American Samoa assesses the potential of archaeological and historical data to provide information on patterns of resource use from coral reefs, their long-term impacts and effects, and the causes and rates of ecological change. Sources reviewed are listed in an extensive bibliography and their characteristics are summarized in a series of tables that are included as appendices. The tables for archaeological sources rank them according to the amount of information they contain. The tables for historical sources indicate the time period(s) to which each source applies and record the kinds of information that each source contains using a twenty point classification.

The review indicates that the pre-1950 data are much fuller and richer for Hawai'i than they are for American Samoa. In Hawai'i, it should be possible to characterize patterns of fishery resource exploitation and chart at least some changes in these over time using a combination of extant archaeological and historical information. An investigation of long-term changes in inshore resources in Hawai'i will require either new fieldwork, a re-examination of existing archaeological collections, or application of a new analytic method whose utility is not yet established in the Pacific. None of these goals can be achieved with the scant archaeological and historical information available for the pre-1950 period in American Samoa.

The post-1950 fisheries data for both Hawai'i and American Samoa are rich and detailed. They have revealed important aspects of, and changes in, exploitation patterns and the condition of inshore resources.

Contents

1 Introduction

At the request of Western Pacific Regional Fisheries Management Council (WPRFMC), *T. S. Dye & Colleagues, Archaeologists, Inc.* has completed a review of archaeological and historical data concerning reef fishing in Hawaii and American Samoa. The purpose of the review was to assess the potential of the data to provide information on patterns of resource use from coral reefs, their long-term impacts and effects, and the causes and rates of ecological change. These potential sources of information have proved useful to fishery managers in the Pacific, who have adopted what has come to be known as a "data-less" approach to fishery management (Johannes 1998; Dalzell 1998).

The review addresses four substantive topics—human demography, patterns of fishery resource exploitation, temporal changes in fishery resource exploitation, and long-term changes in reef fish populations—set out in the statement of work. Each of these topics has its own set of methods applicable to archaeological and historical data; these are reviewed and summarized to provide a baseline against which the strengths and weaknesses of the historical data can be measured. The review then assesses the likely results of the methods applied to the information in the literature reviewed from Hawai‘i and American Samoa. The reviewed literature is presented in a bibliography of archaeological and historical sources on demography and fishing in Hawai‘i and American Samoa. This bibliography is a central product of the review, which can serve as the basis for future analyses aimed at providing fishery managers with the information they desire. The review ends with some comments on the potential applicability of this type of review to other Pacific Islands.

The review is presented in six sections based on the substantive topics. Changes in human population provide an important datum in assessing the potential effects of fishing practices on ecological change. Section 2 reviews the methods and literature sources on historical demography for Hawai‘i and American Samoa. Both Hawai‘i and American Samoa have seen wholesale changes in patterns of fishery resource exploitation in the modern period as traditional fishing practices were transformed by the introduction of modern fishing gear and boats, and a cash economy based on imports and exports changed patterns of work and diet. Information on patterns of fishery resource exploitation is reviewed in section 3 and for changes over time in section 4. Reviews of archaeological information indicate that, in several island groups, molluscs and turtles declined in abundance through harvest pressure and environmental changes (Dalzell 1998). An emerging literature explores the archaeological methods needed to assess human impact on traditional fisheries (Leach and Davidson 2001) and the possibility of a widespread decline in traditional fishing intensity associated with process of agricultural intensification, increased competition, and possibly resource depression (Allen et al. 2001). The information for long-term changes in inshore resources in Hawai‘i and American Samoa is reviewed in section 5. The potential applicability of this type of review to other Pacific Islands is discussed in section 6. The results of the review are summarized and concluding statements offered in section 7.

The remainder of this section sets out the scope of work provided by WPRFMC and describes the conduct of the review of archaeological and historical sources.

1.1 Statement of Work

The review was guided by a statement of work set out in the contract (Western Pacific Regional Fishery Management Council 2003). The statement of work reads as follows:

> The contractor will review various literature sources on the archaeological record, human population demographics, and recent fishery data and generate a report ascertaining the potential of these data sources to provide the following information:
>
> - a description of the demographics of human populations in the Hawaiian Islands and American Samoa from the period of their first colonization to the present
> - a description of the patterns of fishery resources exploited by historical populations in the Hawaiian Islands and American Samoa, with an emphasis on coral reef fishes and coral reef invertebrates, and turtles
> - a description of the temporal changes in fishery resources exploited in the Hawaiian Islands and American Samoa with emphasis on fish, invertebrates and turtles from coral reefs and associated habitats
> - the possibility of inferring from the historical record the long term changes in reef fish populations associated with historical human populations and their extractive activities, assess the potential to make estimates of the historical annual volume or yields of reef fish and invertebrates taken from the reefs in the Hawaiian Islands and American Samoa, and comment on the applicability of the method to other Pacific Islands

1.2 Conduct of the Review

The review was carried out from June 1, 2003 to October 31, 2003. The archaeological literature was reviewed by Thomas S. Dye, with the assistance of Jeffrey L. Putzi and Windy K. McElroy. The two primary sources of archaeological information are contained in the libraries of the historic preservation offices of Hawai‘i and American Samoa. Archaeological reports at the Hawai‘i Historic Preservation Division library were reviewed at the library in Kapolei. Archaeological reports in the American Samoa Historic Preservation Office (ASHPO) library were downloaded as portable document format files from that library's web site (American Samoa Historic Preservation Office 2003). Reports were reviewed for information on archaeological recovery of fish, shellfish, and turtle. Notes were taken on the level to which the remains of each type were identified, the amount of identified material, and the measurement units used in the report.

The review of archaeological methods was carried out by Dye at the *T. S. Dye & Colleagues, Archaeologists, Inc.* library, the main branch of the Hawaii State Library, and at Hamilton Library, University of Hawaii.

The review of historical literature was carried out by Thomas Graham, Robert T. B. Iversen, and Dye. The work was begun by Iversen, whose involvement in the project was cut short by health problems. Iversen turned over the materials he had collected to Graham. Historical sources of information about Hawai'i and American Samoa started becoming available shortly after Europeans first visited the two island groups in 1778 and 1722, respectively. A search was made for historical sources that pertained to human demography and inshore fishery resources and their exploitation. These sources were collectively reviewed in terms of their potential to reveal historical demographics, patterns and trends of resource exploitation, and long-term changes in the condition of inshore resources. The intent of the review is to identify the potentially useful sources and to highlight the types of information that each provides. Throughout this report, the term "inshore resources" is used to describe the living marine resources found in shallow-water coastal waters. It is difficult to draw a line between inshore resources and neighboring resources, such as deep-water demersal resources or coastal pelagic resources, and no attempt to do so is made here. The scope of this assessment is general enough that this is not a problem—inshore resources are treated here in only general terms. Still, the review paid more attention to certain types of inshore resources than others. Reef-associated finfish and invertebrates were treated as the focus. Other resources, including sea turtles, seaweeds, and nearshore pelagic finfish such as *Selar crumenophthalmus* were given less attention, but they were not ignored—information about them was gathered opportunistically.

2 Historical Demography

Population histories of Hawai'i and American Samoa are important background information for an investigation of changing patterns of fishery resource exploitation over time because, absent exports, demand for fish, shellfish, and turtle is local and presumably related to population size. The prehistoric periods of Hawai'i and American Samoa were much longer than the periods characterized by historical records and so the use of archaeological information is indispensable for determining the timing of first settlement by Polynesians and for charting changes in population over the time during which historical records were not kept. The introduction of history to the islands in the eighteenth century did not immediately improve the historical demographic record and it introduced diseases to which the Hawaiians and Samoans had little or no immunity (e.g. Bushnell 1993b), leading to population declines in both groups.

The following sections review and assess the methods of historical demography as it is practiced by archaeologists and historians, review and summarize the bibliographic resources, and assess the potential of historical demographic data to estimate population histories useful for an investigation of fishery resource use.

2.1 Review and Assessment of Methods

Although historians occasionally make use of archaeological data to investigate population history, the data sets most often used by archaeologists and historians are different from one another. This section first reviews the archaeologist's methods, which because of the fragmentary nature of the archaeological record are somewhat more complex and difficult than those of the historian. The historian's methods are dealt with briefly in the second part of the section.

2.1.1 Archaeological Methods

Archaeological data are useful to the historical demographer who wishes to determine the date an island group was first settled and evaluate data, usually fragmentary and often oblique, on population change.

Archaeological data associated with the first human settlement of Oceanic islands are surprisingly difficult to find. Early populations of settlers were undoubtedly small and the remains of their settlements potentially disturbed by every subsequent traditional and historical development (Graves and Addison 1995). In American Samoa, the search for early sites is aided by the distinctive, dentate-stamped Lapita pottery produced by the first settlers of the region, which makes early sites highly visible to the archaeologist (Bellwood 1979; Davidson 1979; Kirch 2000). Investigation of pottery-bearing sites in American Samoa is eased somewhat by large body of results on similar sites in the neighboring island groups of Western Samoa, Fiji, and Tonga, which provide context for their dating and interpretation. In Hawai‘i, one of the last island groups to be settled by Polynesians, at a time when pottery production had been abandoned by Polynesians or was in the last throes of a protracted decline in Western Polynesia, there is no useful artifactual indicator of early sites and the search there has proved very difficult. Lack of an artifactual indicator of early settlement means that relatively great stock has to be placed on ^{14}C dating, a technique that has proved difficult for Hawaiian archaeologists to grasp fully (Davidson 1992). A persistent problem has been Hawaiian archaeologists' failure to control for the "old wood problem" (Taylor 1987; Bowman 1990) which can add as much as 1,000 years to the dated age of an archaeological event in Hawai‘i (Dye 2000). A different archaeological approach to determining the date of first settlement does not rely on the discovery and interpretation of archaeological sites, but instead uses dated paleoecological evidence for the types of environmental changes associated with initial human settlement on a pristine oceanic island (Kirch and Ellison 1994). This approach has detractors, who point to the difficulty in many circumstances of distinguishing natural environmental changes from those caused by man, opening the possibility of assigning a too old date to first settlement (Anderson 1994).

Archaeologists have developed several approaches to estimating characteristics of prehistoric populations(Schacht 1981; Hassan 1981), three of which—the site census, life-table, and ^{14}C date proxy approaches—have been applied to Pacific islands.

The first, and most widely used, is the site census approach, which can either estimate the direction and rate of population change or the absolute population at a given point in time. In practice, the method involves taking a census of dated architectural units. Population change over time can be inferred directly from changes in the number or aggregate size of the censused architectural units and an absolute population estimate can be derived if an assumption is made about the number of people represented by each of the units. The simplicity of this approach is somewhat deceptive and its application often founders on the reliability with which the duration of occupation for each of the architectural units can be established (Schacht 1984). Ideally, dates for construction and abandonment of each archaeological unit in the census would be determined through archaeological investigation, enabling a determination of the number or aggregate size of units inhabited in a given year. In practice, however, archaeological dating methods and their applications are rather crude and it is usually not possible using ^{14}C dating or artifact styles to represent time in intervals shorter than a century. If, given this limitation, the population of a region is estimated by century, then a problem potentially arises if the average occupation span of the architectural unit in the census is different than a century. If, for example, the average occupation span of an architectural unit in a region is 50 years, then population estimates for each century will be twice the actual regional population because at any one time about half of the architectural units would have been abandoned. Schacht (1984) has worked out a sophisticated statistical model of settlement growth that ameliorates this type of problem in situations where the chronological periods over which a settlement was occupied and the period of maximum population can be reliably determined. This approach is potentially applicable to American Samoa where sites can be assigned to broad periods based on the type of pottery present at the site or its absence. In Hawai‘i, where archaeologists have not been able to find a widely distributed artifact type that can be used as a chronological indicator, the approach is not applicable, and an alternate approach based on accurate estimation of the construction and abandonment dates of architectural units would be required.

Although archaeologists have for many years collected estimates of sex and age-at-death for skeletons, this information wasn’t used to estimate population size and change until the late 1960s, when life-tables developed by statisticians in the insurance industry were first applied to the study of skeletal collections (Saunders and Katzenberg 1992; Katzenberg and Saunders 2000). Investigators realized that the size of the population that contributed skeletons to a cemetery could be estimated if the duration of the cemetery could be known and the skeletons in the cemetery were a complete representation of the deceased members of a community (Ubelaker 1989:135 ff.). As the brief discussion of archaeological dating earlier indicates, the first condition is difficult to meet in practice. However, the second condition, having to do with the complete representation of the deceased members in the community, has proven almost impossible to achieve. The goal here is to achieve an accurate age-at-death distribution for the population under study. There are two sets of problems, one having to do with the under-representation of young individuals in skeletal collections and the other with the technical difficulties of determining age-at-death of adult skeletons. Environmental and cultural factors bias the preservation and recovery of infant and child skeletal material, which “represents the most demographically variable and sensitive portion of the human life cycle, while constituting the best estimator of a population’s health and well-being” (Roth 1992:177). Many societies, faced with high rates of infant mortality, treat deceased infants and small children differently than deceased adults, leading to an under-representation of young individuals in skeletal collections from cemeteries and ossuaries. This problem is exacerbated by small bone size and incomplete ossification, both of which encourage decay in the ground and militate against recovery by archaeologists. The second problem, determining age-at-death of adults, has proven extremely stubborn, especially for individuals over the age of 50 (Jackes 1992, 2000). The margin of error for this type of estimate, even with the most modern techniques, makes the life-table approach problematic. Even if it were possible to determine accurately the age-at-death of skeletons, the next step of paleodemographic analysis would be to estimate age-specific mortality rates, which involves an assumption that the population is stationary, i.e. closed to migration and with an intrinsic rate of growth equal to zero (Milner et al. 2000:479 ff.). Thus, the method requires one to assume from the beginning a rate of population change, when this is one of the most important things we would like to learn. Milner et al. (2000:483) opine that "it may be time to abandon life-table methods on the grounds that they are not well suited to paleodemographic data." New approaches will require construction of a probability distribution for the age of each skeleton based on its observed traits (Milner et al. 2000:485 ff.), something that hasn't been done for Hawai‘i.

The ^{14}C date proxy method was developed by Rick (1987). It differs from the other methods by using ^{14}C dates as primary data rather than as a means to assign an age to some other class of archaeological remains. The conceptual basis of the method is summarized by the assertion that

> if archaeologists recovered and dated a random, known percentage of the carbon from a perfectly preserved carbon deposit to which each person-year of occupation contributed an equal and known amount, they could estimate the number of people who inhabited a region during a given period (Rick 1987:56).

In practice, a histogram of ^{14}C dates is constructed by one of several methods (see Stolk et al. 1994; Dye and Komori 1992a) and the shape of the histogram is interpreted as reflecting a population growth curve.

Rick specifies three assumptions that must hold for a histogram of ^{14}C age determinations to model changes in population:

1. the ^{14}C age determination sample is representative of the extant archaeological carbon deposit;

2. the extant archaeological carbon deposit is representative of the original carbon deposit; and

3. the amount of carbon added to the original deposit *per capita* per unit time is constant over the period of interest.

Deviations from these assumptions are known as investigation biases, preservation biases, and creation biases, respectively.

In most circumstances it is not possible to know either the annual *per capita* contribution of charcoal to the deposit or the percentage of the deposit comprised by the sample. In these cases, the method yields estimates of the rates and directions of population change but cannot yield estimates of population size. However, in situations where the the period covered by the ^{14}C dates includes a year where the population size is known, then the *per capita* contribution to the sample for that year can be derived. This figure can then be used to derive absolute population sizes for other years covered by the histogram, assuming that creation biases are not strong.

2.1.2 Historical Methods

Historical demographers use a wide variety of data sources to study characteristics of past populations. Primary sources from censuses and vital statistics are often supplemented by various records, observations, and documents. Sources of historical demographic data were listed by Hollingsworth (1969:43–44) in their approximate order of usefulness:

1. censuses, especially if given by name and age
2. vital registration data
3. Bills of Mortality
4. ecclesiastical records, such as parish registers and communicants' lists
5. fiscal documents
6. military records
7. inventories of property
8. genealogies
9. wills
10. marriage settlements
11. eye-witness estimates
12. prices, over the long term
13. number and extent of towns
14. archaeological remains
15. methods of agricultural economy
16. ecclesiastical and administrative geography
17. new buildings
18. colonization of new land
19. cemetery data, both from skeletons and tombstone inscriptions

The list makes clear that most types of data are more useful than those provided by archaeologists and used by paleodemographers. Because many of these types of data provide direct information on population size and other parameters, much of the work of historical demography involves evaluating the accuracy of sources, rather than using the sources as a basis from which to infer population characteristics.

2.2 Summary of Bibliographic Sources

The time of first human settlement of Hawai‘i is a matter of debate among archaeologists. Arguments for a “long” chronology with settlement prior to A.D. 600 (Kirch 1974, 1985; Hunt and Holsen 1991) are countered by arguments from the same data for a “short” chronology with settlement around A.D. 900 (Spriggs and Anderson 1993; Tuggle 1997). One reason for the relatively great differences in archaeologists’ estimates is the failure to control for the dating of “old wood” (Dye 2000). For a variety of reasons, the “short” chronology appears to be best supported by the available data.

Four applications of the site census approach have been attempted in Hawai‘i. Cordy (1981) reconstructed absolute population figures for eight land units on the dry, lava-covered leeward coast of Hawai‘i Island by counting the number of sleeping houses per land unit, estimating their duration of use by dating pieces of volcanic glass found within them, and assigning six persons to a house. Rob Hommon used information on the duration of occupation at 51 volcanic-glass-dated habitation sites in leeward Hawai‘i (Hommon 1976) and 655 archaeological features on Kaho‘olawe Island (Hommon 1980) to estimate changes in site population for those regions. He did not attempt to estimate numbers of people and was careful to point out that site population growth rates would reflect, but not necessarily equal, rates of population growth. Hommon’s work was followed by Kirch (1984:104 ff.), who augmented the leeward Hawai‘i Island sample with information from 62 other sites, most of them dated with the volcanic glass hydration method. Data from leeward Hawai‘i and Kaho‘olawe both yielded sigmoidal growth curves, with site populations reaching a maximum in the sixteenth or seventeenth centuries A.D. and either remaining static or declining thereafter.

Applications of the site census approach in Hawai‘i were criticized. Cordy (1984:23) pointed out that duration of occupation is reliably estimated for relatively few habitation sites (see pg. 7). Clark (1988) summarized several potential sources of uncertainty in the site census approach as it was applied in Hawai‘i. They include:

- the use of volcanic glass for dating at many sites, a dating technique that is now discredited (Olson 1983);
- indiscriminate census of temporary and permanent habitations;
- variations in household size;
- spatial and temporal biases deriving from the small size of the dated sample of habitation sites; and
- use of volcanic glass age determination standard deviations to estimate occupation spans.

He concluded that “detailed regional models of population size and growth are premature,” but that “the growth in population can be depicted by a modified logistic curve” (Clark 1988:29).

The life-table approach was carried out by Kirch (1984), who constructed life tables for skeletal populations excavated at Pu‘u Ali‘i, Hawai‘i Island and Mōkapu, O‘ahu Island. Although the Mōkapu site has not been dated, Kirch suspected that since the windward coast was a locus for early settlement, the "Mōkapu series could be of some antiquity" (Kirch 1984:113). The Pu'u Ali'i series was more confidently dated to the last two centuries before European contact. The life tables for these populations showed that survivorship (l_x) was lower at Pu'u Ali'i than at Mōkapu, and that child and infant mortality (q_x) was higher at Pu'u Ali'i than at Mōkapu. Kirch found these data "tantalizing in their suggestion that ... [Hawaiian] populations were responding to certain density-dependent effects" (Kirch 1984:115–116) and found in them support for the sigmoidal population curves constructed for Leeward Hawai'i and Kaho'olawe.

The paleodemographic data cited by Kirch (1984), with the addition of a series from Keōpū, Hawai'i Island, were later analyzed by Sutton and Molloy (1989). Using advances in paleodemography that recognize the interdependence of life table parameters, their sensitivity to the stable population assumption, and the effects of various parameters of the frequent under-representation of infants in skeletal populations, they show that adult life expectancies at Pu'u Ali'i and Mōkapu were virtually identical, but were exceeded at Keōpū. They also show that birth rates at Mōkapu and Pu'u Ali'i were not significantly different, but were substantially higher at Keōpū. They conclude that Kirch's results are "an artefact of his methodology" (Sutton and Molloy 1989:32) and that they do not support the sigmoidal population curve derived from the site census data. However, they note that "the implications of [the paleoanthropological data] for population growth cannot be adequately assessed" (Sutton and Molloy 1989:35), so questions about the shape of Hawai'i's pre-censal population curve remain open.

The ^{14}C proxy approach was carried out by Dye and Komori (1992b) using a sample of 598 ^{14}C age determinations from Hawai'i. The ^{14}C age determinations were selected from archaeological contexts associated with household activities, under the assumption that cooking, lighting, and other routine daily chores were unlikely to be subject to creation biases. The ^{14}C age determination histogram[1] spanned the period A.D.1–1832, with the year for the recent end of the histogram chosen to coincide with the first census of Hawai'i by missionaries (Schmitt 1973). The height of the histogram for 1832 was set to the population enumerated by the missionaries, thus calibrating the histogram so that it yielded estimates of the absolute size of the population back through the traditional Hawaiian period. Subsequently, Dye (1994) compared the population curve to indices of agricultural growth and religious temple construction, finding support in the comparison for the shape of the population curve.

The population of Hawai'i in 1778, when Cook's officers made the first published estimates, is a matter of debate. Cook's officers themselves had varying estimates, leaving the door open for modern writers to improve upon them with estimates that range from 100,000 to 1,000,000 (see Schmitt 1968, 1971; Stannard 1989). Arguments against estimates at the upper end of this range, in particular the estimates of Stannard (1989), have been made by Bushnell (1993a) and Dye and Komori (1992b).

There were no new population estimates for the period 1779–1822, save for an all island figure attributed to a carpenter who had lived in the islands in the first years of the nineteenth century (Schmitt 1968:23, 24). Several estimates from the 1820s agree well with one another (Schmitt 1968:24, 25). The first attempt at a census of the

[1] The ^{14}C age determination histogram is called an "annual frequency distribution" by Dye and Komori (1992b).

islands was completed by missionaries in 1831–1832, yielding the earliest dependable data on Hawaiian demography (Schmitt 1973:iv). This was followed by another all-island census in 1835–1836 and partial censuses in 1840, 1846, and 1847, the latter three carried out by either the missionaries, the government, or the missionaries and the government (Schmitt 1973:3).

The Hawaiian government census of 1850, which included an accurate enumeration of the inhabited islands, with information on age, sex, and nationality, is a "statistical landmark" (Schmitt 1968). Official censuses were taken in 1853, 1856, 1860 and then every six years until 1896. In 1900, the United States Census Office took over the Hawaii census and has completed an enumeration of the islands every decade since.

This rich demographic record for Hawai‘i is ably summarized, reviewed, and analyzed by Schmitt (1968), Gardner and Nordyke (1974), and Nordyke (1989).

The earliest ^{14}C date associated with human activity in American Samoa was collected from the To‘aga site on Ofu Island of the Manu‘a group (Kirch and Hunt 1993:91). This sample was associated with thin, fine-tempered pottery sherds, some of which were decorated with notches on their rims. Although the To‘aga site did not yield dentate-stamped Lapita pottery, of the type produced by the first settlers of the region, the early To‘aga date is comparable to the calibrated age range of a sample of marine shell from the submerged Lapita site at Mulifanua on ‘Upolu Island (Leach and Green 1989), the oldest known archaeological site in Samoa.

Archaeologists in Samoa have not attempted a detailed estimate of the prehistoric population. Based on the density of surface remains surveyed in Western Samoa, Green and Davidson (1974:281–282) opined that the pre-Contact population was twice the size of the population in the 1840s. An unpublished estimate puts the figure even higher (Kirch 2000:312, note 21).

Although Samoa was sighted by the explorers Roggeveen in 1722 and Bougainville in 1768, the first Europeans to venture ashore sailed with Lapérouse in 1787 (Gilson 1970). Twelve of them lost their lives there, and the islands quickly came to have a poor reputation among European seamen, who passed Samoa by in favor of Tahiti, New Zealand, and Hawai‘i. Consequently, little was written about Samoa until missionaries settled there in 1830. The first population estimate for Samoa, for the year 1839, was reported by the United States Exploring Expedition (Wilkes 1845). A second estimate made by a visitor in 1849 was followed, in 1853, by a census taken by missionaries, "which is probably the first realistic estimate of population, although not necessarily completely accurate" (McArthur 1968:114). The missionaries compiled censuses again in 1863 and 1874 and the British Consulate produced estimates of population in 1879, 1887, and 1899. After the Treaty of Berlin, which divided Samoa between Germany and the United States, the commandants of Naval Station, Tutuila enumerated the population of American Samoa in 1900, and at various intervals until 1920 (McArthur 1968:141). Since 1920, American Samoa has been included in the decennial census of the United States.

2.3 The Potential for Historical Demography

Hawai‘i has a rich and detailed record of demographic history. A variety of archaeological methods, although all rather crude, yield broadly similar results, and the outlines of population change in pre-Contact Hawai‘i are now reasonably well established. The absolute size of the Hawaiian population at the time of Cook in 1778 is a matter of debate, but the subsequent calamitous decline of population is not. A reasonably accurate census of the islands was completed relatively early in the historic period in 1836, and this was followed up by increasingly accurate efforts at short intervals, yielding a population record of the early historic period matched by few, if any, island groups in the Pacific. The Hawaiian government produced good census information for the last half of the nineteenth century, after which time the Hawaiian Islands were included in the decennial United States census.

The record for American Samoa is not nearly so rich and detailed. Archaeologists have not attempted to estimate population changes over the pre-Contact period, and it is unlikely that this could be achieved given the relatively sparse inventory of well-investigated archaeological sites there. There is an unpublished estimate of the population size at the time of contact with Europeans, but the first census of American Samoa, of questionable accuracy, was not made until 1853, more than a century later. Thereafter, censuses were made approximately every ten years, with increasing accuracy. Thus, for most of Samoan history, there is no demographic information and only scant materials that might be used to develop a demographic history.

3 Patterns of Fishery Resource Exploitation

This section reviews the methods and materials for estimating the patterns of fishery resources exploited by historical populations in the Hawaiian Islands and American Samoa, with an emphasis on coral reef fishes and invertebrates, and turtles.

3.1 Archaeological and Historical Methods

The methods used by archaeologists and historians to establish patterns of fishery resource exploitation differ considerably, based as they are on completely disparate sets of data. The archaeologist works with the discarded remains of fish, shellfish, and turtles that have been recovered from archaeological sites. These are identified, with reference to comparative fish bone collections and standard reference works. The identified bones are then quantified and the resulting numbers used to estimate the relative abundances of the different kinds of animals. Historians work with records, documents, and observations that provide information, more or less directly, on the conduct and results of inshore fishing. The data take a variety of forms, mostly fragmentary and incomplete, and the historian’s task is to identify, interpret, and synthesize the useful information so that it yields a coherent account of what happened in the past.

3.1.1 Archaeological Methods

The archaeological methods useful for estimating patterns of fishery resource exploitation involve deriving estimates of the relative abundance of taxa from the identified bones and shells recovered from archaeological sites and determining whether the identified remains reflect the full diversity of the prehistoric catch. As it turns out, estimating the relative abundance of taxa from archaeological remains is often difficult and is intimately tied to the units used to quantify the remains. This is an issue that has generated a large, often contentious literature but no reporting standards, thus complicating and often compromising efforts to summarize and synthesize published data. Investigations into the diversity of the prehistoric catch are often subsumed under the heading "niche breadth." They are important for determining the influence of size on the richness and evenness of a sample. The goal here is to know how large a sample is needed to estimate the diversity of the catch from which it derived.

At the outset, it should be noted that remains recovered from an archaeological site are several steps removed from the catch, and that at each step of the way potential biases are introduced that complicate the inference that the abundance of taxa in the archaeological collection actually reflect the abundance of taxa in the catch. A useful way to look at this, set out by Klein and Cruz-Uribe (1984:3) considers the various populations, or assemblages, of which an archaeological collection might be considered a sample:

Life assemblage The community of live animals in their natural proportions;

Death assemblage The animals that are available for deposition;

Deposited assemblage The animals or portions of animals that come to rest at a site;

Fossil assemblage The animal parts that survive in a site until excavation or collection; and

Sample assemblage The part of the fossil assemblage that is collected by the archaeologist.

Here, the catch is called the death assemblage and it is easy to see that the archaeological collection, or sample assemblage, is usually only a partial reflection of the catch, separated from it by the vagaries of human deposition practices, the breakdown of faunal remains in the archaeological site over time, and the recovery efforts of the archaeologist.

There are a host of methods by which faunal remains—the marine shells and fish and turtle bones from archaeological sites—can be quantified and a large literature that summarizes the methods (see Klein and Cruz-Uribe 1984; Reitz and Wing 1999; Ringrose 1993). One review of zooarchaeology counted 122 unique definitions for quantification methods (Lyman 1994). Most commonly used in the Pacific are the number of identified specimens, often abbreviated NISP, the minimum number of in- NISP
dividual, or MNI, and weight. Each of these can be used to estimate relative abundance MNI
of taxa in the *sample assemblage* with varying degrees of reliability and difficulty. None of these measures directly estimates the relative abundance of taxa in the fossil, deposited, death, or life assemblage.[2] The following discussion attempts to point out the strengths and weaknesses of each measure as an estimator of the relative abundance of taxa in the sample assemblage.

[2] A statistic known as the Lincoln Index, applied to paired elements, yields estimates of the relative abundance of taxa in the death assemblage (Ringrose 1993:128 ff.), but to our knowledge this has not been applied to Pacific archaeological remains.

The measure with the most intuitive attraction is MNI, which estimates the smallest number of individual animals in the catch that could have produced all the remains in an archaeological collection. Relative abundances calculated with MNI are used by Pacific archaeologists "to convey what the catch would have looked like when laid out on a mat after a fishing trip" (Leach 1997:6), a characterization that plays up the conceptual appeal of counting individual animals, but ignores the fact that MNI estimates characteristics of the sample assemblage and not the death assemblage. MNI can be calculated from individual elements, for example the umbo of a gastropod, paired elements, such as the dentary of a fish, or multiple elements where the elements cannot be told apart, such as vertebrae. The measure is straightforward when it uses individual elements, but becomes complicated when paired or multiple elements are used, as they typically are when calculating the MNI of fish, turtles, or bivalves. The problem here is that MNI estimates calculated on paired or multiple elements are not additive; for a given taxon, the sum of MNI from sub-units of a collection unit, e.g. the individual 1 m^2 excavation units of a 20 m^2 excavation block, will generally be greater than the MNI calculated for the unit because paired or multiple elements of an individual animal are counted separately if they are collected from different sub-units. This characteristic of MNI is discussed at length by Grayson (1984), who refers to it as the aggregation effect. In practical terms, a literature source must report the MNI of taxa identified by paired or multiple elements for the unit of interest if the data are to be used for comparison. MNI are known to over-estimate rare taxa, over-estimate taxa with many identifiable parts in highly fragmented collections, and under-estimate these same taxa in collections with little fragmentation (O'Connor 2001:706). MNI estimates are sensitive to stochastic factors and in this way are much less robust than estimates made with NISP.

Less intuitively attractive is the NISP measure, which, in practice, counts every identifiable element and element fragment.[3] Taxa with a large number of identifiable elements—a good example, common in Pacific faunal collections, is the spiny puffer of the family Diodontidae, each individual of which has approximately 500 distinctive dermal spines (Leach 1997:11)—will yield high NISP values compared to taxa with a small number of identifiable elements. A correction for this divides the NISP for each taxon by the number of identifiable, or identified, elements of the taxon, although this is rarely accomplished in the Pacific. Also, taxa with identifiable elements that fragment easily are likely to be over-represented relative to taxa with sturdier identifiable elements in collections with a high frequency of fragmentary remains. This is especially problematic with collections of invertebrate remains, where tiny fragments are often easy to identify. Despite these potential problems, many investigators find NISP a useful measure of relative taxonomic abundance. In an analysis of fish remains from the Cook Islands, Nagaoka (1994) found that MNI and NISP values for each taxon varied in a predictable fashion, indicating that they carried similar information on relative abundances. Thus, given the relative ease of obtaining NISP estimates and their mathematical manipulability, they appear to be superior to MNI for most purposes.

Use of sample weights to estimate relative abundance of taxa is relatively rare among archaeologists (Reitz and Wing 1999:191), primarily because the weight of an

[3]An alternative designation for NISP is total number of fragments, or TNF.

animal's remains varies widely among taxa. A correction for this variability multiplies the weight of identified remains by a value for each taxon that describes the relationship of meat weight to the weight of inedible remains that might be deposited in archaeological sites. Corrected in this way, bone weights provide estimates of the relative weight of meat contributed by each taxon to the sample assemblage. A problem with this procedure is that, for many taxa, the meat weight ratio is not constant over the life span of the animal (Casteel 1978), a fact that might or might not introduce significant errors into an analysis. In practice, weights are often used to quantify shellfish remains, where they provide "a simple and quite effective method for establishing the relative economic importance of different shellfish taxa" (Leach 1997:8), but only rarely for vertebrate remains, where the use of MNI and especially NISP are more common.

3.1.2 Historical Methods

Fishery resource exploitation patterns can be broken into two components: the attributes of the fishing activities; and the attributes of the catch.

Potentially interesting attributes of fishing activities include the number of people fishing (called here "participation"), the types of fishing gears and methods employed, and the amount of fishing effort exerted. Fishing effort is typically expressed in terms of the number of people, vessels, or fishing gears that are active per unit of time. When expressed on a per-unit-area basis, fishing effort is sometimes called "fishing effort density." Other attributes include who fishes and where and when fishing occurs. In this report, all these attributes of fishing activities are sometimes generally referred to as "effort."

fishing effort

Potentially interesting attributes of the catch include the number or weight of a given resource that is harvested, produced, landed, or killed per unit of time. When expressed on a per-unit-area basis, catch is called "yield." Like effort, there are many ways to characterize and categorize the catch, such as by period, area, habitat type, taxa, fishing method, motivation (e.g., commercial, recreational, subsistence), disposition (e.g., consumed locally, exported, discarded), product form (e.g., live, frozen, dried), and the sizes, ages, and sexes of the fish. For the purposes of this assessment, two of the more important characteristics of the catch are its species composition, and for a given species, its size composition. In this report, all these attributes are sometimes generally referred to as "catch."

The fishery resource exploitation attributes identified above can be inferred from a number of types of sources, including:

1. direct quantitative measurements of the attributes;
2. direct but only qualitative or anecdotal observations of the attributes; and
3. circumstantial information.

The approaches that can be used with each of these information types are briefly discussed below.

Direct Quantitative Measurements A direct quantitative census of all fishing effort or all catch during a given time period in a given area could yield highly precise and accurate estimates of those attributes. If the estimates were based on sample data (e.g., from a creel survey) rather than census data (e.g., from market data), they would be somewhat less precise.

Although this is the most valuable type of data, it is generally rare. Even where detailed and reliable sample or census data are available, they often comprise only small subsets of the measure of interest, often for relatively brief time periods and small areas. In Hawaiʻi, for example, commercial inshore landings have been systematically censused for more than 50 years, but information on non-commercial fishing has been generally limited to the results of short-term sample-based surveys in specific areas.

Direct Qualitative or Anecdotal Observations Data of a descriptive and anecdotal nature are relatively common. The early years of the historic record in the Pacific Islands, which are dominated by the observations of short-term visitors from Europe, contain nothing but data of this type. Later writers, in the 1800s, including missionaries, colonial administrators, visiting researchers, and local residents, left more detailed documentation of fishing practices, but again, little of it was quantitative.

Short-term observations and investigations often yield documentation of types of fishing methods and types of exploited resources, but without any indication of absolute measures of effort or catch or even of the relative importance of various methods and species. Where information is provided about the latter—that is, the composition of effort by method and the composition of the catch by species, the information can be misinterpreted in two ways. First, in the case of observations by outsiders, there may be a bias toward documenting the more exotic, exciting, and conspicuous methods and species, at the expense of more familiar, boring, and hidden ones. This is especially true of incidental observations—that is, records made by observers who did not specifically set out to examine those attributes of fishing activities.

Second, whether recorded by outsiders or local people, it is difficult to distinguish between cultural importance and economic importance. Or more precisely, it is difficult to distinguish between value and volume. Leach and Davidson (1988), for example, examined the importance of the rainbow runner (*Elagatis bipinnulata*) on two Polynesian outlier atolls in Micronesia, and determined that although the species had great socio-cultural importance, as evidenced in folklore and song, its contribution to the diet of the atolls' populations was relatively small (see Dalzell 1998). Similarly, pelagic fishing, and skipjack tuna (*Katsuwonus pelamis*) in particular, has often been emphasized as being especially important in Hawaiian culture. Newman, however, argued that

> [i]t is a spectacular technique and this might have caught the attention of the early observers, who found it romantic, but in terms of consistent food supply it is a reasonable conclusion that inshore was the primary area, followed by the benthic (Newman 1970:56, 57).

Circumstantial Measures For many areas and time periods, direct information about the exploitation attributes of interest, whether quantitative or not, is lacking. That leaves circumstantial information, of which there are many types. Described in the paragraphs that follow are some of the indirect information types that are likely to be the most available and useful with respect to examining inshore fishery exploitation patterns in Hawai‘i and American Samoa during the historical period. Each of these information types is treated here as a "factor" or suite of factors, in the sense that they can be used to explain or infer certain characteristics of fishery exploitation patterns. Note that these factors are also potentially useful for making inferences about the characteristics and condition of inshore resources, a topic addressed in Section 5. In general, the more of these factors that can be accounted for, the more powerful the explanatory model will be. These factors are roughly equivalent to what Jackson et al. termed "historical proxies" (in their case, proxies for "ecosystem structure," in the context of reviewing long-term human impacts on ecosystems):

> Historical proxies include demographic, customs, and commercial records, as well as explorers' and naturalists' descriptions of sights and events and nautical charts marking reefs, coastal wetlands, and other landmarks (Jackson et al. 2001:637).

It is emphasized that the direction of cause-and-effect among these factors and between these factors and the measures of interest (i.e., catch or effort) can generally be in either direction, often making it difficult to make inferences. For example, an observed decline in the contribution of parrotfish to people's diets might have been caused by a decline in the abundance of parrotfish on the reef. Alternatively, it might have been caused by another factor, such as development of improved offshore fishing technologies or a shift in dietary preference toward other meat products. In the latter cases, the dietary shift likely would have been accompanied by an *increase* in parrotfish abundance on the reef, not a decrease. Armed only with information about the dietary shift, it would be clear that fewer parrotfish were being caught, but it would not be possible to identify any changes in fishing effort on parrotfish or in parrotfish abundance on the reef.

Fishing Effort and Catch Effort and catch were identified above as the main attributes of interest, but they are included here as potentially useful indirect factors because each of the two can be used to make inferences about the other. A few examples follow.

The most important relationship among exploitation attributes is that between fishing effort and the magnitude of the catch. Unfortunately, the complex nature of the relationship confounds the ability to use one to make inferences about the other. Catch can be expected to increase with increasing effort only to a certain point, after which it will decrease (the general relationship described here is for equilibrium conditions and does not apply to pulse or short-term situations).

Characterizations of fishing gears and methods are not only potentially useful measures in themselves, but they are also potentially useful in characterizing the composition of the catch, since fishing methods are often highly taxa-specific.

The composition of the catch by taxa reflects not just the fishing methods used, but also the relative abundance of the different species on the reef. For example, an observed decline in the contribution of large carnivores to the catch over a given period could be explained by either a shift in fishing strategies (i.e., species selectivity of the methods) or a decline in the relative abundance of large carnivores on the reef. Further, the latter case, if supported by the evidence, could be reflective of an overall increase in fishing effort. This is because fishing tends to target the higher trophic levels and larger sizes of fish. In other words, fishing effort can be expected to be related to the species composition of both the catch and the exploited resources in the water. For example, see Butler (1994) and Dalzell (1998) for an example of such a difference in the composition of the catch between sites in prehistoric Melanesia and Polynesia, and Adams et al. (1997) regarding the same general differential pattern today.

Just as fishing tends to target the higher trophic levels, it tends to target the larger fish within a given population, although there are important exceptions. So like the composition of the catch, the size structure of the catch of particular species can reflect the level of fishing effort. The size structure of the catch can also be used to determine absolute characteristics of the targeted populations with respect to fishing, such as the proportions of the populations being removed per unit time (i.e., their fishing mortality rates).

fishing mortality

Human Population Size, Distribution, and Diet A promising approach in many situations for making inferences about effort and catch is to use human population size as an indicator. Fishing effort, for example, can be expected to be positively and fairly strongly correlated with human population size. Human population size and catch are also strongly related, but the relationship is more complex, since the direction of the correlation between effort and catch is not consistent across all levels of effort. For this reason, human population size alone is not a good indicator of catch or trends in catch. It must be combined with knowledge about where the population size—or more specifically, effort—lies relative to the point at which the correlation between effort and catch changes direction.

The catch of a given resource can be treated as being equal to the consumption of the resource, where consumption is equal to the product of human population size and average per capita consumption. With estimates of both those measures, catch can be estimated (e.g. Dalzell et al. 1996:Table 25). Estimates of human population size are available in population censuses, and for earlier years, in anthropological studies and even casual observations. Potential sources of per-capita consumption estimates include nutritional surveys and other types of socioeconomic and anthropological studies (Dalzell 1998, 1991). Naturally, the greater the detail of the data with respect to food product types, the more useful they are for estimating absolute or relative consumption rates for particular inshore fishery products. Important challenges with this approach include the fact that the composition of people's diets can be expected to vary substantially according to many variables, including area and time—particularly seasonally. Titcomb wrote that "Hawaiians often became fond of the well-known fish of their region, fads developed, whims of the chiefs varied" (Titcomb 1972:31). Naturally, the composition of the diet can be expected to vary according to distance from the coast. And in highly stratified societies, the diets of different socioeconomic classes may be quite different. Observations of the diet of kings may be poor indicators of the diet of commoners.

Exports and Imports The amount of a given resource of interest that is exported from the area of interest is in itself an interesting attribute, and it should obviously be taken into consideration if a human-population-and-consumption approach is used. Generally, reef finfish tend not to be traded very widely in the Pacific Islands, but some invertebrates are, or have been, so highly valued abroad that the amounts exported have far exceeded the amounts used locally (Adams et al. 1997). Examples include sea cucumbers (bêche-de-mer or trepang) (Class Holothuroidea), trochus shell (*Trochus niloticus*), and pearl oysters (*Pinctada* spp.).

When using a human population-and-consumption approach it is also important to account for imports, but this is much more complex than accounting for exports because it is a matter of determining the imported amounts not only of inshore resources, but of all food items that substitute for local inshore resources in the local diet. For example, in many Pacific Islands, imported fish and meat products have increasingly replaced local reef fish in the diet. From a practical standpoint, it might be easiest to treat this factor not in terms of imports, per se, but rather in the broader context of the composition of the human diet, which is addressed further below.

Other Fisheries and Food Sources, and Dietary Preferences People's diets (and thus fishery resource exploitation patterns) are a function of many factors—all of which can be treated in terms of supply and demand. At the most basic level, diets are a function of the relative availability of different food sources. People living on islands with relatively large amounts of arable land, such as the relatively large islands of Melanesia, are likely to rely less on fisheries resources than people living on the smaller islands of Polynesia and Micronesia. Dalzell et al. (1996) estimated the average annual per-capita production of coastal fisheries products to be 32 kilograms for the Melanesian Islands, compared to 61 kilograms and 63 kilograms for the islands of Polynesia and Micronesia, respectively.

Following are a few examples of the types of dietary shifts that might have been important during the historical period in the Pacific Islands. The motivation to exploit resources as cost-effectively as possible would generally favor inshore and resources, especially invertebrates, over offshore and deepwater resources. But as the more accessible resources became scarcer, exploitation would be expected to shift toward what were formerly the more difficult-to-catch resources, and even to non-fishery resources. For example, Dalzell found that in some Pacific Islands: "...declines in mollusc resources forced early human populations to increase exploitation of other marine resources, and to rely increasingly on agriculture" (Dalzell 1998:247).

The development and decline of non-inshore fisheries is obviously linked to the development of new and improved fishing technologies, addressed further below, but the factors leading to such development can be much broader. In Hawai‘i, for example, the offshore commercial fishing industry developed through the late 1800s and early 1900s in concert with the rapid influx of immigrants from Japan and elsewhere, who came to dominate the industry. The onset of World War II, however, resulted in the virtual elimination of offshore harvesting operations in Hawai‘i (Schug 2001). This abrupt decline, which did not rebound quickly after the war, must have had important effects on the inshore fishery.

Improved and New Fishing Technologies Fishing technologies and methods naturally evolve with time, even in highly isolated societies. In cases where new materials or ideas are introduced from the outside, changes in technologies and methods can occur rapidly. Some of the more conspicuous introductions made in the Pacific Islands since European contact include metal, used to make hooks and spear tips, synthetic fibers, glass and plastic face masks, motorized vessels, scuba and hookah gear, synthetic poisons, dynamite, and electronic depth sounders and navigation devices.

Aquaculture The farming of reef fish products for food can be treated like any alternative food sources. Because farming is costly, the development of such cultured production might reflect the degree of scarcity of its wild counterpart. But such development could also occur independently of changes in resource scarcity, such as through the development of cheaper culture technologies. The cost of cultured production could also be offset by a preference for cultured product over wild product.

In the Pacific Islands, aquaculture is mostly done to produce especially high-valued export products, such as giant clams (Tridacnidae), which, not coincidentally, tend to be relatively rare on the reef. One important example of aquaculture for domestic consumption is the use of brackish and saltwater fishponds in Hawaiʻi, a practice that goes back at least a few centuries before European contact.

Social Controls The regulatory environment is a crucial factor. Directed resource management, for example, has a general aim of manipulating effort and catch, so changes in the management regime can alter effort and catch, and consequently, attributes such as per-capita consumption of particular resources. An obvious example is the imposition of a ban on a given resource. The result could be a decrease in its catch to virtually zero, with no corresponding change in, for example, human population size. Clearly, effort and catch patterns are obviously very strongly shaped by the socio-political environment, including rules imposed by secular and religious leaders, patterns of fishing rights that have evolved over centuries, and society's entire package of social norms. Two examples follow.

Dye (1990) examined the factors related to a decline in offshore fishing in the Marquesas Islands during the late prehistorical period, as evidenced in a shift from a highly varied to a simple fish-hook kit. He argued that the decline was related to the rise of a social class system that led to a large portion of the population increasingly losing access to the fishery resource.

Dalzell (1998) pointed out the effects of the introduction of the Seventh Day Adventist Church to the Pacific Islands. The church proscribes the eating of, among other things, fish without scales, shellfish, turtles, and dugong, so islands dominated by Adventists have become effective refuges for these resources.

Biophysical Environment An obviously important factor (or group of factors) in terms of the condition of inshore resources and patterns of their exploitation is the condition of the resources' supporting habitat or ecosystem. While a population's *actual* productivity change in response to the degree of fishing pressure on the population, its *potential* productivity changes in response to the condition of its environment, including the broader reef system, surrounding waters, and all the other biological elements of the ecosystem. In other words, the environment's carrying capacity for the resource of interest is subject to change.

Some changes in the condition of the environment can be treated as stochastic variability around average or typical values, such as year-to-year changes caused by variation in oceanic conditions, which affect recruitment to the population. Other changes are more enduring, such as those associated with climatic and oceanic events and cycles. The frequencies and periods of such changes can range from years or decades (e.g., storms; ENSO events; outbreaks of crown-of-thorns starfish, *Acanthaster planci*) ENSO to centuries or millennia (e.g., sea temperature; sea level). Other changes are massive and essentially irreversible, such as those stemming from volcanic activity and erosion, both above and below sea level.

Both natural and anthropogenic shapers of environmental conditions are potentially important. Examples of anthropogenic change include terrestrial sources of coral reef degradation, such as inputs of sediments, chemicals, and nutrients from logging, agriculture, and coastal development. Also potentially important in this category are ecosystem-level effects of fishing. For example, fishing down the population of a given species can result in increases in the abundance of its prey and reductions in the abundance of its predators. Two examples of anthropogenic changes follow.

After examining fossil deposits, aboriginal folklore, and the accounts of European explorers and fishermen, Jackson et al. (2001) concluded that the recurrent mass mortalities of coral on the Great Barrier Reef from the numerous crown-of-thorns starfish outbreaks that had occurred since 1960 were almost certainly new phenomena. The authors suggested that the cause of the outbreaks was either fishing down the starfishes' predators or increases in productivity due to increased runoff of nutrients from the land—in either case, the cause was found to be both recent and anthropogenic.

Jackson et al. (2001) recounted the vast declines in the sizes of sea turtle and dugong populations in the Americas and the Pacific that occurred as a result of hunting since European colonization. The authors emphasized the likely links between the decline in green sea turtles (*Chelonia mydas*) and the die-off of turtlegrass beds in Florida Bay, and between the decline in dugongs (*Dugong dugon*) and the decline of seagrasses in Moreton Bay, Australia.

ciguatera

The name ciguatera is given to a type of poisoning suffered by consumers of fish with sizable amounts of ciguatoxins, which are produced by dinoflagellates. It is serious enough that the presence or absence of the toxins in reef fish is a highly important product attribute to consumers. The prevalence of ciguatoxins in fish is highly area-specific, taxa-specific, and fish-size-specific, the latter two because the toxin becomes more concentrated as it works its way up the food chain. Thus, ciguatera strongly affects fishery exploitation patterns. The prevalence of ciguatera is also known to be related to broader environmental conditions, so changes in those conditions can alter the prevalence of ciguatera, with consequent impacts on exploitation patterns.

3.2 Summary of Bibliographic Sources

3.2.1 Archaeological Sources

Archaeological sources of information on reef fishing in Hawai‘i and Samoa are summarized in appendices B through I. Each appendix contains a table of sources ordered so that sources with the most information are listed at the top of the table and those with the least information are listed at the bottom. There are a large number of tables because each table contains information on one kind of remains—shellfish, fish, or turtle—at a particular level of identification—to lowest taxonomic level possible or not—and measured consistently—by NISP or weight. Presented in this way, the tables provide future researchers with an aid to finding the best sources of information of any particular kind.

Archaeological Reports from Hawai‘i The review indicates that Hawaiian archaeologists regularly identify shellfish remains to the lowest possible taxonomic level. Of the 355 reports from which a quantification of shellfish remains was obtained, 314 reported weights for taxa identified to the lowest taxonomic level possible (Appendix B). Collectively, Hawaiian archaeologists have identified more than 1.5 metric tons of shellfish. The individual collections range widely in weight from 286 kg to less than 1 g. Forty-one reports simply identified the remains as “shell” (Appendix C). These sources typically reported smaller shellfish collections, ranging in weight from 33 kg to less than 1 g, with a total weight of 140 kg.

There is greater diversity in the reporting of fish remains, with less emphasis on identifying fish remains than shellfish remains. Of the 227 reports of fish bone collections from which a quantification of fish remains was obtained, only 103 identify fish bones to the lowest possible taxonomic level. Of these, 75 quantify the remains as weights (Appendix E, 25 quantify the remains as NISP (Appendix D), and three quantify the remains as MNI. These latter reports include Davis (1991:60, 61), who identified a minimum of 583 individual fish, Rechtman and Wolforth (2000:25), who identified a minimum of 180 fish, and Athens and Magnuson (1998:31), who identified a minimum of 55. The collections reported as weights range from 14 kg to less than 1 g, with a total weight of 41 kg. A total of 115,478 identified fish bones were reported in collections ranging from 32,052 identified specimens to 4 identified specimens. Of the 124 reports that don’t identify fish remains to the lowest possible taxonomic unit, 112 report the remains as weights (Appendix F) and 12 report them as NISP (Appendix G). The weights of collections in which fish bone is not identified to lowest possible taxonomic level range from 14 kg to less than 1 g. The number of identified specimens in collections where the fish bones are not identified to lowest possible taxonomic level range from 32,052 specimens to 4 specimens.

Turtle bone is relatively rarely reported in Hawaiian archaeological reports; only 24 reports were found that list turtle bone among the faunal remains recovered during excavation. Fifteen of these report the turtle remains as weights (Appendix H) and nine report them as NISP (Appendix I). Turtle bone is typically recovered in small amounts. Among the collections quantified by weight, turtle bone ranges from 78.5 g to 0.75 g. Among those quantified by NISP, turtle bones range from 212 to 2.

Archaeological Reports from American Samoa There is relatively little faunal data reported for American Samoa. This is partly due to factors of preservation; many archaeological sites in Samoa are located today in garden lands, whose volcanic soils, ably tilled for hundreds or thousands of years, have broken down and incorporated organic materials, including shells and animal bones, that were deposited in them. There are nine archaeological sources that report collections of shellfish remains (Appendix J); three of the four largest collections derive from the Manuʻa Islands, primarily from shoreline deposits of calcareous sand. The single relatively large collection from Tutuila derives from a series of small test pits. The other five collections are very small and it is unlikely that they contain much useful information on patterns of resource exploitation.

One fishbone collection from American Samoa has been identified and reported as NISP. This is the work of Nagaoka (1993), who reliably identifies the pattern of fishery resource exploitation in the material. Identified fishbone collections reported as weights are extremely small; Cleghorn et al. (2000:37) reports 18 g of fish bone, Herdrich et al. (1996:65) 13 g, Shapiro and Cleghorn (1999:62) 10 g, and Moore and Kennedy (1996a:47) 2 g. Best (1992:33) reports 98 unidentified fish bones, and Eisler (1995:77) tallies another 13 unidentified fish bones.

Turtle bone has been reported from two archaeological sites in American Samoa. Nagaoka (1993:199, 200) reports 89 turtle bones collected from the Toʻaga site on Ofu in the Manuʻa Islands and Latinis et al. (1996:34) report 9 g of unidentified turtle bone from Taʻu Island.

3.2.2 Historical Sources

The historical periods of Hawaiʻi and American Samoa are divided into sub-periods. One approach for selecting convenient sub-periods would be to choose temporal boundaries that correspond to watershed events, such as sudden changes in systems of governance or dramatic changes in the way fisheries were prosecuted. Another approach would be to base the sub-periods on the types of information that are available. For example, a year in which fish landings data started being regularly collected might be a convenient starting point for a sub-period. Here, a little bit of each of these two approaches is used, and the result is three sub-periods—the same for both Hawaiʻi and American Samoa. Following is a brief description of the basis for choosing them.

Before 1900 Both Hawaiʻi and Samoa first made contact with voyagers from Europe in the late 1700s. Throughout the 1800s both island groups were influenced by visiting explorers and traders and by Christian missions that established themselves. The documentation of fishery exploitation patterns during this period consists mostly of qualitative information—first as recorded by short-term visitors, and later as recorded by both visitors and foreign and local residents.

1900 to 1950 After years of dispute among Britain, Germany, and the U.S., Eastern Samoa was annexed by the U.S. at the turn of the century, just a few years after the annexation of the Republic of Hawaiʻi. The exercise of U.S. power brought changes that affected both fishery exploitation patterns and the documentation of those patterns.

After 1950 After a strong military presence on both island groups during World War II, their demographics and economies changed dramatically. The interest of the federal government increased, resulting in statehood for Hawai‘i in 1959 and substantial investments in the public sector of American Samoa starting in the 1960s. At the same time, the amount and detail of information about fishery resources and their exploitation greatly increased.

Summaries of the bibliography for the historical period are given in Appendix K and Appendix L for Hawai‘i and American Samoa, respectively. For each of the sources (in rows), indications are given of the types of relevant information (in columns) that the source provides. The listed information types are potentially useful for characterizing fishery resource exploitation patterns, as described in Section 3.1.2, as well as for characterizing changes in those patterns (Section 4) and characterizing exploited resources and changes therein (Section 5). The information types are numbered and briefly described below. The search for historical sources did not treat all these information types equally—the complete list of sources that touch on all the listed information types would be impossibly long. Information that was directly related to inshore resources and their exploitation received the highest priority.

In the tables of appendices K and L, the first through fourth columns collectively describe the scope of the information provided, with one column for each of the three sub-periods identified above and one column that refers to the geographical area of focus, if any. The remaining columns indicate whether or not the source provides a given type of information. In these latter columns, the character “x” is used to indicate that the source includes information of that type. For some of the information types, a “q” is used to indicate that at least some of the information is quantitative.

Column 1. Before 1900 Information pertaining primarily to the period before 1900.

Column 2. 1900–1950 Information pertaining primarily to the period 1900–1950.

Column 3. After 1950 Information pertaining primarily to the period after 1950.

Column 4. Area Any more specific areas of focus, such as Main Hawaiian Islands (MHI) or Northwestern Hawaiian Islands (NWHI), or specific islands (note that “Hawai‘i” means the island of Hawai‘i).

Column 5. Participation Information on the number of people or vessels engaged in resource exploitation; a “q” indicates that quantitative information is provided.

Column 6. Fishing effort Information on the amount of fishing effort expended; a “q” indicates that quantitative information is provided.

Column 7. Gears and methods Information on fishing gears, materials, or methods; a “q” indicates that quantitative information is provided—specifically, quantitative information about the composition of fishing effort by gear or method.

Column 8. Catch composition Information on the composition of the catch by taxa, including even casual remarks about particular fish types; a “q” indicates that quantitative information is provided.

Column 9. Catch magnitude Information on the amount of fish harvested, landed, or killed per unit of time; a “q” indicates that quantitative information is provided.

Column 10. Catch per unit of effort Information on catch per unit of effort; note that CPUE may be used as an indicator of resource abundance, so it fits within the “resource size and status” information category, but it is treated separately here because measures of CPUE are relatively common; a “q” indicates that quantitative information is provided.

Column 11. Resource size and status Information on the size or productivity of a given resource, either in absolute terms or relative to its potential size or productivity; examples include relatively direct measures, such as from underwater visual surveys, and estimates derived from fisheries data; also included are “partial” measures of resource status, such as of growth, mortality, or recruitment rates; a “q” indicates that quantitative information is provided.

Column 12. Human population Information on human population size, density, distribution, or composition; a “q” indicates that quantitative information is provided; note that information sources about human population are treated more fully in Section 2.

Column 13. Human diet Information on human food consumption patterns, such as amount of fish consumed per capita per unit of time or composition of the diet by fish taxa; a “q” indicates that quantitative information is provided.

Column 14. Attributes of fishermen Information on the characteristics of the people engaged in fishery exploitation, such as by area of residency, social or political status, or ethnicity.

Column 15. Aquaculture Information on the degree of development of, and production from, aquaculture; a “q” indicates that quantitative information is provided.

Column 16. Social controls Information on marine tenure patterns and management practices, and more generally, the package of social norms that shape fishery exploitation patterns.

Column 17. Biophysical environment Information on environmental conditions, such as descriptions of marine habitats and zones in which exploitation takes place; note that ciguatera-related information is treated under this type.

Column 18. Environmental change from non-fishing Information on changes in environmental conditions from causes other than fishing, whether anthropogenic or natural.

Column 19. Environmental change from fishing Information on changes in environmental conditions specifically caused by fishing.

Column 20. Preferences and values Information on preferences among, or values of, food types, especially for fishery products; a “q” indicates that quantitative information is provided, such as prices.

Column 21. Markets and trade Information on the disposition of locally produced fishery products and the local use of imported food products; a “q” indicates that quantitative information is provided.

Column 22. Other fisheries and food production Information on the prevalence and relative importance of fisheries and other food production activities other than inshore fisheries, either as sources of livelihoods or sources of food; a “q” indicates that quantitative information is provided.

Column 23. Bibliography Whether or not the source is a substantial source of other information sources.

3.3 The Potential to Describe Patterns of Fishery Resource Exploitation

This section builds upon the material presented in the previous sections to assess the potential of the reviewed sources of information to describe patterns of fishery resource exploitation. This is a fundamental step in the analysis of both the archaeological and historical sources; without the ability to describe patterns of fishery resource exploitation, subsequent steps designed to identify changes over time cannot be pursued confidently.

3.3.1 Patterns Based on Archaeological Sources

The archaeological sources for American Samoa provide information on patterns of fishery resource exploitation for one island, Ta‘u in the Manu‘a group. The archaeological faunal collections for that island have been ably analyzed by Nagaoka (1993), but it is not possible to determine with the available evidence whether the situation on Ta‘u was characteristic of the rest of American Samoa, or was idiosyncratic in some way. Experience in Hawai‘i suggests that the latter might be the case.

The typical archaeological faunal analysis in Hawai‘i focuses on the environmental zones that were exploited and the fishing techniques that might have been used to capture the animals whose remains were recovered from the archaeological site. There are several excellent descriptions of patterns of fishery resource exploitation in the archaeological literature (e.g. Kirch 1982; Goto 1986; Hay et al. 1986). These generally portray local fishing industries that are well-adapted to the types of resources available in nearshore waters in the immediate vicinity of the archaeological sites from which faunal remains are collected. Thus, the overall picture is one of resource exploitation patterns that vary with variations in nearshore marine environment. The same pattern might be expected in Samoa when faunal collections from other islands are excavated and analyzed.

There is a surfeit of archaeological information on fishery resource exploitation in Hawai‘i that is suited for analysis along the lines of the studies cited above. A synthesis of the available materials can be expected to firmly establish traditional Hawaiian patterns of fishery resource exploitation through much of the archipelago.

3.3.2 Patterns Based on Historical Records

The potential to describe patterns of fishery resource exploitation based on historical sources from Hawai‘i and American Samoa is outlined in the following sections, which break down the historic era of both groups into three periods based on the types and quality of available fishery information.

Hawaii—1778 to 1900 For the period 1778–1800 there is little information in historical sources that is relevant to describing inshore resource exploitation patterns in Hawai‘i. The journals of the early European voyagers comprise virtually all of the available information (e.g. Cook 1974). In searching for information about past fishing practices, Newman (1970) reviewed the journals of the principals in all the major voyages by Europeans that visited Hawai‘i up until 1800 and found little of interest, concluding:

> The journals checked during the course of this research constitute virtually the whole of written literature available for the late eighteenth century. As can be seen, the picture developed from these sources is exceedingly sketchy and about all that is known is that nets and fishhooks were in use during this period (Newman 1970:52).

For the period 1800 to 1900 there were other exploratory voyages reaching Hawai‘i that yielded documentation of fishing patterns – again, mostly anecdotal information about fishing gears and methods (e.g. Campbell 1816; Reynolds 1835; Wilkes 1845). As the nineteenth century progressed, much more detailed accounts of fishing gears and methods and the predominant species that were captured by them were written, as were descriptions of the broader socio-political and economic environments in which fishing was carried out (e.g. Ellis 1836; Beckley 1883; Corney 1896; Kamakau 1976; Malo 1951; Deering 1899). Kahaulelio (1902), for example, recorded his firsthand accounts as a fisherman and observer of fishermen, including personal memories as far back as the mid-1800s.

These and many other sources dating back to the time of European contact were reviewed and synthesized by Titcomb with respect to finfish Titcomb (1972) and invertebrates Titcomb (1978), with a focus on the use of fish as food and the customs related to the use of fish. Buck (1957) documented the material aspects of fishing. Newman (1970) reviewed historical sources to reconstruct fishery exploitation patterns during each of four successive periods between 1778 and 1900. The data revealed in the review were mostly limited to descriptions of fishing gears and methods and the predominant species caught with each method.

The traffic of whaling ships in the 1800s has been seen as a potentially useful source of information about fishing during that period. Iversen et al. (1990b), for example, reviewed the logs of 113 visits by whalers to Kaua‘i, Ni‘ihau, and the Northwestern Hawaiian Islands in search of accounts of fishing by native Hawaiians. No pertinent information was found.

The social norms that governed fishing and related activities underwent dramatic and sudden changes between European contact and 1900, including the extension of kapu

konohiki

the monarchy to all the Main Hawaiian Islands in 1810, the abandonment of the *kapu* system in 1819, and King Kamehameha III's enactment of a set of laws in 1839 that apportioned Hawai'i's fishing grounds among the commoners, the landlords or *konohiki*, and himself. The fishing-related laws of the Kingdom, as well as the constitution itself, continued to undergo substantial changes throughout the century. Accounts of these changes are available in many works, including contemporary writings (e.g. Jordan and Evermann 1902; Massee 1926; Kosaki 1954) and relatively recent reviews (e.g. Iversen et al. 1990b).

One potentially fruitful approach for the period prior to 1900 would be to examine historical sources about the use of fishponds. Because of the relative durability of Hawai'i's fishponds, observations made up to the present can be used to evaluate patterns of exploitation prior to 1900 and even prior to European contact. As discussed in Section 3.1.2, information about fishponds can reveal characteristics of not just production from the ponds, but of inshore fisheries in general, because the development and operation of ponds was probably closely related to aspects of the capture fisheries. Those relationships were probably shaped by the degree of wild resource scarcity, the prevailing systems of tenure and rules regarding access to the resource, and preferences among fish products. For example, the apparently substantial costs of constructing and operating fishponds could have been justified by a lack of wild fishery resources. Alternatively, pond-produced fish may have had greater value than wild-caught fish, perhaps by virtue of their status as a food of the elite, or the ponds themselves might have been valuable as chiefly possessions. Fishpond development might also be explained as the result of the natural tendency for people to enclose and own what are otherwise boundary-less resources. Whatever the roots of fishpond development were, observations of the number, sizes, and locations of ponds, estimates of their productivity, and observations of their degree of decay at given points in time (e.g. Cobb 1903, 1905b; Bell and Higgins 1939; Summers 1964; Devaney et al. 1976) can probably be used in combination with information about the prevailing demographic, socio-political, and economic conditions to reveal important aspects of inshore exploitation patterns.

Finally, the size, distribution, and composition of Hawai'i's human population underwent profound changes in the period up to 1900. Even a crude examination of human demographics would reveal some of the basic characteristics of inshore exploitation patterns. More refined inferences could be made if demographic information were examined together with other important factors, such as shifts in fishing methods, composition of people's diets, social controls over fishing, and the labor and food-production aspects of the local economy.

In summary, the utility of the information directly related to inshore fishing that is available for the pre-1900 period is mostly limited to making a catalog of gears, methods, and exploited species. Most of the available sources describe the relationships between particular methods and species only very loosely, but several authors have attempted to provide rigorous descriptions of which species were captured with which methods (e.g. Newman 1970:Table 5). From the available sources it is possible to make some inferences about the relative importance or prevalence of certain of these methods and species, but as noted in Section 3.1.2, there are constraints to using this type of information. There is also a substantial amount of information available to reconstruct other important attributes of fishing patterns, including who fished—such as individuals versus groups, when and where they fished, some of the customs and rituals associated with fishing and the distribution of the catch, and more generally, the systems of authority and controls under which fishing took place. Most importantly, information about the size, distribution, and composition of Hawaiʻi's human population can be used as a powerful explanatory factor with respect to inshore fishing attributes.

Hawaii—1900 to 1950 The U.S. Government made its first efforts at documenting fishing patterns in Hawaiʻi in 1901, when John Cobb, as part of a larger investigation by the U.S. Fish Commission, compiled what appears to be the first set of quantitative data on commercial fisheries activity in Hawaiʻi—primarily for the year 1900 (Cobb 1903). A second investigation and data compilation followed in 1903 (Cobb 1905b).

In 1928 the Territory of Hawaiʻi's Board of Commissioners of Agriculture and Forestry, through its Division of Fish and Game, started including data on commercial fish landings and value, as well as the numbers of fishing licenses issued, in its biennial reports. Between 1948 and 1959, the Division also published monthly statistics of the commercial catch by species. The Division of Fish and Game became part of the Department of Land and Natural Resources in 1962 and later changed its name to the Division of Aquatic Resources.

Hamamoto (1928) used commercial data provided in the 1927 issue of the annual publication Hawaiian Japanese Annual & Directory (Nippu Jijisha -1941, in Japanese) to make an estimate of total commercial fisheries production in Hawaiʻi. It is not clear whether the data in the Directory came from the Territory of Hawaiʻi reports or from other sources. In 1938, Bell and Higgins (1939) investigated Hawaiʻi's fisheries and their potential for development through a visit to Honolulu and Hilo. They compiled fish sales data for the years 1928 through 1937 and remarked on changes that had occurred since Cobb's 1901 investigation.

With Hawaiʻi's annexation by the U.S. in 1898 came profound changes in the way fisheries were managed. The size of the human population grew, especially with immigration and the development of the sugar economy. The distribution of the population also shifted with continuing urbanization. Descriptions of these and other important socio-political and economic changes are readily available in many works.

In summary, quantitative data on fish landings and value, by species, area, and period, are available for most of the first half of the twentieth century, but quantitative information about non-commercial fisheries appears not to be available. Closer examination of the commercial data along with circumstantial information would probably yield a reasonable estimate of the contribution of the commercial catch to the total catch and thereby indicate just how useful the commercial data are for making inferences about the entire inshore fishery. In any case, catalogs of fishing gears and methods and exploited species could be constructed from the numerous available descriptions. Determining the relative importance of particular methods or species could be done to a certain extent. As with the pre-1900 period, examination of the prevailing social norms that governed fishing-related activities would likely reveal important aspects of inshore fishing patterns, as would information about the use of fishponds, the broader economy, and especially, the size, distribution, and composition of the human population, as well as people's diets.

Hawaii After 1950 Iversen et al. (1990b) documented the personal accounts of a number of native Hawaiian fishermen, former fishermen, and elders. Although the investigation was not, with the exception of lobster, focused on inshore fishing, some of the accounts did refer to inshore fishing. Most of the information related to the second half of the 1900s, but some of the accounts reached into the first half of the century.

Commercial fisheries data have been systematically reported in Hawai‘i since 1900. The data collection system presumably improved its degree of coverage and reliability over time, and 1948 is the earliest year included in the State of Hawai‘i's Commercial Fisheries Reporting System and associated database, maintained by the Division of Aquatic Resources since 1948. Fishermen that sell any portion of their catch are required to be licensed by the state, and licensed fishermen are required to submit monthly reports to the Hawai‘i State Division of Aquatic Resources, which maintains and processes the data in its Commercial Fisheries Reporting System. Saltwater fishpond operators and aquarium fish collectors are required to submit special forms—the Pond Operator's Monthly Fish Report and the Aquarium Fish Catch Report, respectively.

Until October 2002, the commercial data were limited to landings only; since then, the entire catch, including discards, are supposed to have been recorded. Fishing effort, by gear type, started being rigorously recorded in October 2002; up to that time fishing-days was the only measure of fishing effort. The sales value of landings is also recorded—before October 2002 by the fishermen, and since then through a separate data collection program for primary fish dealers.

The commercial data are used by the Division of Aquatic Resources to produce regular reports with volumes and values of commercial landings, by species, area, and method (e.g., Commercial Marine Landings Summary Trend Report, produced by the Division of Aquatic Resources since 1997). The data are also available on the web site of the Western Pacific Fishery Information Network, or WPacFIN (WPacFIN, Honolulu Laboratory, National Marine Fisheries Service 2003), and they are summarized and compiled in annual reports produced as "Fishery statistics of the Western Pacific" by the WPacFIN. More detailed outputs of the commercial data with respect to the inshore resources managed under the Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region (Western Pacific Regional Fishery Management Council 2001), including time series from 1966 of commercial landings and catch-per-unit-effort, are available in DeMello (2003); Western Pacific Regional Fishery Management Council (2002). Most of these national, territory, and state governmental sources include separate data for fishpond production and value.

Data on non-commercial fishing activity in Hawai‘i, often generally referred to as "recreational fishing" in the literature, have never been systematically and regularly collected. The best available sources are short-term and locale-specific surveys, usually relying on creel sampling approaches and/or telephone interviews. Examples include a 1990-1991 survey of the small boat fishery of O‘ahu (Hamm and Lum 1992) and creel-type surveys at Hanalei Bay on Kaua‘i (Friedlander et al. 1995; Everson and Friedlander 2003), Hilo Bay on Hawai‘i (Kahiapo and Smith 1994; Lowe et al. 1995), and Kāne‘ohe Bay on O‘ahu (Everson 1994; Everson and Friedlander 2003).

Some of these surveys were conducted under the Main Hawaiian Islands Marine Resources Investigation (MHI-MRI), a cooperative initiative coordinated by the State of Hawai‘i Division of Aquatic Resources (Lowe 1995a, b). The project has focused on five demonstration sites: Kāne‘ohe Bay on O‘ahu, Hilo and Kailua-Kona on Hawai‘i, Hanalei Bay on Kaua‘i, and the Kihei Coast on Maui. The reports of all the investigations conducted under the initiative will soon be available on a web site dedicated to the MHI-MRI (M. K. Lowe, Hawai‘i Division of Aquatic Resources, pers. comm.).

Comparisons between creel survey data and the commercial landings data have revealed large disparities—possibly due both to underreporting of commercial landings and the fact that non-commercial catches are relatively large (Friedlander 1996; Lowe 1995a).

The Hawai‘i Marine Recreational Fishing Survey (HMRFS), initiated by the National Marine Fisheries Service (NMFS) and the Hawai‘i Division of Aquatic Resources (HDAR) in 2001, is a creel-type survey designed to cover all inshore fishing in the Main Hawaiian Islands. Effort and catch data are collected through the Marine Recreational Fishery Statistics Survey (MRFSS), which has been conducted in the continental U.S. since 1979 (Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii 2003). Data from the Hawai‘i survey have not yet been made available. How long the survey will continue is not known.

In an effort to synthesize the results of the various recreational fishery data sets and make them more useful, the Fisheries Monitoring Economics Program of the Pacific Islands Fisheries Science Center (PIFSC; formerly the Honolulu Laboratory of the Southwest Fisheries Science Center) initiated the Recreational Meta Data Project. The project focuses on the pelagic fisheries, but data from the inshore fisheries have been compiled, as well. Reports and data from various surveys and investigations, going back as far as 1928, are available on the project web site (Fisheries Monitoring Economics Program, Pacific Islands Fisheries Science Center nd).

Most inshore fishing in the Northwestern Hawaiian Islands is of a commercial nature, so the data are generally available through the State of Hawai‘i’s Commercial Fisheries Reporting System, which has been managed by the Division of Aquatic Resources since 1948. The lobster fishery in the Northwestern Hawaiian Islands, which started in 1979 and expanded rapidly in the 1980s, is federally managed so a separate set of data is available. These data are maintained by the PIFSC and periodically reported in a variety of forms, including the technical reports of the PIFSC and the annual reports on the “Crustacean Fisheries of the Western Pacific Region” published by the Western Pacific Regional Fishery Management Council.

A recreational inshore fishery operated at Midway in the Northwestern Hawaiian Islands during the last half of the 1990s. Fisheries data were collected and managed by the U.S. Fish and Wildlife Service after 1996.

Hawai‘i’s fisheries regulatory environment continued to undergo substantial changes in the second half of the twentieth century. The economy shifted to tourism, which, together with continued population growth, was accompanied by physical development on a fairly large scale, with consequent impacts on inshore habitats and ecosystems. Accounts of these and other important socio-political, economic, and environmental changes are readily available.

In summary, a number of quantitative data sets for non-commercial fisheries became available since 1950. Although most of these sources contain only short-term and locale-specific data, together with the more regular and long-term commercial landings data, they can be used to infer fairly detailed characteristics of Hawai‘i's overall inshore exploitation patterns. Efforts are increasingly being made to synthesize the various data sources in order to better characterize Hawai‘i's inshore fisheries, including the Recreational Meta Data Project and studies conducted under the Main Hawaiian Islands Marine Resources Investigation. Although the more detailed nature of the inshore fisheries data in the post-1950 period lessens the need to rely on circumstantial information, such information can be used to validate findings and to explore the factors that shape fishery exploitation patterns. Like the pre-1950 period, potentially useful circumstantial information includes demographic and diet data and information about fishing-related controls. Information that is especially relevant for the post-1950 period includes export and import data and information about the condition of inshore habitats and ecosystems. The latter is more fully addressed in Section 5.

American Samoa to 1900 The first European voyage to visit Samoa appears to have been that of Jacob Roggeveen, who did not land but who met Samoans that boarded his vessel while anchored off the Manu‘a group in 1722. The crew of the de Bougainville voyage similarly did not land, but they made contact and traded with Samoans in 1768 (de Bougainville 1772). Members of the expedition of La Pérouse actually set foot on Samoan soil in 1787, on Tutuila (La Pérouse 1799). The voyage of the *Pandora*, captained by Edwards, who was searching for the *Bounty* mutineers, followed in 1791. Other early voyages that reached Samoa included those of de Freycinet in 1817-1820, von Kotzebue in 1815-1818 and 1823-1826, d'Urville in 1838, and Wilkes in 1839 (Wilkes 1845). The Wilkes Expedition is especially notable because it resulted in the appointment of an American Consul, an access agreement for U.S. vessels to use Pago Pago Harbor, and the establishment of the first rules imposed by Westerners. The fishing-related information available in the accounts of these voyages appears to be limited to descriptions of fishing methods, such as those recorded during the La Pérouse voyage (La Pérouse 1799).

Other historical sources for the nineteenth century include the writings of Christian missionaries. The first missionaries to Samoa were the Wesleyans, who arrived in 1828. Much more influential, however, was the London Missionary Society, now known as the Congregational Christian Church of Samoa, led by John Williams starting in 1830 (Holmes 1974). European missionaries soon followed. Missionaries and other non-native residents during the early 1800s wrote accounts of fishing practices (Williams 1840; Moyle 1984; Turner 1989; Stair 1983). As with the early explorers, these fishing-related accounts were mostly limited to qualitative descriptions of fishing materials, gears, and methods, but they were accompanied by descriptions of household and village economies and of the social and political environment within which fishing was practiced, giving a fairly strong sense of the importance of fishing and fish products and the social norms governing fishing and the use of fish. Also important is the fact that these accounts generally relied not just on first-hand observations, but also on the knowledge of local informants, which included both their own memories and the farther-reaching memories of society as a whole, as reflected in stories, legends, proverbs, and other forms of knowledge passed among generations. For example, many of the proverbs compiled and collected by Schultz (1994) in the mid-1800s relate to fishing practices.

Much of the relevant fishing-related information in the sources published during the 1800s was compiled and synthesized by Krämer in 1902, who added the accounts of his own informants, as well (Krämer 1995). His descriptions of fishing gears, methods, and practices, as well as of the reef environment and some of the particular resources that were harvested, are particularly detailed. Also potentially useful are some of the not-yet-translated publications of German writers, such as Demandt (1913).

In summary, the utility of the information directly related to inshore fishing that is available for the pre-1900 period is mostly limited to making a catalog of gears, methods, and exploited species. From the available sources it is possible to make some inferences about the relative importance or prevalence of certain of these methods and species, but as noted in Section 3.1.2, there are constraints to using this type of information. There is also a substantial amount of information available to reconstruct other important attributes of fishing patterns, including who fished—such as individuals versus groups, when and where they fished, some of the customs and rituals associated with fishing and the distribution of the catch, and more generally, the systems of authority and controls under which fishing took place. Information about Samoa's overall economy, particularly the development of the plantation economy in the last half of the 1800s, can be used to determine the importance of inshore fishing as both a livelihood and a food source. Perhaps most importantly, information about the size, distribution, and composition of Samoa's human population can be used as a powerful explanatory factor with respect to inshore fishing attributes.

American Samoa—1900 to 1950 The turn of the century saw the annexation of the eastern islands of Samoa by the U.S., whose navy administered American Samoa until after World War II. There are a number of sources that describe the new administration and its effects (e.g. Gray 1960). Although the annexation was obviously a profound change on some level, some writers, such as Hiroa (1930), provided evidence that it had relatively little effect on indigenous systems of authority.

Hiroa (1930) documented Samoan material culture, including detailed descriptions of fishing materials, devices, and methods and some of the principal species captured with each method.

In summary, quantitative fisheries data were still not available in the first half of the twentieth century. Like the pre-1900 period, detailed descriptions of fishing gears and methods are available, and there are numerous descriptions of the broader socio-political and economic landscape. As with the pre-1900 period, examination of the prevailing social norms that governed fishing-related activities would likely reveal important aspects of inshore fishing patterns, especially if examined together with information about the size, distribution, and diet of the human population.

American Samoa After 1950 Inshore fisheries information for the 1950s and 1960s appears to be limited to qualitative descriptions. For example, Van Pel (1956), of the South Pacific Commission, made a brief assessment of American Samoa's fisheries in 1954. The focus of the report was pelagic resources but it included some general statements about the characteristics of the inshore fishery. Holmes (1974) documented observations of fishing practices made during visits in 1954 and 1962.

The American Samoan Government starting gathering fisheries data on a regular basis in 1971, collecting catch reports from foreign and local fishermen. These data were summarized in annual reports (e.g. Aitaoto 1985). However, since the reporting by local fishermen was on a voluntary basis, the reporting rate was relatively poor and the data were found not to be very useful with respect to subsistence fishing.

Starting in 1975, quantitative estimates of effort and catch started to become available for the shoreline fishery of the island of Tutuila. Hill (1978) made observations of the inshore fishery along a portion of the Tutuila shoreline in 1975 and 1976, providing detailed descriptions of the relative use of various methods, as well as who used them where and what environmental conditions. Hill also provided quantitative estimates of effort and catch. In 1979, the approach used by Hill was expanded to cover a larger portion of Tutuila (Wass 1980). The shoreline creel survey was restarted on a regular basis in 1990 (see Ponwith 1992) and it produced Tutuila-wide estimates of shoreline effort and catch, by method and species, for the years 1991 through 1995 (Craig et al. 1993; Saucerman 1994, 1995b, a; WPacFIN, Honolulu Laboratory, National Marine Fisheries Service 2003).

Boat-based fishing around Tutuila started being monitored through a creel survey in 1979, but it was limited to major landing sites that were mostly used by commercial fishermen, and it was not until 1985 that the boat-based creel survey covered all the fishery components.

Since 1990, commercial fish sales, by species, have been censused through a receipt-based monitoring system. The system was recently modified such that fishing method is also recorded. Fish imports are monitored through the same system (WPacFIN, Honolulu Laboratory, National Marine Fisheries Service 2003).

The data from the shoreline and boat-based surveys and the sales census are collected and managed by the Department of Marine and Wildlife Resources. Through the Western Pacific Fisheries Information Network (WPacFIN), the data are compiled into annual reports published by the Pacific Islands Fisheries Science Center, as well as reports of the American Samoa Government. The data are also available on the WPacFIN web site (WPacFIN, Honolulu Laboratory, National Marine Fisheries Service 2003).

Also available for the latter part of this sub-period are the results of occasional interview-based surveys that had primary objectives other than quantifying effort or catch. These include Severance and Franco (1989); Des Rochers and Tuilagi (1993); Tuilagi and Green (1995), and Curren and Sauafea (2000). Some of these sought to document current conditions while others also explored the past. For example, Severance and Franco (1989) examined historical sources of information with respect to offshore fishing. Their findings also related to some inshore species, including sharks, trevallies (*Caranx* spp.), and some demersal species, including spiny and slipper lobsters and certain groupers. The authors sought and found remarkable continuities in fishing practices from the pre-European contact period (as evidenced in legends and proverbs) into the 1980s, albeit it with important changes with respect to fishing methods and equipment, the distribution of the catch, and other aspects.

In summary, quantitative data for the inshore fishery became available starting in 1975, and they are limited to the island of Tutuila. These data provide fairly detailed descriptions of inshore fishing activities, including effort and catch by period, area, method, species, and fish size. The results of a number of more qualitative investigations are useful in terms of revealing the importance of inshore fishing as a livelihood and a food source. Information about the size, distribution, and composition of the human population and about fishing-related controls are also available. Finally, circumstantial information that may be especially pertinent for the post-1950 period includes information about the broader economy—which shifted profoundly, export and import data, and information about the condition of inshore habitats and ecosystems. The latter is more fully addressed in Section 5.

4 Temporal Changes in Fishery Resource Exploitation

This section assesses the suitability of the sources reviewed in Section 3 to answer questions about changes over time in fishery resource exploitation in Hawai‘i and American Samoa. For the archaeological sources, a primary constraint is the confidence with which archaeological collections can be placed in chronological order. Unfortunately, many archaeologists working in Hawai‘i and American Samoa take a rather lackadaisical approach to dating and produce data of questionable utility. This discussion is followed by the methods used to infer change from historical documents. The section ends with assessments of the potential to describe changes in fishery resource exploitation for the prehistoric and various historic periods of the two island groups.

4.1 Chronological Methods in Archaeology

One of archaeology's great strengths is its ability to yield information on change over time. The archaeological record is a diachronic record, one that accumulates over time, and this property often makes the investigation of change more straightforward than an investigation of synchronic phenomena. Thus, although methods for estimating the relative abundance of taxa are difficult to apply and interpret, as discussed in section 3.1 on page 14, changes over time in the relative abundance of taxa are relatively easy to detect and interpret with archaeological data. A measure like NISP, for example, measures relative abundance of taxa, a synchronic measure, rather poorly because different taxa have different numbers of identifiable elements and identifiable elements fragment at different rates (see pg. 3.1.1). However, because the number of identifiable elements per taxon and their fragmentability are both constant, a difference in the relative proportion of a taxon measured by NISP in two archaeological collections with similar degrees of fragmentation separated only by time can be interpreted with confidence (see Drennan 2001:667).

diachronic

synchronic

This circumstance has led to an active field of inquiry for Pacific archaeologists. Although archaeological studies of change over time in fishery resource exploitation have only begun to appear in the last decade and a half, the results from widely separated island groups are sufficiently similar for Allen et al. (2001) to identify a common trajectory of decline in foraging range and intensity. The possible causes of the decline include agricultural intensification and growth of animal husbandry systems that would diminish the role of fish and shellfish in the diet, increased competition and chiefly control of fishing gear, and possibly resource depression.

In a practical sense, the weakness of the archaeological record for estimating changes in fishery resource exploitation derives primarily from the chronological methods developed in archaeology and their use, or misuse, by archaeologists. The reasons for the failure of dating projects to yield useful results are several and varied:

- poor control over sample provenience, in particular dating amalgams of charred material originally dispersed throughout a stratigraphic layer or collected from the sieve;
- failure to specify the archaeological event being dated and to distinguish it from the dated event (Dean 1978; Taylor 1987);
- use of the now-discredited volcanic glass dating technique (Olson 1983);
- inadequate characterization of ^{14}C dated material and failure to control for the "old wood" problem (Dye 2000), whose effects are documented for Hawaiʻi (Dye and Carson 2002); and
- calibration without benefit of prior chronological information, which can be incorporated within a Bayesian statistical framework (Buck et al. 1996).

As a result of these problems, it is often impossible to place sites in chronological order based on the results of dating analyses. This is especially so in Hawaiʻi, where the prehistoric period is one of the shortest in the world, about 1,000 years. The longer time-frame of Samoan prehistory minimizes somewhat the problems caused by this lack of precision in archaeological dating, and the presence in Samoa of artifacts with restricted temporal distributions, such as pottery types, provides an alternative means to assign sites to chronological periods.

In this situation of limited dating reliability, the importance of collections made at stratified archaeological sites increases. Here, the law of superposition enables the archaeologist to order the collections by age based on their position in the stratigraphic sequence.

law of superposition

stratigraphic sequence

4.2 Inferring Changes from Historical Documents

One obvious approach for identifying temporal changes in exploitation patterns is to compare an estimate of a given attribute for a given time period with an estimate of the same attribute for another period. The ability to determine with a useful level of confidence whether or not there has been a change is, of course, constrained by the precision of the two estimates. In general, estimates of exploitation attributes in Hawaiʻi and American Samoa during most of the historical period can be expected to be relatively imprecise, in which case it will be possible to identify temporal changes only in cases where the estimates differ by a relatively large degree. Further, the precision of estimates of exploitation attributes can be expected to decrease with increasing time before the present.

A second approach to identifying temporal changes is to rely on estimates of the temporal difference itself, rather than comparing independent measures from the two time periods. For example, a given observer might notice and record that the catches of a given taxon were much greater during his early fishing years than during his later fishing years. In that case, there would be no uncertainty as to whether or not there was a difference in the two “measurements.” There would, however, be the problem of measurement error, such as stemming from biases associated with the fisherman’s memory, or from his failure to account for certain confounding factors in making his determination. One obvious limitation of this approach is that the interval of time that can be examined is limited by the period of observation, or generally, the span of a human life. Of course, part of the purpose of this assessment is to examine the potential to overcome the limitations of such short-term observational windows—in other words, to cope with the “shifting baseline syndrome” (Pauly 1995). For example, in arguing for the need to consider historical, archaeological, and paleoecological information when examining the structure and pace and magnitude of change of coastal ecosystems, Jackson et al. (2001:636) noted: “The historical magnitudes of losses of large animals and oysters were so great as to seem unbelievable based on modern observations alone.” And further: “The shifting baseline syndrome is thus even more insidious and ecologically widespread than is commonly realized.” Notwithstanding the utility of a long-term perspective, observational periods on the scale of decades and even years are certainly useful with respect to the historical periods of Hawai‘i and American Samoa.

Section 3.1.2 identified the main fishery exploitation attributes of interest and identified a number of factors that could potentially be used to infer the absolute or relative states of those attributes. Without quantitative data, determining the absolute states of effort and catch attributes is difficult, but relative measures may be possible, such as prevalence rankings among methods and species. Relative measures with respect to time may also be possible without quantitative data. Even information solely about directional changes in some of the factors listed in Section 3.1.2, such as human population size, can be enough to infer important changes in exploitation patterns.

During the historical period in Hawai‘i and American Samoa—a period of little more than two hundred years—particularly rapid and dramatic shifts in many of these factors occurred, so dramatic shifts in fishery resource exploitation patterns probably also occurred. A few examples follow of how changes in those factors might be related to changes in fishery resource exploitation patterns. This is an extension of the discussion in Section 3.1.2, but with a focus on temporal changes.

For much of the historical period in Hawai‘i and American Samoa, the predominant type of written information about inshore fishing practices was descriptions and inventories of fishing gears and methods. For the purpose of examining changes over time in, for example, the magnitude of fishing effort or catches, the utility of such information is limited. But evidence of changes over time in the inventory of gears and methods and their relative importance can still be useful. For example, one can examine the pace at which materials and methods changed in response to contact and trade with the outside world. Such changes are linked with the relative efficiencies of old and new materials and methods, as well as with their relative costs. A shift in methods is not only a probable indication of an increase in overall fishing efficiency, but also of a shift among the resources that were being exploited.

There are also important links between fishing methods and the prevailing social controls over fishing. In many Pacific Islands, the use of particular methods was owned or controlled by particular individuals or groups. Newly introduced methods, however, often fell outside those controls, allowing them to be used more freely than traditional methods. This could have led to shifts in where, when, and by whom fishing was done, and most critically, how much fishing took place. A second link between fishing methods and the regulatory environment is that in many cases, the introduced methods could be handled by fewer people than the older methods they replaced. Again, this has implications in terms of societal controls over fishing activities. The fewer the people needed to successfully use a given fishing method, the less opportunity for a central authority to control the use of the method. For example, Wass (1980) cited a shift in fishing gears and methods in American Samoa as a likely contributor to the decline of the authority of the traditional *tautai*, or fishing specialist.

tautai

Information about changes in the socio-political environment—particularly regarding marine property rights and other fishing-related controls—can be a powerful tool for identifying changes in fishing practices. The value of property rights and the severity of fishery-related controls can be expected to reflect resource scarcity to at least some degree. They also provide important indications of who and how many people have access to the resource. Dalzell (1998) cited the example of the Maori people of New Zealand as a particularly good illustration (Waitangi Tribunal 1988; Ruddle 1995). Following European settlement in the nineteenth century, the native Maori population became economically and socially marginalized; they were dispossessed of their fishing rights and were effectively replaced by the European settlers as the primary fishery resource users. Within 100 years of European contact, Maori fishing patterns had changed so dramatically that until recently, most modern New Zealanders mistakenly believed that Maori fishing practices in the past were mostly limited to shellfish gleaning.

4.3 The Potential to Describe Changes in Fishery Resource Exploitation

The potential to describe changes in exploitation patterns is a function of the availability of information about those patterns through time, which was addressed in Section 3.3. This section highlights some of the more promising approaches and a few previous investigations that specifically examined temporal changes.

4.3.1 Changes in Pre-Contact Hawai‘i

Most often, variability in archaeological collections of marine vertebrates and invertebrates in Hawai‘i is interpreted as a reflection of the variability in nearshore marine environments proximal to the archaeological sites where collections were made (e.g. Kirch 1982, 1985; Goto 1986). This is due in part to the primary goals of most archaeological analyses of faunal remains, which are to characterize the marine environmental zones that were exploited and to infer the types of gear needed to capture the fish and shellfish whose remains were recovered. This bias toward synchronic analyses is strong enough that faunal collections from Hawaiian archaeological sites have generally not been subjected to rigorous diachronic analyses, even when these collections have been made at deeply stratified and rich sites (e.g. Hay et al. 1986). One exception to this is the work of Goto (1986:375), who documented a shift in the catch from carnivores to herbivores at Waiʻahukini, Hawaiʻi Island.

The large body of data produced by archaeologists would appear, however, to be suited for analyses of change in the composition of the catch, although information on the size of fish or shellfish is not generally reported, thus making it impossible to track this aspect of change. The data on fish remains are limited somewhat due to reporting practices, which too frequently fail to tabulate NISP in favor of weight, a metric whose properties in archaeological analysis are not well developed. It might be possible to augment the large collections reported as NISP by re-analyzing and counting the specimens in identified collections reported as weights (Appendix E). If this work were to be undertaken, it should focus on large collections, preferably from stratified sites where ^{14}C dating results can be supplemented with stratigraphic information.

4.3.2 Changes in Pre-Contact Samoa

The scant faunal record from American Samoa precludes analyses of change over time that go beyond the work of Nagaoka (1993) with the large collections of vertebrate and invertebrate remains from the deeply stratified Toʻaga site in the Manuʻa Islands. Nagaoka's analysis pointed to a pattern of stability in the marine resources exploited over time, and it appears that information on change in the prehistoric period of American Samoa will have to wait for the excavation and analysis of suitable collections from other archaeological sites.

4.3.3 Historical Changes in Hawaiʻi

That exploitation patterns may have changed dramatically and rapidly after European contact is highlighted in the remark that "... iron fishhooks fashioned by the Hawaiians themselves were being made by the time the [Cook] expedition left Kealakekua Bay" (Newman 1970:52). Hill (1978) noted that with respect to the Pacific Islands in general, by the end of the nineteenth century the variety of fishing methods had been reduced and many traditional materials and devices had been replaced with imports.

As described in Section 3.3, there is very little historical documentation of fishery resource exploitation patterns—aside from a few passing descriptions of fishing methods and gears used—at the time of contact, or indeed, until the early 1800s. It would therefore be difficult to use data specifically about fisheries in order to identify changes that took place between the time of contact and later periods for which more detailed documentation is available.

Although the quality and quantity of fishing-related information about Hawaiʻi improved with time, even until the early 1900s the information was largely limited to descriptions of fishing methods and references to the dominant species captured with those methods. It would therefore be difficult to use data specifically about fisheries in order to identify changes in exploitation patterns from the time of European contact until about the turn of the twentieth century. The circumstantial information described in Section 3.3, however, could be fairly powerful.

In spite of the paucity of fishing-related information for the eighteenth and nineteenth centuries, Newman (1970) found reason to make some fairly strong conclusions about the nature of change during that period—to wit, that there was very little. Noting that the only introduced materials during that period were sinkers of lead and iron, European-manufactured metal fishhooks, metal fishhooks crafted by Hawaiians, the cast net, and possibly the gill net, Newman concluded that marine exploitative techniques were stable through the nineteenth century. However, the analysis was limited to the types of fishing effort, and not its magnitude. Clearly, the dramatic changes in the size, distribution, and composition of the human population in the nineteenth century must have had substantial impacts on the magnitude of effort and catch, if not the composition of effort by methods or the composition of the catch by species.

The impact of the adoption of the few new fishing materials and devices during the eighteenth and nineteenth centuries should not be discounted without a close examination. The mere fact that the new materials and devices were adopted implies that they were either cheaper to obtain or use or they brought a greater return per unit cost. The effect would have been an increased incentive to use the new/modified method relative to other methods, which would have led to a shift in effort among methods, and thus probably a shift in the composition of the catch. Such shifts in effort could have occurred both within the inshore realm and between the inshore realm and the deep benthic and pelagic realms. Indeed, they could have occurred between the capture fishery sector and other economic sectors, including aquaculture and agriculture. In short, the introduction of lead, iron, metal fishhooks, the cast net, and possibly the gill net may have led not only to substantial shifts in exploitation patterns among methods and resources, but also to a change in overall inshore fishing effort and/or catch, at least on a per capita basis. The possibility of shifts of this type can be explored through analysis of the structural and functional changes in materials and gears and how those changes were related to target resources, and through close examination of the available information about the relative prevalence of fishing methods. Cobb (1903, 1905b), for example, provided quantitative data on commercial landings by method and species at the end of the nineteenth century.

Shomura (1987) examined landings data for the period 1900-1986, specifically, data for the years 1900, 1950, 1953, 1985, and 1986. The available data were limited to commercial data, and incomplete data at that. In spite of the shortcomings in the data, he found such large changes that he concluded: "... barring gross shortcomings in the statistical data bases, some fundamental changes in the resources and fisheries appear to have occurred since the turn of the century" (Shomura 1987:13). The changes included a dramatic decline in the reported landings of inshore species (what he termed "coastal species," including the resources associated with "embayments, nearshore areas, and reefs"), decreasing from 3.6 million pounds in 1900 to 0.6 million pounds in 1986. A decline of 44 percent was seen in the reported landings of neritic-pelagic species (which consisted primarily of *'ōpelu* and *akule*) during the same period. Shomura offered a number of possible causes for the dramatic changes, including the possibility of gross shortcomings in the data, overfishing, shifts in exploitation patterns among resources, and changes in resource biomass due to pollution or anthropogenic changes to habitat, including reduction of fresh water inflows, the loss of ponds, filling of mudflats and coastal areas, building of shoreline bulkheads, and creating sand beaches where none existed previously.

'ōpelu
akule

Weng and Sibert (2000) examined the fisheries for *'ōpelu* and *akule* in the Main Hawaiian Islands using data from the years 1966 through 1997. They concluded it was unlikely that either species was overfished with respect to maximum sustainable yield. They also found a positive correlation between precipitation and the stock size of *akule* (with a two-year lag) that could explain changes in stock size and catches on time scales with strong climatic signals.

With respect to fishermen shifting their attention among resources, Shomura (1987) found large increases in landings of pelagic and slope and seamount resources during the 1900-1986 period, a trend he found to be expected given the improvements in vessels, fishing gears, navigational aids. He also suggested that the dramatic decrease in inshore landings, particular of surgeonfish and parrotfish, might be partially explained by shifts in consumers' preferences caused both by changes in the ethnic composition of Hawai'i's population and the increase in the number of tourists.

The various sets of creel survey data available for the post-1950 period can be used to describe fairly detailed attributes of exploitation patterns in certain areas and time periods. But the surveys would be useful in identifying temporal changes only if repeated, and only if their outputs have an acceptably high degree of precision. The studies conducted under the Main Hawaiian Islands Marine Resources Investigation, and, if continued for a long enough period, the Hawai'i Marine Recreational Fishing Survey, should yield estimates of various attributes of effort and catch that are comparable over time.

In summary, quantitative fisheries data can be used to identify at least gross changes in Hawai'i's inshore exploitation patterns since 1900, and the data are such that more subtle changes could be detected for the period since 1950. For the period prior to 1900 only inventories of fishing methods and exploited species and circumstantial information are available, but they have the potential to reveal important shifts in fishing patterns. The single most powerful type of circumstantial information is human demographic data, which is relevant for the entire historical period. Information about shifts in people's diets, prevailing social controls, and the character of the local economy could also be fruitfully applied to entire historical period. For the period since 1900 it would also be important to take into account information about exports and imports and changes in the condition of inshore habitats.

4.3.4 Historical Changes in American Samoa

As described in Section 3.3, there is very little historical documentation of fishery resource exploitation patterns—aside from a few descriptions of fishing methods and gears used—at the time of contact. Detailed written accounts of fishing gears and practices appear not to have emerged until the mid- and late 1800s. It would therefore be difficult to use data specifically about fisheries in order to directly identify changes that took place between the time of contact and later periods for which more detailed documentation is available.

Although the quality and quantity of fishing-related information for American Samoa improved with time, even until the 1970s the information was largely limited to descriptions of fishing methods, references to the dominant species captured, and qualitative descriptions of how much fishing was being done and how much fish was being caught.

It would therefore be difficult to use data specifically about fisheries to identify changes in exploitation patterns from the time of European contact until about the post-1950 period. The circumstantial information described in Section 3.3, however, could be fairly powerful.

There are a number of sources from the last quarter of the twentieth century that provide quantitative measures of inshore fishery exploitation patterns, including effort and catch. They include Hill (1978); Wass (1980); Ponwith (1992); Des Rochers and Tuilagi (1993); Craig et al. (1993); Saucerman (1995b). These direct quantitative sources relied on either creel surveys or household surveys that measured only the then-current exploitation patterns, but several interview-based sources examined past patterns, as well (e.g. Severance and Franco 1989; Des Rochers and Tuilagi 1993). Tuilagi and Green (1995), for example, provided measures of temporal changes in catch that went back as far as the earliest memories of the informants—about 70 years. Some of the findings in these sources are highlighted below.

Observations from as early as 1975 pointed to a decline in inshore fishing activity and importance:

> Yet the reef fishery of the present has dwindled in importance and in diversity to the point that some parts of it diving, line fishing) seem to be as much sport fishing as subsistence fishing (Hill 1978:6).

Hill (1978) and Wass (1980) noted that new technologies and improved gear efficiency had contributed toward the use of more generalized fishing methods in American Samoa, and traditional methods and gears designed to capture specific kinds of fish in particular kinds of locations were no longer being used.

Given the six-fold increase in human population between 1899 and 1980, Wass speculated that "[t]otal effort ... is probably greater than it was at the end of the nineteenth century because of the much larger population" (Wass 1980:79). Wass concluded, however, that per-capita effort had declined, as had catches, because of habitat degradation, as well as decreasing dependency on inshore resources.

Although it is not surprising that per-capita inshore effort would have declined since European contact, it is remarkable that from 1979 to 1994, a period that saw a steep increase in human population size, *total* inshore fishing effort on Tutuila was found to decline substantially, as indicated in the following accounts.

atule

Craig et al. (1993), based primarily on Wass (1980) and Ponwith (1992), described an 8 percent decrease in effort and a 26 percent decrease in catch (54 percent if the highly variable catch of *atule* is ignored) in the shoreline subsistence fishery of Tutuila between 1979 and 1991. Given the 46 percent increase in human population during that 12-year period, the per-capita catch on Tutuila dropped from 19.4 to 9.8 pounds. Reasons cited for the decline included socioeconomic factors (including less available leisure time, a shift in dietary preferences, and an increasing preference to buy fish rather than to catch them), possibly overexploitation (as evidenced by the decrease in catch-per-unit-effort), along with hurricane damage, attrition of fishermen, and increasing imports of fish products from Samoa and Tonga. Two species that were exceptions to the general decline were *atule* and *palolo*. Saucerman (1995a) reported that from 1991 to 1994, effort on the island of Tutuila declined about 30 percent and catch decreased about 70 percent, although a portion of the changes could be attributed to an especially active *atule* fishery in 1991.

Tuilagi and Green (1995) investigated changes even farther back in time—to the earliest memories of people that they interviewed. They specifically asked about how fishing for reef fish, giant clams, and *palolo* had changed during the respondents' lives. *palolo* All respondents reported decreases in catches of giant clams, 70 percent reported decreases in catches of reef fish, and 43 percent reported decreases in catches of *palolo*.

In summary, quantitative fisheries data can be used to identify fairly detailed changes in inshore exploitation patterns since 1979. Prior to that time, only qualitative accounts of inshore fishing patterns are available, along with fairly detailed inventories of fishing methods and exploited species. Valuable circumstantial information is available for the entire historical period, the most powerful type being human demographic data. Qualitative information about shifts in people's diets, prevailing social controls, and the character of the local economy could also be fruitfully applied to entire historical period. For the period since 1950 it would be especially important to also take into account information about exports and imports and changes in the condition of inshore habitats.

5 Long-Term Changes in Inshore Resources

This section discusses the potential for reconstructing long-term change in inshore resources. From the archaeological point of view, this is a difficult task, although new methods drawn from foraging theory might yield useful results. These new methods have not been applied to collections in Hawai'i and American Samoa. Methods of inferring resource characteristics from historical sources are reviewed, and the potential to describe long-term changes from the reviewed sources is assessed.

5.1 Alternative Archaeological Explanations for Faunal Change

Archaeologists have no direct way to estimate the composition of reef fish populations from the remains recovered at an archaeological site. The measures discussed in section 3 are all used to estimate characteristics of the sample assemblage (see pg. 15), which is several steps removed from the living population. Instead, the interpretation of changes over time in the relative frequency of taxa detected in the archaeological record are generally interpreted with reference to ancillary data that are related to the identified change with a linking argument. For example, Kirch and Yen (1982:292) argued that the absence of moray eels in the latest faunal collections from Tikopia and their presence earlier in the archaeological sequence was due to the imposition of an ethnographically recorded taboo on eels. Similarly, Dye (1990) used archaeological evidence for changes in fishing gear to explain a decline in the relative abundance of pelagic and deeper-water benthic fish in archaeological collections from the Marquesas Islands. In both of these cases there was no reason to suspect that the fish taxa whose relative abundances in archaeological collections declined over time were also declining in abundance in the wild. Recently, archaeologists have adopted a prey choice model from foraging theory to explain changes in relative abundance for which ancillary data for interpretation are not available (Butler 2001). This approach ranks taxa according to their profitability to the fisherman, then tracks the relative abundance of high ranking taxa to low ranking taxa. Declines in the relative abundance of high ranking taxa are interpreted as prey resource depression. Once profitability criteria have been established, this type of approach can be used with existing collections as they are reported in the literature. An example of the approach elsewhere in the Pacific is Butler (2001), who augments an argument based on the prey choice model for resource depression in inshore fishing on Mangaia Island in the Southern Cook Islands with evidence for a decline in body size over time in a small sample of Serranidae, a high-ranking prey.

Prey size is another way to assess changes over time in reef fish populations, independent of information on relative abundances of taxa. This line of investigation was first pursued in the Pacific with shellfish, which were found to decline in size at various localities in the Pacific (Swadling 1976; Anderson 1981; Kirch and Yen 1982; Spenneman 1987), arguably due to predation by humans. This was followed in New Zealand by several claims that fish size also declined over time due to over-exploitation (see Leach and Davidson 2001). The interpretation of changes in fish size is a complex matter, however, possibly involving "changes in fishing technology, changes in preferred fishing grounds, changing sea conditions, which variously inhibited or permitted canoe fishing away from the coast, and changes in surface sea water temperatures over time" (Leach and Davidson 2001:160).

5.2 Inshore Resource Characteristics from Historical Sources

This review generally refers to "populations" as the resource unit of interest, but the same general approaches for assessing the status of populations can be applied to communities and ecosystems, as well. For example, the species composition of an exploited fish community and the ecological dynamics among species and populations may be attributes of interest.

In the strictest sense, the terms "population," "stock," and "resource" have different meanings, but in the context of this review the distinctions are not overly important. Briefly, "population" refers to a group of interbreeding organisms. "Stock" refers to a group of organisms that is defined for convenience's sake with respect to assessment and management, the ideal of which would be a population. "Resource" refers to exploited organisms generally, including stocks, communities, and ecosystems.

5.2.1 Attributes to be Examined

The most pertinent characteristics of a fish population or stock with respect to examining fisheries production are its size (e.g., abundance or biomass) and its potential, or unfished, size. A population's potential productivity is a function of inherent biological characteristics such as growth rate, recruitment rate, and natural mortality rate. But its actual fisheries productivity is a direct function of its size relative to its potential size, which is determined by the fishing mortality rate (the proportion of the population removed by fishing per unit time), which is a function of fishing effort. Productivity is also a function of more subtle attributes of effort and catch, particularly the fish sizes (and ages and sexes) captured relative to the population's unfished size structure. Other characteristics of fish populations and their relationship to fishing patterns may also be important, such as their spatial-temporal patterns of migration, spawning, and recruitment, but this review will focus on the actual and potential sizes of populations as the most pertinent attributes.

Both the actual and potential size of a population can vary with time. A population's potential, or unfished, size is equivalent to the ecosystem's carrying capacity for that particular population. It is the size toward which the population would tend in the absence of fishing. The degree of short-term variability around that value varies according to the biological characteristics of the population. Slow-growing, long-lived species, for example, can be expected to exhibit less variability than fast-growing, short-lived species. More importantly in the context of long-term assessments of population change, the unfished population size (or some useful temporal average thereof) can be expected to change over fairly long time scales. Such changes could be of a cyclical nature, correlated with climatic or oceanographic cycles (e.g., ENSO events). They could also be non-cyclical, the result of relatively unidirectional changes in the nature of the habitat or the larger ecosystem. On the scale of thousands of years, important agents of such change might include volcanic activity, erosion, and sea level changes, which can dramatically alter the size and characteristics of inshore habitats (and thus the potential size and productivity of particular populations). On the scale of tens or hundreds of years, acute disturbances to habitat, such as from storms, may be important, and more chronic factors, such as erosion and sedimentation, can also be important. Anthropogenic impacts to habitat, such as pollution of inshore waters and land-clearing activities that lead to erosion and sedimentation, can be important agents of change on the scale of decades, centuries, and millennia. Fishing itself, if it substantially alters the structure or dynamics of the larger ecosystem, can also affect a population's potential size. For example, the fishing-down of a predator population might result in an increase in the unfished size or carrying capacity of a population of its prey.

5.2.2 Information Types and Analytical Approaches

The types of information and corresponding approaches that are available for describing resource attributes and trends in those attributes can be viewed as being on a continuum, ranging from direct to very indirect. For the purpose of this assessment, this continuum is broken into three types.

***In Situ* Observations** One of the most direct types of information available is *in situ* observation of the resource. Modern underwater visual surveys typically rely on the use of a sampling design that is stratified by important factors such as habitat type. Counts, and sometimes length measurements, of fish, by species, are carried out within relatively small sampling areas, and the results are used to generate estimates of abundance, biomass, and/or size structure, by species. Quantitative underwater visual surveys became a common approach for assessing shallow-water reef resources in the last half of the twentieth century, but qualitative information of this type goes back to the beginning of the historic period. Examples include accounts of remarkable fish schools or runs and documentation of years in which particularly large or small runs (e.g., recruitment events) were observed. Unfortunately, such qualitative accounts tend to favor the more conspicuous and spectacular events, which may be one explanation for the apparently universal tendency to perceive fishery resources in the past as being bigger and better than in the present.

Catch and Effort Information A type of information about fish populations that is only slightly removed from *in situ* observations is catch and effort data, such as counts, weights, and sizes of landed fish and associated measures of fishing effort. This information can be collected opportunistically from fishermen or it can be collected in a more systematic and directed fashion. An example of the latter is standardized fishing (often called "experimental" fishing), in which as many characteristics of effort as possible are kept constant or strictly controlled in order to obtain standardized and comparable measures of such attributes as catch-per-unit-effort. One variation is to fish down the target populations as rapidly and fully as possible, which can yield useful information about the biological attributes of the populations. Another variation is to take biological inventories of water bodies through the application of poisons, electrocution, and explosives.

A large body of fish stock assessment methodologies relying on measurements of various attributes of effort and catch has developed during the last 50 years (e.g., see Appeldoorn 1996 for a summary of methods particularly applicable to reef fish). The data that are available for most of the historical periods of Hawai‘i and American Samoa are such that only relatively crude assessment approaches, using measures of fishing effort, catch, and catch-per-unit-effort (CPUE), particularly temporal comparisons of such measures, would be applicable. This discussion therefore centers on the relationships between effort, catch, CPUE, and stock size.

Effort can be expected to be negatively correlated with stock size. Inferences about stock condition can therefore be made by comparing effort measures with reference values. To identify changes over time, obviously the most valuable references would be measures for the same area from other periods. Also potential useful reference values would be measures from other areas (expressed on a per-unit-area, per-unit-time basis), and many such measures are available in the literature.

Catch can be expected to be correlated with stock biomass or abundance, but as described in Section 3.1.2, the relationship is complex, with catch peaking at some immediate level of effort. Making inferences about resource condition is therefore somewhat difficult. For example, if yield (catch per unit area per unit time) during a given period is found to be less than yield during a previous period, two contrasting inferences could be made: stock size either increased or decreased. Knowledge about the directional change in effort over the time period would be required to conclude which of the two was the more likely. As with effort, measures of yield can be compared not just over time, but with other reference values, as well. Potentially useful references include actual inshore yields from other Pacific Islands and estimates of potential yield, such as maximum sustainable yield, made elsewhere (e.g. Dalzell et al. 1996). Ideally, these types of yield comparisons would take into account as many explanatory factors as possible, such as general geographic location, island and habitat type, and size of the study area.

Like effort, CPUE can be expected to be fairly tightly (but negatively) correlated with stock size. Again, inferences about stock condition can be made by comparing CPUE measures with reference values, particularly values recorded from the same area in other periods, but also values from other areas, many of which are available in the literature (e.g. Dalzell et al. 1996). For the purpose of such comparisons, CPUE measures have the advantage over effort and catch of not needing to be converted to by-area units.

Although measures of CPUE are potentially very useful, their use as indicators of stock status can be problematic. First, the relationship between CPUE and stock size is unlikely to be linear, or even tight, across the entire range of stock size. Second, tropical inshore fisheries typically involve many fishing methods, the units of effort for which are not strictly comparable. With respect to tracking temporal changes, this is a problem only if the composition of effort among fishing methods has shifted over time. Third, measures of CPUE are typically based on small sample sizes, so they often have high degrees of uncertainty associated with them. Fourth, there are many exogenous factors other than stock abundance that influence CPUE, and it is difficult to track and account for these factors to the extent necessary to make meaningful comparisons.

Another potentially important relationship is that between fishing effort and the species composition of the exploited fish community (e.g., as reflected in the species composition of the catch). As noted in Section 3.1.2, fishing tends to target the higher trophic levels, so the greater the fishing pressure, the smaller would be the expected contribution to the catch of the higher-trophic-level species, such as the larger piscivores. Similarly, the relationship between fishing effort and the size structure of particular populations (e.g., as reflected in the size structure of the catch of particular species) can be put to use. As noted in Section 3.1.2, fishing tends to target the larger sized individuals (with important exceptions), so the greater the fishing pressure, the smaller would be the expected size structure of the catch of a given species.

As noted previously, the sizes of some populations or stocks can be expected to be much more variable from year to year than others, irrespective of fishery exploitation patterns. Whatever approach is used to evaluate trends in population characteristics and however long the period of interest is, it important to take into account any expected natural temporal variability. For example, an account of the catch in a single given year of *Selar crumenophthalmus*, a nearshore pelagic species, would not be a very useful indicator of the size of the stock during that era.

Circumstantial Measures As emphasized throughout Sections 3 and 4, even where direct measurements of effort and catch are lacking, there may be information that can be used as indirect measures. Most critically, since stock size is inversely correlated with fishing effort, and fishing effort and human population size are likely to be strongly positively correlated, one can expect a strong (negative) correlation between human population size and stock size. In most cases it would be difficult to determine the exact nature of these relationships, in which case absolute estimates of stock biomass or abundance would be unattainable. But the high degree of certainty in the directions of these relationships means that even measures of human population size alone can serve as useful indicators of trends in stock size. Of course, as discussed in Section 3.1.2, the more explanatory factors that can accounted for, the better. Again, important factors might include shifts in the distribution and composition of human population, changes in people's diets, changes in social controls over fishing, and shifts in the amounts of fish exported and food products imported. For some time periods, changes in the potential size and productivity of the resource are likely to be especially important to consider, such as changes resulting from environmental disturbance, habitat degradation, or habitat enhancement.

Several market-based indicators of stock status may also be available. For example, price is generally strongly related to scarcity, so fish prices can be used to make inferences about the status of fish populations. Similarly, where fishing rights are traded on an open market, the value of those rights, and indirectly, the status of the exploited stocks, can be inferred. Examples from Hawai‘i include the fishing rights that were traded in the latter part of the nineteenth century and the rental market for fishponds. The utility of these market-based approaches is limited by the fact that the market is shaped by demand as well as supply, so without information about trends in demand, information about trends in value would have limited utility.

5.3 The Potential to Describe Long-Term Changes in Inshore Resources

It is relatively difficult to infer changes in fishery resources with archaeological and historical data. Even today, stock assessment with good data on characteristics of the catch is as much art as it is science. With the patchy and often inconsistent data of archaeology and early historical records, the difficulty of the task is multiplied. This section assesses the potential for Hawai‘i and American Samoa, focusing on the kinds and quality of data available for various periods.

5.4 The Prehistoric Period in Hawai‘i and American Samoa

The archaeological record of American Samoa has, at present, little or no potential to describe long-term changes in inshore resources. In the single analysis with some potential along these lines, Nagaoka (1993) found the remains from the To‘aga site to be marked by stability, rather than change. Thus, investigation of this issue would appear to require the collection of additional faunal material from either well-dated or well-stratified archaeological sites.

The archaeological record of Hawai‘i has somewhat greater potential, but this has so far gone unrealized. The lack of reported data on sizes of vertebrate and invertebrate remains blocks a potentially fruitful avenue of investigation; progress along these lines will require either re-examination of extant collections, or a change in the reporting practices of Hawaiian archaeologists. Another line of inquiry, more immediately promising than the investigation of changes in size, is the application of prey choice models from foraging theory. The initial results of this type of analysis on a collection of shellfish from a Hawaiian archaeological site were reported to the Society for Hawaiian Archaeology in October, 2003, with results that indicated no evidence for change in the resource at a site on the north coast of Kaua‘i Island (Morrison 2003). An appeal of the approach is that it can be applied to published data, without the need to re-examine collections. The approach is relatively novel, however, and has not yet been subject to scrutiny and criticism. It is thus too early to predict whether it might become established as an acceptable means of using archaeological materials to track trajectories of resource depression and rejuvenation.

5.4.1 Hawai‘i—1778 to 1900

The accounts of early visitors to Hawai‘i do not provide very rigorous measures of the condition of inshore resources. There are many anecdotal references to the size and productivity of inshore resources, but they are generally superficial and lacking useful frames of reference. Scientists on some of the voyages collected marine organisms, but with their focus on the diversity of species, the results are not very helpful in terms of resource abundance.

Although qualitative and quantitative measures of effort, catch, and CPUE are generally lacking for the early historical period, there are a few that may be useful, including the examples of snapshot CPUE measures in the literature identified by Scobie (1949). They include CPUE measures for netting (Deering 1899; Cobb 1902), crayfish diving (Cobb 1902), shark noosing (Bryan 1915), flying fish netting (Corney 1896; Campbell 1816), the use of a *lau*, or leaf, method (Corney 1896), and limpet and periwinkle gathering (Ellis 1836). Scobie (1949) also compiled estimates of annual commercial catches per person, by fishing method, for native Hawaiian fishermen only, based on data provided by the U.S. Fish Commission.

As described previously with respect to fishery resource exploitation patterns, a promising approach for identifying at least gross changes in the size of inshore resources during the pre-1900 period would be to use human population size—and its geographical distribution—as a proxy. Inferences made in this manner could be refined by accounting for even just directional changes in such factors as the composition of effort among fishing methods and social controls, as described in previous sections. Certain changes to the biophysical environment may also be important to consider, including the sedimentation of estuaries and inshore waters due to clearing of coastal and upland forests.

5.4.2 Hawai‘i—1900 to 1950

The first half of the twentieth century saw documentation of commercial landings data in addition to the kinds of qualitative fisheries information that were available in the pre-1900 period. The landings data were not accompanied by rigorous measures of effort so it would be difficult to use trends in landings to make inferences about trends in resource size. But crude measures of effort are available in the reported numbers of fishing licenses issued (e.g. Cobb 1902, 1905b). There are also a few accounts that looked specifically at temporal changes:

> The fauna of the reefs is much less abundant than in the period of the first extensive explorations, those of Dr. Oliver P. Jenkins, in 1889, and of Jordan and Evermann in 1901. Probably no species had been exterminated

> by overfishing, but many once common have now become rare (Jordan et al. 1927).

During a 1938 investigation, Bell and Higgins (1939) found anecdotal evidence pointing to a decline in the abundance of inshore fishery resources, caused both by fishing too intensively and with methods that were indiscriminate with respect to species and sizes captured. Most of the evidence was in the form of views "expressed repeatedly by members of the fishing industry, sportsmen, businessmen and legislators who were interviewed individually or who volunteered information in public hearings" (Bell and Higgins 1939:14).

Titcomb (1972) reviewed a variety of mostly qualitative sources with respect to the historical abundance of fish. Most of the sources suggested greater abundance in the past.

Cobb (1902, 1905b) provided detailed information on prices of fish in the major markets of Hawaiʻi at the turn of the century. He was one of many observers that remarked on the high prices of fish. Jordan and Evermann (1902) attributed the high prices to overfishing. Others, including much of the public, blamed them on collusion among the fish dealers. In fact, the territorial government investigated that possibility in the 1930s (Bell and Higgins 1939). Whatever the basis for the remarkably high prices, further investigation along these lines might lead to useful information about the condition of Hawaiʻi's inshore resources.

The data provided by Cobb (1905a) on the value of fishing rights, which were openly traded, might be useful with respect to the value—and therefore scarcity—of inshore resources. Cobb made general comparisons among the islands and within islands, such as stating that "[p]ractically no effort is made to collect rent for any of the fishery rights of Hawaii" (Cobb 1905a:760), due in part to the sparseness of the population and lack of markets. He also provided the annual amounts paid in or around 1900 for the right to acquire particular fishery rights, ranging from $20 for fishery rights to an area at Kauaʻi to $1,375 for the rights to two areas near Honolulu. He attributed the high price for the latter to "the excellent market at Honolulu" (Cobb 1905a:759). He noted that the value of many fishery rights in the islands were of insufficient value to be rented at all. The lack of a market for fishery rights in other areas, such as around the island of Hawaiʻi, he attributed in part to the "disinclination of the people to pay rent" (Cobb 1905a:760). The latter may be a reflection of the erosion of the legal durability of the rights.

5.4.3 Hawaiʻi After 1950

Like the first half of the twentieth century, most of the fisheries data produced in the second half were limited to commercial landings data. However, since about 1948, the landings data were accompanied by measures of effort. Effort was recorded only to the level of fishing-trips or fishing-days, rather than fishing-hours. But the fact that commercial fishing activities were censused (albeit imperfectly) rather than sampled, combined with the long time series that is available, means that the CPUE estimates should be quite useful for identifying trends in resource size. It is likely that the data also suffer from lumping of multiple species. Still, if substantial changes in resource size occurred, they should be apparent in these data.

In reviewing the inshore fisheries of the Main Hawaiian Islands, Smith concluded that "in heavily populated areas, fishing pressure appears to exceed the capacity of inshore resources to renew themselves" (Smith 1993:34), and that "the most disturbing trend is towards steadily increasing fishing effort in inshore ecosystems that are already heavily exploited" (Smith 1993:47).

Many *in situ* observations of inshore resources have been made since 1950, in both the Main Hawaiian Islands and the Northwestern Hawaiian Islands. Being sampling-based methods, the results tend to have sizable levels of uncertainty associated with them, but they should provide a useful basis for tracking changes over time. In a few instances, in-water estimates of resource size have been accompanied by effort, catch, and CPUE data, which provides a direct means of assessing the size of the resource relative to its potential size (e.g., by examining the proportion of the stock that is removed per unit of time). Unfortunately, the estimates generated by *in situ* observations and fisheries data are often relatively imprecise and sometimes biased, so direct comparisons of this type might not be useful.

One challenge in examining trends in measures of resource size, whether they be in-water estimates of abundance or CPUE estimates, is distinguishing the effects of fishing from other effects, such as habitat degradation. For example, Shomura (1987) cited overfishing, pollution, and various forms of habitat degradation, as well as shifts among target species and data problems, as possible causes of the large declines since 1900 in commercial landings of certain types of fish, including inshore species.

As for circumstantial sources of information about the condition of inshore resources, the post-1950 period is fairly richly documented, and this information should prove useful in combination with the available *in situ* and fisheries data. Fairly detailed information is available on human demographics, controls related to fishing, exports of fish and imports of food products, the composition of people's diets, and changes to the biophysical environment.

5.4.4 American Samoa to 1900

The accounts of early visitors to Samoa do not provide very rigorous measures of the condition of inshore resources. There are a number of anecdotal references to the size and productivity of inshore resources, but they are generally superficial and lacking useful frames of reference. For example, the recorded observations of John Williams, a prominent missionary who visited Samoa in 1830 and 1832, do not delve much deeper than the statement: "The coast abounds with fish and turtle, and the Samoans are exceedingly expert in catching them" (Williams 1840:130). Scientists on some of the voyages collected marine organisms, but with their focus on the diversity of species, the results are not very helpful in terms of resource abundance.

As described previously with respect to fishery resource exploitation patterns, a promising approach for identifying at least gross changes in the size of inshore resources during the pre-1900 period would be to use human population size—and its geographical distribution—as a proxy. Inferences made in this manner could be refined by accounting for even just directional changes in such factors as the composition of effort among fishing methods, as described in previous sections.

5.4.5 American Samoa—1900 to 1950

Quantitative inshore fisheries data are lacking for the first half of the twentieth century, so like the pre-1900 period, anecdotal accounts of resource size and fishing success are among the most valuable sources, as are the sources of circumstantial information identified for the pre-1900 period. With respect to the condition of Samoa's coral reefs, Mayor (1924) provided what appears to be the first set of quantitative information.

5.4.6 American Samoa—After 1950

There are a number of sources that provide information about the condition of inshore resources and changes therein in the post-1950 period. Sources with quantitative measures of CPUE or in-water estimates of resources size include Hill (1978); Wass (1980); Ponwith (1992); Des Rochers and Tuilagi (1993); Craig et al. (1993); Saucerman (1995b, a); Green (1996). Additional sources with either qualitative assessments of inshore resources condition or syntheses of previous investigations include Van Pel (1956); Severance and Franco (1989); Green (1997); American Samoa Coral Reef Task Force (1999); Western Pacific Regional Fishery Management Council (2001). For the most part, these sources pointed to increasingly depleted inshore resources. Most sources implicated both overfishing and habitat degradation as causal factors. A few examples follow.

Craig et al. (1993), relying primarily on Wass (1980) and Ponwith (1992), found a substantial decline in CPUE in the shoreline subsistence fishery of Tutuila between 1979 and 1991 and cited fishing as a likely causal factor, but also hurricane-related damage to coral reefs.

Saucerman (1995a) found that from 1991 to 1994, CPUE declined about 60 percent, although part of the decline could be attributed to an especially active *atule* fishery in 1991. Saucerman noted that although the decline in CPUE may have been indicative of overfishing, habitat degradation probably also contributed to the decline in CPUE and catch. A lack of any noticeable change in the species composition of the catch or the size structures of the catch of principal species were cited as evidence pointing to causes other than overfishing. Saucerman also noted that dramatic changes in the relative abundance on the reef of certain non-food fish species, as determined by underwater surveys (see Green 1996), provided further evidence of habitat degradation.

Green (1997) found evidence in various sources that the more accessible coral reefs were seriously over-fished. The report noted that the coral reefs were recovering from a series of natural disturbances, as well as a number of chronic human-induced impacts, including alteration of shoreline and coastal habitats, upland erosion and consequent sedimentation, and pollution. Shoreline alterations, combined with the harvesting of turtles and eggs, was reported to have resulted in serious declines in populations of green and hawksbill sea turtles.

As for circumstantial sources of information about the condition of inshore resources, the post-1950 period is fairly richly documented, and this information should prove useful in combination with the available *in situ* and fisheries data. Fairly detailed information is available on human demographics, controls related to fishing, exports of fish and imports of food products, and changes to the biophysical environment. With respect to the latter, there is a substantial amount of information for the post-1950 period about the condition of the coastal and inshore environments of American Samoa. Sources include quantitative in-water assessments of coral reefs and their resources (Dahl and Lamberts 1977; Green 1996) and descriptive accounts of changes in the inshore environment, particularly adverse changes associated with natural disturbances, shoreline alteration, sedimentation, and pollution (e.g. Craig et al. 2000b). There are also records of the numerous acute disturbances to coral reefs that have taken place in the last few decades, including outbreaks of crown-of-thorns starfish (*Acanthaster planci*) (Wass 1979), coral bleaching events (Craig 1995b), and severe storms (Green 1996).

6 Potential Applicability to Other Pacific Islands

This section discusses in very general terms the potential applicability of the archaeological and historical methods discussed above to other Pacific islands. Because applicability is very closely tied to the quantity and quality of available data, which vary considerably among and within island groups, the comments are intended as general guides, rather than specific indications of potential.

6.1 Demography

Archaeological methods have been applied to the population of New Zealand (McFadgen et al. 1994), where the results of archaeological research are abundant. The archaeological methods have not been applied to other island groups in the Pacific, to our knowledge, and it is unlikely that other island groups have yielded sufficient data to support application of the methods. On islands with a relatively long history of human settlement, such as Samoa and islands farther to the west, intensive land use practices over a long time have had a marked effect on the survival of the kinds of archaeological remains needed to reconstruct demography, thus ensuring that future application of the methods will, in any case, be fraught with difficulty.

The picture brightens for the historical period, where the work of McArthur (1968), Rallu (1990), Pool (1991), and others has yielded a large body of serious scholarship on the demographics of the historic era for many Pacific islands.

6.2 Patterns of Fishery Resource Exploitation

The potential applicability of archaeological methods for estimating patterns of fishery resource exploitation on other islands of the Pacific depends on the quality and amount of faunal data reported for those islands. Many island groups have richer faunal records than American Samoa, which has seen relatively little archaeological work on faunal remains. Few, if any, island groups will have the large quantity of data available in Hawai‘i. In general terms, island groups with relatively large expanses of calcareous soils will yield larger and better-preserved faunal collections than will volcanic islands with limited deposits of calcareous sediment. The quality of the faunal data are also influenced by the units of quantification. NISP is the preferred unit of quantification. Both MNI and weight present problems that would hinder comparative work.

Hawaiʻi and American Samoa shared with most other Pacific Island groups many of the same experiences during their historical periods: in most cases, contact was made by European explorers, traders followed, cash-based plantation economies developed, colonial powers established themselves, and ultimately either integration or independence was achieved. There were, of course, important differences among islands, such as the characteristics of their inshore resources, their demographic histories, their systems of authority, their economies, and people's preferences among food products. But the quality of information about those characteristics is probably similar throughout the Pacific Islands, so the methods described here are likely to have the same potential and the same constraints in most of the Pacific Islands.

6.3 Temporal Changes in Fishery Resource Exploitation

The potential to describe changes in fishery resource exploitation with archaeological materials from other Pacific islands is subject to the same limitations as the description of patterns of resource exploitation, discussed above, with the additional limitations imposed by uncertainties in dating and the possible absence of stratified archaeological sites that would affect the ability to order faunal collections chronologically. These latter limitations are eased somewhat for the islands west of Samoa, which are characterized by archaeological sites that yield ceramics. Ceramic-bearing sites are relatively easy to place in chronological order, and faunal collections from these sites might be used productively in a comparative analysis, even absent precise dating by means other than the kind(s) of pottery they yield. Islands east of Samoa generally lack pottery, requiring a heavier reliance on ^{14}C dating methods.

As with the potential to describe exploitation patterns, the methods described here for identifying changes in exploitation patterns from historical sources should also be applicable throughout most of the Pacific Islands.

6.4 Long-Term Changes in the Condition of Inshore Resources

The ability of archaeological methods to track long-term changes in the condition of inshore resources is wholly dependent on the ability to place faunal collections in chronological order, and the considerations noted in the previous section apply here as well. There are two potential approaches. Tracking changes in the sizes of animals that make up the catch will involve re-examination of archived collections from appropriate sites to collect the size information, which is not routinely reported by archaeologists. Application of prey choice models from foraging theory have the advantage that they do not require re-examination of collections, but will work with published data. The potential drawback of this approach is that it has not been subject to the scrutiny and criticism that will determine whether it becomes an accepted method in archaeology.

The methods described here for identifying changes in the condition of inshore resources from historical sources are generally applicable anywhere, including other Pacific Islands. The outputs, naturally, would depend on the type and quality of the available data.

7 Summary and Conclusions

Sources of archaeological information for Hawai‘i appear to be sufficient to characterize patterns of fishery resource exploitation, chart at least some changes in these over time, and investigate long-term changes in inshore resources. The literature contains some excellent characterizations of patterns of fishery resource exploitation for local areas, and these could be used as models for the re-analysis of the large body of material that has been collected from throughout the islands. An analysis of this sort might be expected to identify and characterize broad regional patterns of resource exploitation tied to characteristics of the nearshore marine environment. The investigation of change over time is poorly developed in Hawaiian archaeology, and research into changing patterns of resource exploitation would necessarily deal with probably small subsets of the available data chosen to meet the fairly strict data requirements of established methods. The primary problem here is likely to center on the difficulty of arranging archaeological faunal collections in chronological order. Once this is accomplished, however, indications of change are likely to be found, as they have been in several Pacific Island groups. Investigations of patterns of resource depression and rejuvenation will require either a re-examination of existing collections, or application of methods whose utility is not yet established in the Pacific. Work along these lines could prove important for Hawaiian archaeology and yield advances in the analysis and interpretation of faunal remains.

Archaeological collections from American Samoa offer little of the potential of those from Hawai‘i. A credible characterization of the pattern of resource exploitation on one island in the Manu‘a group has been published, but this collection yielded no evidence for change over time. If further progress is to be made in American Samoa, it will require an excavation program designed to recover suitable collections of faunal remains.

Not surprisingly, the farther back in time one looks the fewer and less quantitative are the historical data about inshore resources and exploitation patterns.[4] In Hawai‘i and American Samoa, the post-1950 period produced a rich collection of quantitative information that has revealed important aspects of, and changes in, exploitation patterns and the condition of inshore resources. Further synthesis of existing sources would probably reveal additional characteristics and changes. The first half of the twentieth century saw fairly detailed documentation of the commercial component of inshore fisheries in Hawai‘i, but virtually no quantitative information about non-commercial fisheries in either Hawai‘i or American Samoa. Up to the beginning of the twentieth century, documentation about inshore resources and fisheries is mostly limited to anecdotal information.

Although the inshore fisheries information is relatively limited for most of the pre-1950 period, the available information about the broader political and economic conditions in which Hawaiians and Samoans lived is detailed enough to provide valuable clues about fishery resources and exploitation patterns. Most critically, there is reasonably good information about the size and distribution of the human population. Even

[4]Historical events and trends potentially important for the interpretation of patterns and changes in inshore fishing are listed in appendix A.

on its own, that information can be used to reveal gross trends in effort and catch and the condition of inshore resources. This approach is likely to be especially powerful for the period prior to the twentieth century, because with just a few exceptions, there were essentially no exports of inshore resources and no imports of substitute food items. There are also many accounts of the social norms that shaped fishing patterns, including marine tenure patterns, systems of civil and religious authority, and specific rules governing access to, and use of, fishery resources. Although it is difficult to identify the root cause of fishing-related controls—for example, whether or not they evolved in response to resource scarcity, this information can at least be used to infer some of the likely outcomes of such controls. Finally, in the case of Hawai‘i, observations about the existence and use of fishponds can provide important information not only about pond production, but also about the use and condition of inshore resources in general.

A Historical Events and Trends

Listed below are some of the more conspicuous events and trends in the histories of Hawai‘i and American Samoa that may have had important effects on inshore fishery exploitation patterns and inshore resources since the late 1700s. A few examples of findings and quotes related to these events are also given. These examples do not comprise an exhaustive assessment of these events with respect to inshore fisheries—they are intended only to highlight a few of the possible ways in which they were connected to inshore fisheries and resources.

A.1 Hawai‘i

- Materials and ideas introduced by explorers, missionaries, whalers, and traders, starting in 1778

  Campbell (1816) reported that by 1809 the king had his own forge, iron goods were in general use, and wire hooks were being used to catch *aku*.

- The gradual centralization of authority that began before European contract, culminating in Kamehameha's taking control of all the Main Hawaiian Islands by 1810

  "Kamehameha established a pattern of more centralized rule to overcome the Hawaiian tendency to rebel … controlled the sandalwood trade … appointed loyal governors on the outlying islands … centralized the religious system" (Langlas 1998:171).

- Early impacts of Westerners on customary systems of authority

  The authority of the chiefs began to be undermined even upon the arrival of Cook's ships at Kealakekua Bay. Cook's arrival occurred in a season in which boats should not have been about, but his breaching of the local rules brought no ill to the crew: "Quite unconsciously Cook had challenged the regulative mechanisms of the society and exposed the prescriptive devices to criticism" (Scobie 1949:272).

- Overthrow of the *kapu* system, in 1819

- Human population decline, reaching a low of about 0.05 million people in 1876, and its rebound through the twentieth century, reaching about 1.2 million in 2000

- The sandalwood trade, which peaked in the 1820s and ended by mid-century with the depletion of sandalwood trees

  Merlin (1998:170): "... by 1827 heavy taxes, paid in sandalwood, were being levied on commoners ... in order to retire a debt of $500,000 owed American merchants from spending by Kamehameha II." "Large numbers of people were forced to abandon their subsistence activities to search for wood, and Western visitors reported seeing processions of 2,000-3,000 men carrying sandalwood down from the forests."

  Culliney (1988) suggested that the virtual disappearance of pearls from Pearl Harbor after the 1820s may have been due to the estuary becoming especially turbid as a result of sandalwood felling in its watershed.

- The trade in sandalwood and the subsequent development of Hawai‘i as a base for whalers driving the shift from a subsistence to a cash economy

  Reynolds (1835) observed in 1832 that it had become customary for fish and other commodities to be sold in a square near Honolulu's waterfront. In 1851 Honolulu's first regular market house for fishery products was built (Cobb 1905a).

  Referring to the 500 whaling ships that visited Hawai‘i for provisions each year during the heyday of whaling, MacDonald remarked "[w]hereas in the 1820s trade had been under the control of the chiefs, by the 1850s independent farmers paid market fees to trade with visiting vessels" (MacDonald 1998:172).

- The process of urbanization, starting at Waimea on Kaua‘i and Kealakekua Bay on Hawai‘i immediately after Cook's visit, then in the early and mid-1800s shifting to Lahaina on Maui and Honolulu on O‘ahu with the development of the whaling industry in the Pacific

  "By 1860, 22 percent of the Hawaiian population lived in Honolulu" (Langlas 1998:174).

  "... the growth of the towns increased the demand for fish at particular points. It greatly stimulated fishing activities in ponds adjacent to the main centers ... At the same time the increased local demand in nearby fishing areas was the beginning of over fishing" (Scobie 1949:286).

- The conversion to Christianity, which greatly accelerated in the 1830s, following closely behind the abandonment of much of the indigenous religious system by decree of the monarchy

  Because there were fewer sacred days in the Christian calendar compared to the number observed previously, "the advent of Christianity held the possibility of increasing [fisheries] production" (Scobie 1949:283–284).

- The establishment and development of centralized fishing rules, starting with Kamehameha III's 1839 set of fishing-related laws, including the division of fishing grounds among himself, the landlords or *konohiki*, and the commoners

  "His majesty the King hereby takes the fishing grounds from those who now possess them from Hawaii to Kauai, and gives one portion of them to the common people, another portion to the landlords, and a portion he reserves to himself" (quoted in Jordan and Evermann 1902:361).

- The *māhele* of 1848-1850, resulting in the land interests of Hawaiians being privatized and able to be held by foreigners

  "The 10 *ali'i nui* [high chiefs], 24 *kaukau ali'i*, or lesser chiefs, and 218 *konohiki*, or land stewards, were all required to give up 50 percent of lands they administered to the government. The majority of the government land was sold to foreigners" (Kame'eleihiwa 1998:173).

  "Understanding that land, water and inshore fisheries management cannot function separately on remote Pacific Islands, the impacts and environmental consequences of the *Mahele* extend to the depths of fisheries administration, conservation, and management in Hawai'i today" (Lowe 2003:33).

- The use and decline of fishponds

  "Complaints were frequently heard ... that pond operators, instead of augmenting the fish supply, were actually contributing to its destruction by greatly overstocking the ponds with young fish" (Bell and Higgins 1939:9).

  The shift of people to the towns resulted in the deterioration of fishponds far from the towns (Scobie 1949).

- The introduction of new materials and methods, including face masks, torches, and in about 1890, the cast net

- The remarkably high fish prices

  "The fisheries of Honolulu are rapidly falling off in amount, with a corresponding rise in the prices of fish, which are now perhaps higher than in any other seaport town in the world. One cause of the falling off is to be found in overfishing within a limited area" (Jordan and Evermann 1902:371).

  "The visitor to Honolulu is immediately impressed with the relatively high price of fish on the retail markets. This condition has obtained for so long a period that it has received a great deal of public attention and during the past year has been the subject of an inquiry by a special investigating committee of the Territorial Legislature" (Bell and Higgins 1939:12).

- The formation of the Republic of Hawai'i and annexation by the United States, in 1898

  "Under the Republic the White establishment was firmly in power: few Hawaiians and no Asians, or Whites without property, were given the vote. The lands of the monarchy (crown land), designated as public property under the Republic, became part of government land" (Langlas 1998:177).

- The development of the sugar economy and immigration, particularly in the late 1800s and early 1900s

  "Whereas in 1876 Asians made up only 4.5 percent of the population, by 1890 they were 33 percent and by 1900, 56 percent" (Langlas 1998:1998).

  Scobie (1949:266) noted that within 100 years of European contact, the fisheries were dominated by foreigners: "The Hawaiians had virtually disappeared from the fishing industry."

  Observing the situation in 1937, Bell and Higgins (1939:14): "Thus 51 percent of the [licensed] fishermen in Hawaii are aliens as compared with 49 percent citizens, despite the fact that many restrictions are placed on alien fishing."

  Immense quantities of canned, salted, smoked, and dried fishery products, such as salmon, cod, skipjack, mackerel, herring, sardines, shrimps, lobsters, oysters, clams, mullet, etc., are imported and consumed by the people, particularly on the sugar plantations" (Jordan and Evermann 1902:379).

- The expansion of commercial inshore fishing to the Northwestern Hawaiian Islands, including its beginnings in the first few decades of the 1900s, the intensive but short-lived pearl oyster fishery at Pearl and Hermes Atoll in the late 1920s, development of the *akule* fishery in the 1950s, the general decline of Northwestern Hawaiian Islands fishing in the 1960s and 1970s, and the rapid development of the Northwestern Hawaiian Islands lobster fishery in the 1980s

  Describing the results of a biological survey in 1930, three years after the initiation of the pearl oyster fishery at Pearl and Hermes Atoll, Galtsoff (1933:40) concluded: "At present this minimum [break-even daily collection rate] cannot be attained at Pearl and Hermes Reef, for the oyster population has reached a dangerously low limit and is threatened with extinction."

  Remarking on the various vessels involved in commercial fishing in the Northwestern Hawaiian Islands in the 1930s and following World War II, Iversen et al. (1990a:9) stated: "However, besides bottomfishing, these vessels also fished for lobsters, reef fish and inshore species and turtles . . . "

- World War II, with its sudden and dramatic changes to the economic and regulatory environments

  "With the entry of the United States in the Second World War came the imposition of area and time restrictions on fishing activities in Hawai‘i that virtually eliminated offshore harvesting operations" (Schug 2001:29).

- The rapid increase in coastal development, particularly since the 1950s

  Shomura (1987) cited a number of important impacts of such development, including reduction of fresh water inflows, the loss of ponds, filling of mudflats and coastal areas, building of shoreline bulkheads, and creating sand beaches where none existed previously.

- The rapid increase in tourism, particularly since the 1950s

- The continuing development of controls on inshore fishing, including the *de facto* marine protected areas established as a consequence of the strong military presence

  "Fully-protected no-take reserves in the MHI have been shown to have higher standing stocks of reef fishes compared to areas where fishing is permitted or areas with partial protection from fishing . . . yet these reserves account for less than 1% of the area surrounding the MHI" (Friedlander 2003:230).

- The intentional and incidental introduction of alien species, including mangroves and a number of marine fishes, including *ta'ape* (*Lutjanus kasmira*)

- The increase in the frequency of inter-island jet flights in the 1970s, encouraging marketing in Honolulu of fish from other islands, and the increase in air traffic between Hawai'i and both the U.S. mainland and Japan, opening new markets for fresh Hawai'i fish

- Changes in the prevalence of ciguatera

  "Jacks as a group became associated with ciguatera due to a number of poisoning cases associated with kahala (*Seriola dumerili*), a favorite target of bottomfish fishermen until the concerns of ciguatera in the 1980s in Hawai'i. The dangers posed by ciguatera in jacks as a group and the potential legal liability posed by the sale of such fish caused the main fish markets in Hawai'i to refuse to handle such fish from 1990 onwards. Consequently targeting of jacks dropped considerably after this period" (Friedlander and Dalzell 2003:179–180).

  "Spearfishers and shoreline gatherers on Kaua'i share concerns about *ciguatera* with local *kupuna*. All agree that its incidence has increased in recent years . . . The good news is that, while ciguatera inhibits human fish consumption and sales, it is a strong deterrent to overfishing and may be relatively harmless to other predatory species in the coastal zone" (Lowe 2003:46).

- Coastal development in the last half of the twentieth century, resulting in substantial alteration of coastline habitat, upland erosion and consequent sedimentation, land-based pollution, and diverted streams

  Regarding the Main Hawaiian Islands, Lowe (1995a:685) concluded that despite all the detrimental impacts to the marine environment stemming from coastal development and other non-fishing activities, "overfishing still constitutes the driving force in the depletion of inshore fisheries."

  Shomura (1987) identified anthropogenic habitat degradation and pollution as two possible causative factors for the apparently massive decline in Hawai'i's catches of inshore resources from 1900 to 1986. But he also identified shortcomings in the available data, overfishing, and shifts among target species as other possible causes.

- Fish stock enhancement and habitat enhancement activities in the last half of the twentieth century

"… experimental releases [of *moi*, *Polydactylus sexfilis*] have made significant contributions to Oʻahu recreational moi fishery" (Ziemann et al. 2003:203).

"Thousands of [tire-and-concrete fish habitat] modules were added to the existing artificial reef sites, resulting in a dramatic increase in fish communities in these areas" (Ziemann et al. 2003:203).

A.2 American Samoa

- Materials and ideas introduced by the early visitors, starting in 1722

  The high value of metal fishhooks appears to be reflected in the experience of the crew of the Wilkes Expedition, who, upon landing on Taʻu, "were immediately surrounded by Samoans wanting to trade for fishhooks and tobacco" (Holmes 1974:13). Upon trying to leave the island, "The king and several other chiefs climbed into the ship's longboat and refused to leave until they were given gifts of fishhooks" (Holmes 1974:13).

- The activities of missionaries, starting in 1828, resulting in the conversion of most Samoans to Christianity by 1900

  "Beginning with their project of reducing the Samoan language into writing in 1834, the London Missionary Society workers have had a profound impact both religiously and educationally upon Samoan lives" (Holmes 1974:12).

  With respect to impacts on Samoa's social and political systems, however, Holmes argued that "[w]hat was undoubtedly the most devastating influence for change on most Polynesian cultures—the coming of Christianity—had little effect on the social structure of Samoa, since Samoan culture had less invested in religious sanctions" (Holmes 1974:96). Further, "it was possible for the society to accept another religion without affecting the status or authority of the chiefs" (Holmes 1974:95).

- The development of commercial plantations, starting about 1850

- The imposition of the U.S. colonial administration in 1900 and consequent changes to traditional systems of authority

  Many observers have found Samoans to be more conservative than other Polynesian societies with respect to retaining their customs, particularly their customary systems of authority. Based on observations made in 1927, Te Rangi Hiroa concluded that "[e]xcept for the doing away with some of the highest ranks, corresponding to that of petty kings and provocative of war in grasping power, the introduction of a foreign culture has made little fundamental difference to the basis of Samoan society" (Hiroa 1930:5). Further, "[p]ersistence of custom has led to the retention of much native material culture in Samoa" (Hiroa 1930:6).

  Gray (1960) recounted a striking case in 1900 of the U.S. Naval administration depriving a chief of his authority after the chief punished a man for not complying with the customary obligations regarding the distribution of the catch of *atu* (*Katsuwonus pelamis*).

- The introduction of improved fishing gears and methods

  Wass (1980) noted that new fishing technologies and improved gear efficiency had contributed towards the use of more generalized fishing methods. Traditional methods and gears designed to capture specific kinds of fish in particular kinds of locations were no longer being used. Wass also found a decrease in the relative amount of fishing being done by groups versus individuals.

  Scuba gear started being used for inshore commercial fishing in 1995. Until the practice was banned in 2001, it was found to yield twice the catch-per-unit-of-effort as free diving (American Samoa Environmental Protection Agency nd).

- World War II, with Pago Pago a major naval base

- Increased post-World War II interest and intervention by the federal government, starting with the administrative transfer from the Navy to the Department of Interior in 1951, the reorganization of the education system in the 1960s, and the opening of Pago Pago International Airport in 1962

  "This metamorphosis has accelerated over the last three decades, for the increased Western interest in the Pacific which accompanied and followed World War II has prompted a second wave of change comparable in magnitude to that experienced during the early colonization of Pacific islands by nations of the West" (Hill 1978:2).

- Emigration to Hawai'i and the U.S. mainland, with 1,300 people leaving in 1951 after the dismantling of the naval base Pago Pago, and by the end of the twentieth century, about 250,000 Samoans living outside of Samoa

- Severe storms, such as in 1915, 1986, 1990, and 1991

  Hurricane Ofa in 1990 and Val in 1991 destroyed most coral growth down to a depth of 10-15 meters in most places around Tutuila (Maragos et al. 1994).

- Crown-of-thorns outbreaks, such as in 1967-70, 1977-80, and 1982-85

  The crown-of-thorns outbreak of 1978 led to losses of up to 95 percent of the live coral in many areas (Wass 1979).

- Coral bleaching events, such as in 1994 and 1998

  In some locations, the 1994 coral bleaching event affected most of the corals that remained after the damage caused by the previous storms and crown-of-thorns outbreak (Craig 1995b).

- Urbanization and the shift away from a subsistence economy, accompanied by increasing inputs of federal aid, particularly during the last half of the twentieth century

  Wolf Management Services (1969) identified federal aid and remittances from family members living abroad as the primary components of the economy.

  Wass (1980:78): "Canned and frozen fish, poultry and meat are an attractive alternative to self-caught fish because they are convenient to purchase and store, offer a variety of taste, make excellent gifts for weddings, funerals and other cultural functions, and convey a sense of prestige to those that use them" (Wass 1980:78).

Craig et al. (1993) and Saucerman (1995a) reported substantial declines in fishing effort and catch from 1979 to 1994. In addition to identifying habitat degradation and overfishing (as evidenced by a decrease in catch-per-unit-effort) as possible causes of the decline, the former report cited socioeconomic factors as being important, including less available leisure time, a shift in dietary preferences, and an increasing preference to buy fish rather than to catch them. The report also noted increasing imports of fish products from Samoa and Tonga.

- Development of the commercial fishing and fish processing industry, starting with the establishment of the Van Camp Seafood Company cannery in Pago Pago in 1954 and the Star Kist cannery in 1963, the development of the bottomfish fishery in the 1980s, and the rapid development of the locally based longline fleet in the 1990s

- Coastal development during the last quarter of the twentieth century, resulting in substantial alterations to coastline habitat, upland erosion and consequent sedimentation, and land-based pollution

  Saucerman reviewed measures of various attributes of effort and catch from 1991 through 1994—including substantial reductions in effort, catch, and catch-per-unit-effort, as well as findings of underwater coral reef surveys and other anecdotal information, and concluded that "[s]ome of the data indicate that habitat degradation is the cause of the decline in the fishery" (Saucerman 1995a:447).

- Population growth, with the population of Tutuila growing from about 5,000 in 1900 to more than 60,000 in 2000

  Citing a population growth rate of 2.5 percent, Craig et al. (2000b:769) stated that "[p]erhaps the most serious environmental and social problem facing American Samoa is its uncontrolled population growth" (see Craig 1995a; Craig et al. 2000a).

  Given the high rate of human population growth, it is remarkable that fishing effort (and catch) in the shoreline subsistence fishery declined substantially in the last two decades of the twentieth century (Craig et al. 1993; Saucerman 1995a).

B Shellfish Identified in Archaeological Reports from Hawai‘i

Source	Weight (g)
Sullivan et al. (1996:78)	285818
Barrera (1989a:222)	142840
Donham (2000:7.76)	126333
O’Hare and Goodfellow (2003:180)	120900
Hay et al. (1986:4–106, 4–135)	64876
Jensen (1990b:100)	62302
Dunn and Rosendahl (1992:29)	52159
Corbin (2000b:67)	50210
Rosendahl (1973:6tables)	40197
Fredericksen et al. (1998:136)	39590
Hammatt et al. (2000a:21, 22, 24, 25)	34594
Jensen (1990a:60)	30277
Yent and Ota (1983:57, 59, 61)	29342
Yent and Estioko-Griffin (1980:517–519)	17211
Henry et al. (1992:19)	16018
Hammatt et al. (2000b:154)	15767
Cleghorn (1975:29)	13107
Walker and Rosendahl (1988:170–81)	12919
Henry et al. (1997:200–215)	12498
Davis and Spear (2002:Appendix A)	12478
Toenjes (1986:31, 67, 75, 90)	11815
Rosendahl (1972:36, 39, 59, 63, 67, 73, 77)	11395
Jensen (1991a:23)	10637
Jensen (1992:A-50)	10299
Donham (1998:B-3–B-8)	9311
Donham (1987:113, 114)	8001
Hammatt et al. (1992:98, 99)	7003
Corbin (2000a:38)	6736
Hammatt and Meeker (1979:38)	6374
Rechtman (1998:34, 35)	6276
Dunn et al. (1995:A-55, A-59)	6233
Lebo and Clark (1997:146–148)	5978
Pantaleo and Clark (1992:38)	5680
Fredericksen and Fredericksen (1995:41)	5289
Spear (1993:36)	5268
Hammatt et al. (1985a:120)	5103
Walker and Haun (1989:20, 21)	5017
Hartzell (1997a:145–147)	4195
Kennedy et al. (1994:C1)	4177
Dye et al. (2002b:232)	4099
Hammatt et al. (1994a:46–48, B-10)	4096
Roberts and Roberts (2001:Appendix C)	3999
McDermott et al. (1993:234)	3913
Hammatt et al. (1994a:B-10)	3852
O’Hare and Wolforth (1998:Section 2)	3733
Walker et al. (1996:89)	3689
Hammatt and Craddock (1992:136)	3588
Griffin and Lovelace (1977:145)	3536
Elmore et al. (2001:C4)	3489
Rosendahl (1999a:45, 46)	3326
Robins et al. (1998:105)	3311
Carson (1998:A-1)	3300
Komori (1987:48, 62)	3165

* Long table(s) without totals, weights not tallied.

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Source	Weight (g)
Donham (1989:105)	3116
Head et al. (1995:B-21)	3108
Rechtman and Clark (2002:18, 26)	3097
Hammatt and Clark (1980:71–76)	3024
Colin and Hammatt (2003:51–53)	2955
Pantaleo et al. (1992:100–102)	2899
Hommon (1983a:28)	2774
Davis (1991:63)	2772
Cleghorn (1976:54)	2691
Ayres (1970:45)	2612
Clark et al. (1997:389)	2583
Walker and Rosendahl (1992:94)	2542
Fredericksen et al. (1993a:18)	2508
Donham (1990b:35)	2427
Estioko-Griffin and Lovelace (1980:133–137)	2425
Borthwick et al. (1997:87)	2419
Kirch (1973:22)	2394
Buffum and Spear (2002:Appendix B)	2298
Barrera (1989b:5)	2264
Jensen and Donham (1988:73, 77, 88)	2256
Borthwick et al. (1999:71)	2245
Jensen (1994:83)	2213
Walker et al. (1985:118)	2199
Charvet-Pond and Rosendahl (1992:32)	2194
Hammatt and Toenjes (1991:118)	2138
Rosendahl and Haun (1987:54, 56)	2085
Hammatt et al. (1984:78–79)	2020
Jensen and Goodfellow (1993:30)	1996
Burgett et al. (1996:57)	1931
Heidel et al. (1998:40)	1916
Hammatt et al. (1995:233)	1879
Yent et al. (2000:69, 70)	1877
Yent (1991:36)	1874
Major et al. (1995:72)	1861
Lass (1995:21)	1837
Rosendahl (1999b:15pages)	1796
Buffum and Dega (2001:Appendix B)	1756
Rechtman and Wolforth (2000:22, 23)	1701
Landrum et al. (1990:57)	1698
Schilt and Dobyns (1980:90)	1697
O’Hare and Goodfellow (1999:84)	1692
Donham (1992:75)	1668
Hammatt and Shideler (1992:40)	1665
Hammatt et al. (1986b:75)	1632
Schilz and Allen (1996:88)	1624
Goto (1986:323)	1614
Yeomans (2001:Appendix A)	1602
Hammatt et al. (1987a:94)	1558
Goodwin (1994:vol. 2, 226)	1544
Yeomans et al. (2001:Appendix E)	1540
Cleghorn and Cox (1976:31)	1523
Athens and Magnuson (1998:28–30)	1518
Clark (1987:74, 76)	1509
Hammatt (1979c:42)	1441

* Long table(s) without totals, weights not tallied.

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Source	**Weight (g)**
Donham (1986:44, 46)	1426
Denham and Pantaleo (1997b:Appendix A)	1421
Donham (1990d:39)	1402
Rosendahl (2001:16, 20, 22)	1369
Dunn and Spear (1998:C-1)	1312
Carson (1999:Appendix C)	1307
Spear and Sinoto (1993:26)	1252
Walker et al. (1988:105–108)	1183
Head et al. (1994b:46)	1165
Head et al. (1994a:24)	1156
Hammatt et al. (1985b:30)	1101
Graves and Franklin (1998:46)	1083
Welch (1988:B-3)	1054
Wolforth et al. (2000:23, 24, 33, 36)	1045
Williams et al. (2002:Appendix B)	1031
Walker and Haun (1987:37)	994
Hammatt (1979a:70)	965
Berdy et al. (2001:43)	965
Moore et al. (1997a:24)	963
Hammatt (1991b:18)	929
Stride et al. (2003:68)	856
Fredericksen and Fredericksen (2001a:55)	855
Wickler and Tuggle (1997:150)	841
Denham and Kennedy (1993:22)	799
Masterson et al. (1997:Appendix IIIB)	784
Durst et al. (2001:94)	784
Davis (1984:81)	775
Rosendahl et al. (1983:17, 18, 20)	742
Perzinski et al. (2000a:108)	740
Hommon (1979:16)	717
Tomonari-Tuggle (1994:50)	705
Fredericksen and Fredericksen (2002a:61)	699
Elmore and Kennedy (2002:Appendix C)	688
Graves and Goodfellow (1993:59)	684
Elmore et al. (1999:B-8–B-10)	680
Jensen (2000:12)	660
Rosendahl and Delimont (1988:3)	658
Haun and Henry (2001:11)	656
Barr et al. (1994:240)	648
Carlson and Rosendahl (1990a:13)	642
Jensen (1991b:26)	637
Hammatt et al. (1985c:60)	613
Fredericksen and Fredericksen (1996:18)	586
Chaffee and Spear (1994:61)	585
Connolly III (1980:57)	584
Kirch (1979:43)	578
Rolett (1992:7)	578
Latinis et al. (1997b:35)	577
Hammatt et al. (1987b:58)	576
Dunn and Rosendahl (1989:26)	571
Lee-Grieg (2002:3–25)	570
Dicks and Haun (1987:32)	570
Barrera (1995b:32)	562
Fredericksen and Fredericksen (2000a:68)	547

* Long table(s) without totals, weights not tallied.

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Source	Weight (g)
Dye (1977b:24, 25)	520
Rechtman (2000b:11–32)	496
Beardsley and Kaschko (1998:43, 44)	484
Colin et al. (1995:28, 29)	484
Head and Rosendahl (1995:41)	469
Dixon et al. (2000:216)	466
McDermott and Hammatt (2000:Appendix A)	458
Spear (1992a:18)	454
Hommon (1983b:107)	445
Athens (1991:102)	438
Donham and Kai (1990:15)	431
Hammatt et al. (1986c:64)	429
Denham et al. (1992d:19)	429
Cox (1976:68)	421
Spear and Rosendahl (1987:51)	418
McDermott et al. (2000:Appendix B)	412
Bushnell et al. (2003:Appendix C)	383
Haun et al. (2002:16, 17)	383
McDermott et al. (2001a:Appendix A)	382
Elmore and Kennedy (2000c:40)	369
Jones (2001:154)	360
Rechtman (2000a:21)	358
Dunn and Rosendahl (1991:28)	352
Creed et al. (1995:46)	349
Head et al. (1996:52)	348
Colin et al. (1996:126, 127)	344
Athens (1983:39)	342
Donham and Walker (1990:28)	332
Walker et al. (1991:26)	325
Kaschko (1991:37, 45)	324
Spear (1996:41, 55, 99)	314
Robins et al. (2000:116)	311
Fredericksen and Fredericksen (2000b:82)	302
Carlson and Rosendahl (1990c:27)	300
Hammatt et al. (1986a:66)	291
Allen-Wheeler (1981:67)	281
Kolb et al. (1997:207)	276
Wulzen and Wolforth (1997:19)	275
Clark and Rechtman (2002:22, 27)	274
Kennedy et al. (1992b:23)	262
Anderson and Schilz (1998:61)	258
Hurst and Allen (1992:124–127)	256
Colin and Hammatt (1997:10)	253
Spear (1987:24)	250
Corbin and Gothar (2000:27–28)	246
Crozier (1971:5)	245
Rechtman and Henry (1999:16)	244
Moore and Kennedy (1994b:A4)	244
McDermott and Hammatt (1997:25–27)	237
Fredericksen et al. (1993b:12)	230
Clark and Rechtman (2001:14)	230
Corbin (2001:37)	220
Davis (1989:72)	217
Hammatt and Shideler (1984:33)	217

* Long table(s) without totals, weights not tallied.

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Source	Weight (g)
Elmore and Kennedy (2000d:D-1–D-3)	213
Rosendahl (2000:35, 38, 40, 42)	210
McNeill (1988:42)	204
Haun and Henry (2000:30, 38)	203
Elmore and Kennedy (2001a:18)	202
Elmore and Kennedy (2000b:37)	201
Head et al. (2003:32)	200
Perzinski et al. (2002:225)	189
Fredericksen and Fredericksen (2000c:15)	188
Barrera (1995a:12)	186
Miller (1993:113–137)	185
Dang et al. (1993:17)	183
Winieski et al. (2002:200)	175
Denham et al. (1992b:26)	174
Fredericksen and Fredericksen (1997:46)	168
Hammatt and Shideler (1989:31)	165
Moore and Kennedy (2002:A6)	164
Denham et al. (1992c:53)	158
Hammatt (1979b:46)	153
Elmore et al. (2002:C1)	150
Lebo and McGuirt (2000a:98, 99)	149
O’Hare and Goodfellow (1994:73)	143
Latinis et al. (1997a:67)	142
Hammatt et al. (1996:33, 34)	139
Graves et al. (1998:33)	136
Perzinski et al. (2001:37)	132
Athens (1988:61)	131
Shun and Streck (1982:11)	129
Dye (1977a:6)	119
Wulzen and Goodfellow (1995:38)	118
Carson and Spear (1999:A-1)	115
Welch (1989:17)	113
Zulick et al. (2000:171)	104
Flood et al. (1994:138–145)	101
O’Hare and Rosendahl (1993:46)	98
Fager and Graves (1993:27)	98
Sinoto and Titchenal (2002:60)	96
McDermott et al. (2001b:60)	94
Borthwick and Hammatt (1994:34)	91
Hammatt and Folk (1980:92)	91
Hammatt and Borthwick (1986:63)	86
Borthwick et al. (1994a:44)	81
Crozier and Barrera (1974:37)	81
Rechtman et al. (2002a:21, 30)	80
Borthwick and Hammatt (2001:68)	80
Walker and Rosendahl (1998:24)	79
Folk et al. (1998:51)	77
Shun (1992:53)	75
McIntosh and Cleghorn (2000:60)	75
Spear (1992b:18)	73
Carter (1989:10–14)	70
Hammatt et al. (1994c:143–149)	69
Elmore and Kennedy (1999:20)	68
Fredericksen and Fredericksen (2002b:88)	62

* Long table(s) without totals, weights not tallied.

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Source	Weight (g)
Bonk (1988:13)	61
Erkelens (1996:93)	59
Spear and Burgett (1999:Appendix D)	57
Hammatt (1991a:56, 58)	56
Fredericksen and Fredericksen (2000d:44)	49
Dunn and Rosendahl (1993:14)	44
Dunn et al. (1999:A5)	44
Major and Klieger (1996:76)	44
Hammatt et al. (1993:36)	42
Perzinski et al. (2000b:29)	39
Tome et al. (2002:A-5)	37
Walker and Goodfellow (1991:13)	33
Dye et al. (2002c:105)	32
Firor and Rosendahl (1994:43)	31
Elmore and Kennedy (2000a:22)	30
McGerty et al. (1997:62)	27
Borthwick et al. (1994b:68)	23
Weisler (1989:45–46)	23
Henry and Graves (1993:21)	23
Rosendahl (1983:21)	23
Rechtman and Dougherty (2002:13)	19
Moore and Kennedy (1995:A4)	14
Dockall (2003:41)	13
Donham (1990a:17)	13
Moore and Kennedy (2003:A-2)	12
Haun (1986:85)	11
Yeomans and Fager (2000:42)	10
Devereux et al. (1998:57)	10
Kennedy and Denham (1992b:20)	8
Nees et al. (1998:27–28)	7
Eblé et al. (1995:10–13)	7
Moore and Kennedy (1994a:23)	7
Firor and Rosendahl (1991:25)	6
Watanabe (1986:n.p.)	5
Elmore and Kennedy (2000e:Appendix C)	2
Elmore (2000:36)	1
Jensen (1990c:24)	*
Barrera and Hommon (1972:36–52)	*
Clark and Riford (1986:91–94)	*
Denham and Pantaleo (1997a:Appendix B)	*
Hammatt and Folk II (1981:179)	*
Kennedy et al. (1992c:42–44)	*
Kennedy and Denham (1992a:31–33)	*
Kennedy and Denham (1992c:23)	*
Landrum (1993:48–51)	*
Moore et al. (1993:80)	*
Putzi et al. (1998:105, 106)	*
Rechtman et al. (2002b:229, 249, 308, 315, 329)	*
Sinoto (1976:Appendix I)	*
Tuggle (1994:54)	*
Tuggle (1995:139–146)	*
Kennedy et al. (1992a:156–162)	*

* Long table(s) without totals, weights not tallied.

C Shellfish Listed but Unidentified in Archaeological Reports from Hawai‘i

Source	Weight (g)
Rosendahl et al. (1987:V-38)	33049
Ladefoged (1990:165)	18431
Jones et al. (1994:98)	17746
Tuggle (1993:210)	17624
Hammatt et al. (1998:112)	14776
Hammatt et al. (1994b:160)	7215
Hammatt (1989:22)	6149
McGerty and Spear (1996:82)	3943
Riford (1984:16)	3489
Cordero and Dega (2001:D-1-3)	3337
Hammatt et al. (1988:72)	2632
Bush et al. (2001:125)	1804
Fredericksen et al. (1994:30)	1752
Toenjes et al. (1992:118)	1604
Wolforth and Wulzen (1998:2–23)	1330
Athens and Silva (1983:102)	1174
Haun (1978:69)	907
Ziegler (1990:104)	653
Hammatt et al. (1978:93)	580
Cordy (1978:82)	407
McIntosh and Pantaleo (1998:94)	404
Burgett and Spear (1996a:21)	389
Fredericksen and Fredericksen (1992:18)	271
Burgett and Spear (1996b:25)	201
Colin et al. (1998:58)	162
Denham et al. (1992a:23)	160
Cordy and Athens (1985:45)	70
Hammatt and Ida (1992:32)	61
Borthwick et al. (1992:120)	58
Folk et al. (1994:55)	50
Dunn and Spear (1995:32)	30
Barrera (1998:9)	18
Fredericksen and Fredericksen (2001b:57)	15
Devereux et al. (1998:57)	10
Elmore and Kennedy (2001b:27)	6
Donham (1990c:14)	4
Robins et al. (1994:151)	2
Williams (1989:33)	0

D Identified Fish Reported as NISP in Archaeological Reports from Hawai‘i

Source	NISP	Comment
Dye et al. (2002b:378)	32052	
Wickler and Tuggle (1997:143)	26860	
Ziegler (2000:5.17–5.30)	23963	Good comparative collection
Davis and Spear (2002:Appendix A3)	7404	
Henry et al. (1997:221–224)	5313	
Goodwin et al. (1996:103)	4261	
Hartzell (1997b:134, 135)	3543	
Goto (1986:329–334, 345–349, 399–408)	3516	Only identified fragments counted
Rechtman (1998:35, 36)	1981	
Rechtman and Wolforth (2000:25)	1687	
Davis (1991:60, 61)	1108	
Hay et al. (1986:7C-3, 4)	993	Only identified fragments counted
Kennedy and Denham (1992a:35–42)	661	
Rosendahl (1999a:49, 50)	621	
Hartzell (1997a:142)	316	
Putzi et al. (1998:108)	315	
Rolett (1992:6)	282	
Tuggle (1995:154–159)	173	
Rosendahl and Carter (1988:76)	158	
Durst et al. (2001:100)	119	
Shun (1992:54, 55)	74	
Haun et al. (2002:20)	33	
McDermott et al. (2001b:61)	25	
Rechtman and Clark (2002:27)	16	
Dye et al. (2002c:106)	4	
Tuggle (1994:53)	0	Long tables with no totals

E Identified Fish Reported as Weights in Archaeological Reports from Hawai‘i

Source	Weight (g)
Goodwin (1994:vol. II, 284)	14372
Elmore and Kennedy (2000d:E-1)	11525
O’Hare and Goodfellow (2003:197)	6250
Burgett et al. (1996:57)	1656
Hammatt et al. (2000b:155)	1457
Barrera (1989a:223)	678
Jensen and Goodfellow (1993:33)	647
Goodwin et al. (1996:104)	620
Henry et al. (1992:19)	542
Jones (2001:159)	487
Graves and Goodfellow (1993:63)	312
Moore et al. (1997a:20)	311
Hammatt et al. (2000a:21,22,24,25)	273
McDermott et al. (2000:Appendix B)	235
Elmore and Kennedy (2000e:Appendix D)	208
Elmore et al. (2001:D3)	128
Kennedy et al. (1994:C2–C5)	122
Walker et al. (1996:90)	110
Clark (1987:75, 77)	91
Moore et al. (1997b:53)	90
Williams et al. (2002:B)	90
Hammatt et al. (1987a:94)	82
Jensen and Donham (1988:73, 79, 88)	79
Elmore et al. (1999:B-7)	68
Flood et al. (1994:138–145)	63
McGerty et al. (1997:62)	62
Rosendahl et al. (1983:17, 18, 20)	60
Kirch (1973:23)	49
Yeomans et al. (2001:Appendix F)	46
Dunn et al. (1995:A-55)	45
Head et al. (1995:B-18)	42
Jensen (1994:83)	40
Denham and Kennedy (1993:23–38)	36
Robins et al. (1998:105)	33
Clark et al. (1997:400)	33
Kolb et al. (1997:225)	32
Spear and Sinoto (1993:26)	25
Buffum and Spear (2002:Appendix C)	25
Hammatt et al. (1994c:143–149)	24
McDermott et al. (2001a:Appendix A)	23
Folk and Hammatt (1991:61)	23
Landrum (1993:48–51)	22
Buffum and Dega (2001:Appendix C)	20
Robins et al. (2000:117)	18
Elmore and Kennedy (2002:Appendix B)	17
Chaffee and Spear (1994:61)	16
Rosendahl and Delimont (1988:4)	16
Hammatt et al. (1995:233)	14
McDermott et al. (1993:234)	14
McNeill (1988:44)	11
Fager and Graves (1993:27)	9

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Source	**Weight (g)**
Carson (1999:Appendix D)	9
Miller (1993:113–137)	8
Dunn and Spear (1998:D-1)	7
Athens (1983:40)	7
Head et al. (1994a:24)	7
O’Hare and Goodfellow (1994:73)	6
Hammatt et al. (1987b:58)	4
Berdy et al. (2001:41)	4
Head et al. (1996:52)	3
Head et al. (1994b:46)	3
Kennedy and Denham (1992c:16)	3
Winieski et al. (2002:200)	3
Elmore and Kennedy (2001c:A-7)	2
Dye and Murakami (1998:43)	2
Elmore and Kennedy (2000b:39)	2
Moore et al. (1993:79)	2
Hommon (1979:17)	1
Head and Rosendahl (1996:34)	1
Borthwick and Hammatt (2001:68)	1
Sinoto and Titchenal (2002:61)	1
Head and Rosendahl (1995:41)	*
Wulzen and Wolforth (1997:20)	*
Moore and Kennedy (2003:A-2)	*
Eblé et al. (1995:10–13)	*
Clark and Riford (1986:88–94)	*
Denham and Pantaleo (1997a:Appendix B)	*
Estioko-Griffin and Lovelace (1980:133–137)	*

* Long table(s) without totals, weights not tallied.

F Unidentified Fish Reported as Weights in Archaeological Reports from Hawai‘i

Source	Weight (g)
Rosendahl et al. (1987:V-38)	6132
Hammatt (1979b:46)	1458
Yent and Ota (1983:57, 59, 61)	1436
Hammatt and Folk II (1981:179)	1029
Corbin (2000b:67)	623
Hammatt et al. (1994a:46–48)	516
Rosendahl (1973)	508
Athens (1991:67)	475
Walker and Rosendahl (1992:97)	447
Tuggle (1993:210)	424
Hammatt and Craddock (1992:136)	407
Hammatt and Toenjes (1991:118)	348
Yent (1991:36)	332
Riford (1984:16)	292
Hammatt (1989:22, 28)	269
Sinoto (1978:51, 52)	228
Walker and Rosendahl (1988:170–181)	221
Hammatt and Meeker (1979:38)	219
Hammatt and Shideler (1992:40)	217
Hammatt et al. (1992:98–99)	214
Spear (1993:36)	196
Yent and Estioko-Griffin (1980:517–519)	157
Hammatt et al. (1985a:120)	128
Hammatt et al. (1994b:160)	126
O’Hare and Wolforth (1998:Section 2)	122
Ladefoged (1990:161)	107
Fredericksen et al. (1998:136)	93
Beardsley and Kaschko (1998:45, 46)	81
Colin et al. (1998:58)	76
Bush et al. (2001:125)	73
Wolforth and Wulzen (1998:2–23)	72
Hommon (1983b:107)	56
Komori (1987:48, 62)	50
Kirch (1979:43)	39
Walker et al. (1985:119)	39
Hammatt (1979c:42)	33
Walker et al. (1988:105–108)	32
Major et al. (1995:72)	30
Hammatt et al. (1984:98–99)	29
Haun (1978:69)	27
Fredericksen and Fredericksen (1995:41)	26
Fredericksen and Fredericksen (2001a:55)	25
Hammatt et al. (1978:93)	22
Hammatt (1991a:56, 58)	21
Barr et al. (1994:240)	20
Hammatt and Shideler (1984:33)	19
Davis (1984:81)	17
Athens and Silva (1983:106)	17
Ayres (1970:45)	16
Toenjes et al. (1992:118)	16

* Long table(s) without totals, weights not tallied.

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Source	Weight (g)
Masterson et al. (1997:Appendix IIIB)	16
Perzinski et al. (2001:37)	15
Colin and Hammatt (2003:51–53)	15
Pantaleo et al. (1992:100–102)	14
Fredericksen et al. (1993a:18)	13
Anderson and Schilz (1998:63)	9
Firor and Rosendahl (1994:43)	9
Connolly III (1980:57)	7
McDermott and Hammatt (2000:Appendix A)	6
Ziegler (1990:104)	6
Cleghorn and Cox (1976:31)	6
Fredericksen and Fredericksen (2000c:15)	6
Graves et al. (1998:33)	6
Fredericksen and Fredericksen (2002b:88)	6
Cordy and Athens (1985:45)	5
Hurst and Allen (1992)	5
Fredericksen and Fredericksen (2000b:82)	4
Hammatt et al. (1996:33, 34)	4
Hammatt and Shideler (1989:31)	4
Fredericksen and Fredericksen (1992:19)	4
Spear (1996:41, 55, 99)	3
Fredericksen and Fredericksen (2001b:57)	3
Hammatt et al. (1985c:60)	3
Hammatt et al. (1986b:75)	3
McIntosh and Cleghorn (2000:60)	2
Cox (1976:69)	2
Schilz and Allen (1996:88)	2
Colin and Hammatt (1997:10)	2
Watanabe (1986:n.p.)	2
Hammatt et al. (1986c:64)	2
Dye (1977b:25)	2
Carlson and Rosendahl (1990c:27)	2
Colin et al. (1996:126)	2
Latinis et al. (1997a:65)	2
Perzinski et al. (2002:225)	2
Fredericksen et al. (1993b:12)	2
Davis (1989:72)	2
McIntosh and Pantaleo (1998:94)	2
Donham (1990d:39)	1
Elmore and Kennedy (1999:19)	1
Moore and Kennedy (1994b:A3)	1
Rechtman et al. (2002a:21, 30)	1
Hammatt and Ida (1992:32)	1
Fredericksen and Fredericksen (2000d:44)	1
Hammatt et al. (1993:36)	1
Elmore and Kennedy (2001a:19)	1
Spear and Burgett (1999:Appendix B)	1
Weisler (1989:46)	1
McDermott and Hammatt (1997:25–27)	1
Denham et al. (1992a:25)	1
Borthwick et al. (1994a:44)	*
Haun and Henry (2000:30, 38)	*
Barrera (1995a:12)	*
Carlson and Rosendahl (1990a:13)	*

* Long table(s) without totals, weights not tallied.

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Source	**Weight (g)**
Rechtman (2000b:21)	*
Fredericksen and Fredericksen (1996:18)	*
O'Hare and Rosendahl (1993:46)	*
Kaschko (1991:45)	*
Walker and Goodfellow (1991:13)	*
Dunn and Rosendahl (1993:14)	*
Zulick et al. (2000:171)	*
Perzinski et al. (2000b:29)	*
Athens (1988)	*
Rechtman et al. (2002b:229, 249, 308, 315, 329)	*
Sinoto (1976:Appendix I)	*

* Long table(s) without totals, weights not tallied.

G Unidentified Fish Reported as NISP in Archaeological Reports from Hawai‘i

Source	NISP	Comment
Tomonari-Tuggle et al. (2000:74)	8000	
Hammatt et al. (1994a:B-10)	4876	
Davis (1995:483)	3093	Fish identifications in Barnett ms. at BPBM
Lebo and McGuirt (2000b:83, 93, 125, 147)	1983	
Kikuchi (1963:25a, b)	93	
Dye et al. (2002a:43, 50)	70	
Perzinski et al. (2000a:109)	24	
Major and Klieger (1996:76)	8	
Barrera (1993:6)	7	
Hammatt et al. (1985d:98)	5	
Tomonari-Tuggle and Tuggle (1984:I-9a)	3	
Carlson and Rosendahl (1990b:13)	1	

H Turtle Listed and Reported as Weights in Archaeological Reports from Hawai‘i

Source	Weight (g)
Denham and Kennedy (1993:23–38)	78
Kennedy et al. (1994:C2–C5)	53
Goto (1986:419)	43
Folk and Hammatt (1991:61)	23
Goodwin et al. (1996:104)	16
Hammatt (1979a:70)	15
Fredericksen and Fredericksen (1995:41)	13
Elmore and Kennedy (2001c:A-7)	10
Clark (1987:77)	6
Elmore and Kennedy (2002:Appendix B)	6
Walker et al. (1996:90)	2
Hammatt et al. (2000b:155)	1
Henry et al. (1992:19)	1
McDermott et al. (1993:234)	1

I Turtle Listed and Reported as NISP in Archaeological Reports from Hawai‘i

Source	**NISP**
Ziegler (2000:5.17–5.30)	212
Hartzell (1997b:135)	154
Rosendahl and Carter (1988:76)	92
Goodwin et al. (1996:103)	37
Ziegler (1990:7)	19
Rosendahl (1999a:49, 50)	11
Putzi et al. (1998:108)	5
Lebo and McGuirt (2000b:93)	4
Kirch (1979:46)	2

J Shellfish Identified in Archaeological Reports from American Samoa

Source	**Weight (g)**
Nagaoka (1993:190)	168658
Cleghorn et al. (2000:37)	18784
Eisler (1995:80)	5488
Herdrich et al. (1996:65)	2514
Moore and Kennedy (1996a:47)	81
McGerty et al. (2002:31)	48
Moore and Kennedy (1996b:64)	41
Moore and Kennedy (1999:68)	39
Shapiro and Cleghorn (1999:62)	22

K Summary of Historical Sources for Hawai‘i

Source	1[*]	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Cook (1974)	x[†]			Kaua‘i, Hawai‘i																			
Campbell (1816)	x						x			q[‡]													
Ellis (1836)	x						x			q													
Reynolds (1835)	x																				x		
Wilkes (1845)	x						x					x			x	x	x				x		
Kamakau (1976)	x						x									x							
Dana (1890)	x																x						
Beckley (1883)	x			MHI			x	x						x	x								
Corney (1896)	x						x			q													
Malo (1951)	x						x	x					x			x						x	
Deering (1899)	x						x			q													
Cobb (1902)	x				q		x	x	q	q				x	q	x	x	x	x		x	x	
Jordan and Evermann (1902)	x	x					x	x							x	x				x	x		
Kahaulelio (1902)	x			MHI (Maui)			x	x		x					x	x							
Cobb (1903)	x	x		MHI	q		x	x	q					x	q	x		x	x	x	x		
Board of Commissioners of Agriculture and Forestry, biennial reports, 1905–1958		x	x		q			q	q						q	x				q	x		
Cobb (1905b)		x			q			x	q					x	q	x				x	q		
Cobb (1905a)	x	x		MHI	q		x	x	q					x	q	x		x	x	q	q		
Bryan (1915)	x	x					x	x		x					x	x	x			x		x	x
Stokes (1921)		x					x	x															
Massee (1926)	x	x														x							
Jordan et al. (1927)		x									x												
Nippu Jijisha, -1941		x							q														
Hamamoto (1928)		x			q		x	q	q					x	q	x	x			x	x	x	

[*] See page 26 for column descriptions

continued on next page

[†] x = information present. [‡] q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Galtsoff (1933)		x		NWHI (Pearl and Hermes Reef)			q	q	q	q	q					x	x			q	q		
Bell and Higgins (1939)		x		MHI	q		x	x	q			q		x	q	x			x	x	x		
Division of Fish and Game, 1948–1959		x	x					q	q						q					q			
Scobie (1949)	x	x					x	x		q		x	x	x	q	x	x		x	x	x	x	x
Board of Agriculture and Forestry, 1950			x					q	q						q								
Titcomb (1972)	x	x					x	x		x	x		x		x	x	x			x			x
Yamaguchi (1953)											q												
Board of Agriculture and Forestry, 1954			x					q	q						q								
Brock (1954)			x								q												
Kosaki (1954)	x	x	x													x							
Buck (1957)	x	x					x	x							x	x							x
Summers (1964)	x	x	x	O‘ahu, Moloka‘i											q								
Brock (1965)			x													x					x	x	
Banner (1968)			x	MHI (O‘ahu, Kane‘ohe Bay)													x	x					
Newman (1970)	x			MHI (Hawai‘i, North Kohala)			x	x									x	x	x				x
Branham et al. (1971)			x														x	x					
Summers (1971)	x						x									x	x					x	
Hoffman and Yamauchi (1972)			x	MHI	q	q						q		x		x				x			
Gast (1973)	x			O‘ahu														x					
Devaney et al. (1976)	x	x		O‘ahu (Kane‘ohe)											x	x							
Hill (1976)	x	x	x																				x

*See page 26 for column descriptions

† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kazama (1977)																							
Titcomb (1978)	x	x	x				x	x					x			x				x			
Grigg and Dollar (1980)			x														x						x
Hirota et al. (1980)			x														x						
Hobson (1980)			x								x						x	x	x				
Hudgins (1980)			x										q										
Ito and Uchida (1980)			x	NWHI													x						
Okamoto and Kawamoto (1980)			x	NWHI							q						x						
Division of Aquatic Resources, 1981						q			q							x							
Oda and Parrish (1981)			x														x						
Cooper and Pooley (1982)			x						q				q										
Grigg (1983)	x	x	x														x						
Abbott (1984)			x														x						
Hobson (1984)			x														x						
Skillman and Louie (1984)			x		q																		
Kirch (1985)	x														q		x						x
Maragos et al. (1985)			x	MHI (O‘ahu, Kane‘ohe Bay)													x	x					
MacDonald (1987)				NWHI (Midway)																			
Nakayama (1987)	x	x	x																				x
Randall (1987)			x														x						
Shomura (1987)		x	x		q		x		q			q	x	x	q	x		x	x	q		x	x
Culliney (1988)	x	x	x	MHI (Kane‘ohe), NWHI			x	x			x	x		x	x	x		x	x			x	x
Harman and Katekaru (1988)			x		q	q	q				x					x							

*See page 26 for column descriptions
† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Oceanic Institute (1988)			x										q										
Iversen et al. (1990a)	x	x	x	NWHI			x	x								x							x
Iversen et al. (1990b)	x	x	x				x	x					x			x							x
Omnitrack (1991)			x	MHI		q	q	q	q	q													
Des Rochers (1992)			x															x					
Hamm and Lum (1992)			x	MHI (O‘ahu)		q	q	q	q	q											x		
Smith and Pai (1992)	x	x	x													x							
Brock and Kam (1993)			x																x				
Jokiel et al. (1993)			x	MHI (O‘ahu, Kane‘ohe Bay)													x	x					
Polovina (1993)			x	NWHI		q	x	q	q	q										x			
Pooley (1993b)		x	x		q	q			q											x		x	x
Pooley (1993a)			x		q				q				x			x				x	x	x	x
Smith (1993)			x	MHI	q	q	x	q	q	q						x	x	x	x	q	x	x	x
DeMartini et al. (1994)			x	NWHI (Mid-way)							q												
Eldredge (1994)			x															x					
Everson (1994)			x	O‘ahu (Kāne‘ohe Bay)		q	q	q	q	q							x						
Grigg (1994)			x								q						x	x	x				
Kahiapo and Smith (1994)			x	Hawaii (Hilo Bay)		q	q	q	q	q													
Eldredge and Miller (1995)			x														x						
Friedlander et al. (1995)			x	MHI (Kaua‘i, Hanalei Bay)		q	x	q	q	q													
Grigg (1995)	x	x	x														x	x					
Hui Malama o Mo‘omomi (1995)	x	x	x													x							
Hunter and Evans (1995)	x	x	x														x	x	x				

*See page 26 for column descriptions

† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Hunter et al. (1995)			x														x	x					
Hunter (1995)			x													x	x						
Lowe (1995a)			x	MHI												x		x	x				x
Lowe (1995b)			x	MHI																			x
Lowe et al. (1995)			x	Hawaii (Hilo Bay)		q	q	q	q	q													
Randall (1995)			x														x						x
Bartram (1996)			x													x							
Dalzell et al. (1996)			x				x				q											x	x
DeMartini et al. (1996)			x	NWHI (French Frigate Shoals, Midway)							q												
Friedlander (1996)			x		q		x	q	q		q					x	x	x	x	x			x
Hawaii Division of Aquatic Resources and American Fisheries Society, Hawaii Chapter (1996)			x	MHI													x	x					x
Adams et al. (1997)			x						q														
Division of Aquatic Resources, Commercial Marine Landings Summary Trend Report, 1997–			x					q	q						q					q			
Friedlander and Parrish (1997b)			x								q						x						
Friedlander and Parrish (1997a)			x								q						x						
Friedlander et al. (1997)			x	Kaua‘i (Hanalei Bay)							q						x						

* See page 26 for column descriptions

continued on next page

† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Green (1997)			x		q		q	q	q		q					x	x	x	x	x			x
Grigg (1997)			x														x	x	x				
Gulko (1998)			x														x	x	x				
Juvik and Juvik (1998)	x	x	x									q					x	x				x	x
Kame‘eleihiwa (1998)	x															x							
Langlas (1998)	x	x	x													x	x	x					
MacDonald (1998)	x																				x	x	
Merlin (1998)	x																x	x					
Clark and Gulko (1999)			x														x	x	x				
Coles (1999)			x														x	x					
Glazier (1999)		x	x																				x
Maragos and Grober-Dunsmore (1999)			x								q						x	x	x				
Maragos (2000)			x									q			x	x	x	x	x				x
Tissot et al. (2000)			x													x			x				
Weng and Sibert (2000)			x	MHI		q	x	q	q	q	q					x	x						x
Woo (2000)			x														x	x					
Coyne et al. (2001)			x	MHI													x						
Schug (2001)	x	x										q		x						x	x	x	x
Staples and Cowie (2001)			x														x						
Western Pacific Regional Fishery Management Council (2001)	x	x	x		q		x	x	q			q	q			x	x			x		x	x
DeMartini et al. (2002)			x	NWHI (French Frigate Shoals, Midway)							q								x				
Friedlander and DeMartini (2002)			x								q								x				
Friedlander et al. (2002a)			x														x						

*See page 26 for column descriptions

† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Friedlander et al. (2002b)	x	x	x	MHI (Moloka‘i, Ho‘olehu Hawaiian Homesteads)			x				q	q				x	x					x	
Gulko et al. (2002)			x	MHI, NWHI	q						q	q				x	x	x	x				x
Maragos and Gulko (2002)			x	NWHI							q						x						
Western Pacific Regional Fishery Management Council (2002)			x		q	q	q	q	q	q										q			
DeMello (2003)			x		q		q	q	q	q										q			
Department of Business, Economic Development & Tourism, 1967-			x		q				q		q	q											
Division of Aquatic Resources, Commercial fisheries reporting system, 1948–		x	x		q	q	q	q	q	q										q	q	q	
Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii (nd)			x		q	q	q	q	q	q													
Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii, 2003b			x		q	q	q	q	q	q													
Everson and Friedlander (2003)			x	O‘ahu (Kane‘ohe Bay), Kaua‘i (Hanalei Bay)		q	q	q	q	q	x					x							x

*See page 26 for column descriptions

continued on next page

† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fisheries Monitoring Economics Program, Pacific Islands Fisheries Science Center (nd)		x	x		q	q	q	q	q	q	q					x	x	x	x				x
Friedlander and Brown (2003)			x	MHI, NWHI							q	q				x			x				
Friedlander and Dalzell (2003)		x	x	MHI, NWHI		q	x	q	q	q	q	q							x				
Friedlander and Ziemann (2003)			x								q				q	x				x			
Hawaii Fishing News, 1977-			x					x	q							x	x						
Honolulu Laboratory, Fishery statistics of the Western Pacific, 1986–			x					q	q											q			
Lowe (2003)	x	x	x	MHI	q		x	x		x	x	q	x	x	x	x	x	x	x	x	x	x	x
Miyasaka and Ikehara (2003)			x			q	q	q	q	q						x				q			
Poepoe et al. (2003)	x	x	x	MHI (Moloka‘i, Ho‘olehua Hawaiian Homesteads)			x				q	q				x	x						
Shomura (2003)		x	x					x	x			q				x	x			q		x	
U. S. Census Bureau (2003)			x									q											
U.S. Department of Agriculture, National Agricultural Statistics Service, 2003			x												q								
U.S. Fish and Wildlife Service, unpublished data, 1996–			x	NWHI (Mid-way)		q	q	q	q	q													

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*See page 26 for column descriptions

† x = information present. ‡ q = some quantitative information present.

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Source	**1***	**2**	**3**	**Area**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Walsh et al. (2003)			x	MHI	q			q	q	q							x			q	x		x
WPacFIN, Honolulu Laboratory, National Marine Fisheries Service, 2003		x	x					q	q											q			
Ziemann et al. (2003)			x	MHI				x		q					x		x						x

* See page 26 for column descriptions
† x = information present. ‡ q = some quantitative information present.

L Summary of Historical Sources for American Samoa

Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
de Bougainville (1772)	x[†]						x																
La Pérouse (1799)	x						x																
Williams (1840)	x						x	x															
Wilkes (1845)	x						x					x					x						
Hombron and Jacquinot (1853)	x							x															
Dana (1890)	x																x						
Turner (1989)	x						x									x						x	
Stair (1897)	x							x	x														
Stair (1983)	x						x	x								x	x						
Krämer (1995)	x						x	x								x	x						x
von Bulow (1902)	x															x							
Demandt (1913)		x					x																
Mayor (1924)		x															x						
Jordan et al. (1927)		x						x															
Hiroa (1930)	x	x					x	x				q[‡]			x	x							x
Copp (1984)	x	x					x									x							
Schultz (1994)	x	x	x				x									x							
Auapa‘au (1956)	x	x					x																
Van Pel (1956)			x				x				x		q	x									
Gray (1960)			x													x							
Larkin (1960)	x	x	x				x									x							
Kennedy (1962)			x				x																
Lewthwaite (1962)	x	x		Western Samoa								q										x	
Wolf Management Services (1969)			x							q		q				x						x	x
Dahl (1970)			x	Tutuila								q					x	x	x				
Lockwood (1970)			x	Western Samoa		x	x	x															

*See page 26 for column descriptions

[†] x = information present. [‡] q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lockwood (1971)			x	Western Samoa		x	x	x														x	
Holmes (1974)			x	Manu‘a (Fitiuta)		x	x	x								x						x	x
American Samoa Office of Marine Resources (1976)			x	Tutuila	q	q			q	q										q	q	x	
Hill (1976)	x	x	x																				x
Stuebel (1976)	x	x	x													x							
Dahl and Lamberts (1977)		x	x	Tutuila (Pago Pago Harbor)													x	x					
Dawson (1977)			x														x						
American Samoa Government, 1978-			x		q															q	q		
Hill (1978)			x	Tutuila		q	q	x	q	q	x		q	x		x	x	x	x		q	x	x
Birkeland and Randall (1979)			x														x	x					
Wass (1979)			x	Tutuila													x	x					
Aquatic Farms, Inc. and AECOS, Inc. (1980a)			x														x						
Aquatic Farms, Inc. and AECOS, Inc. (1980b)			x														x						
Tuiteleleapaga (1980)	x	x	x													x							
Wass (1980)			x	Tutuila		q	q	q	q	q			q			x	x	x		q	q	x	
Wass (1982)			x								x						x						
Caspers (1984)			x				x	x	x		x												
Holmes (1984)	x	x	x																				x
Moyle (1984)	x						x	x															x
Aitaoto (1985)			x					q	q														
Itano and Buckley (1986)			x								x						x						
Gillett and Sua (1987)	x	x	x	Western Samoa																			x

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* See page 26 for column descriptions
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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Meleisea (1987)	x	x	x													x							x
Meyer Resources, Inc. (1987)			x													x							
Ralston and Williams (1988)			x								q												
Severance and Franco (1989)	x	x	x				x	x			x		x	x		x				x	x	x	x
Gillett and Ianelli (1991)			x				x	q		q	q												
Itano (1991)																						x	
Holmes (1992)			x				x									x							
Ponwith (1992)			x	Tutuila		q	x	x	q	q													
Craig et al. (1993)			x	Tutuila	q	q	x	q	q	q		q	x				x	x	x	q	x	x	x
Des Rochers and Tuilagi (1993)		x	x	Tutuila	q	q	x		q	q	x		q										
Hunter et al. (1993)			x														x						
Tuato'o-Bartley et al. (1993)			x								x							x	x				
Eldredge (1994)			x															x					
Maragos et al. (1994)			x														x	x					
Saucerman (1994)			x	Tutuila		q	q	q	q	q													
Craig (1995a)	x	x	x									q						x	x				
Craig (1995b)			x														x	x					
Hunter (1995)			x													x	x						
Saucerman (1995b)			x	Tutuila		q	q	q	q	q													
Saucerman (1995a)			x	Tutuila		q	q	q	q	q	x					x		x	x				x
Tuilagi and Green (1995)		x	x	Tutuila			x		x								x	x					x
Dalzell et al. (1996)			x				x	q	q	q	q											x	x
Green (1996)			x								q						x	x	x				
Kikkawa (1996)			x	Tutuila		q	q			q													
Mundy (1996)			x														x						
Adams et al. (1997)			x						q			q											
Birkeland et al. (1997)			x	Tutuila (Fagatele Bay)													x	x					

*See page 26 for column descriptions

† x = information present. ‡ q = some quantitative information present.

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Source	1*	2	3	Area	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Craig et al. (1997)			x					q	q		q												
Department of Marine and Wildlife Resources, 1997			x				x										x	x	x				
Green et al. (1997)		x	x								q						x	x	x				
Green (1997)			x			q	q	q	q	q	q					x	x	x	x	x			x
Hughes (1997)	x	x	x																				x
Green and Hunter (1998)			x														x						
Green and Hunter (1998)			x														x	x					
Page (1998)			x				x	q	q		x												
American Samoa Coral Reef Task Force (1999)			x														x	x	x				
Green and Craig (1999)			x								q												
U.S. Department of Agriculture, 2003			x		q				q						q								
Craig et al. (2000b)			x									q				x	x	x	x				
Craig et al. (2000a)			x									q											
Curren and Sauafea (2000)			x		q	q	q	q											x				
Fa‘asili and Sauafea (2001)			x													x		x	x				
Western Pacific Regional Fishery Management Council (2001)	x	x	x		q		x	x	q		q	q	q			x	x			x		x	x
Craig (2002)			x									q				x	x	x					
Ralston (2002)	x	x	x																				x
Sauafea-Ainu‘u (2002)			x													x			x				
U.S. Census Bureau, 2002			x		q							q											
American Samoa Environmental Protection Agency (nd)			x							x		q				x	x	x	x				

*See page 26 for column descriptions

continued on next page

† x = information present. ‡ q = some quantitative information present.

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Source	**1***	**2**	**3**	**Area**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
American Samoa Historic Preservation Office (2003)	x	x	x																				x
Enright et al. (nd)	x	x	x				x																
Honolulu Laboratory, 1986-			x		q	q	q	q	q	q										q			
Sorenson, 2003	x	x	x																				x
U. S. Census Bureau (2003)			x									q											
WPacFIN, Honolulu Laboratory, National Marine Fisheries Service (2003)			x			q	x	q	q	q										q			

* See page 26 for column descriptions
† x = information present. ‡ q = some quantitative information present.

Glossary

ahupua'a Traditional Hawaiian land division usually extending from the uplands to the sea.

akule Hawaiian name for the finfish, bigeye scad, *Selar crumenophthalmus* (Carangidae).

atule Samoan name for the finfish, bigeye scad, *Selar crumenophthalmus* (Carangidae).

ciguatera A form of poisoning suffered by consumers of fish with sizable amounts of ciguatoxins, which are produced by dinoflagellates and tend to increase in concentration as they are transmitted up the food chains of coral reef ecosystems.

diachronic Of, or relating to, or dealing with phenomena as they occur or change over a period of time.

ENSO *El Niño—Southern Oscillation* A cyclic climate phenomenon with strong effects on climatic and oceanic conditions in the Pacific, including rain, winds, sea surface temperature, and sea level, on the scale of years to decades.

fishing effort The rate at which fishing pressure is exerted on a stock—expressed, for example, in terms of fishing-gear-units per unit of time (e.g., boat-days per year). Fishing effort and fishing mortality are related through the coefficient, catchability, a measure of the efficiency of the fishing-gear-unit.

fishing mortality The rate at which fish are removed from a population or stock by fishing—expressed, for example, as a proportion of the population or stock per unit time, or typically, as an instantaneous rate, in units of per-year.

kapu Taboo, prohibition; special privilege or exemption from ordinary taboo; sacredness; prohibited, forbidden; sacred, holy, consecrated; no trespassing, keep out.

konohiki Head man of an *ahupua'a* land division under the chief; land or fishing rights under control of the *konohiki*; such rights are sometimes called *konohiki* rights. See also *ahupua'a*.

law of superposition In a series of layers and interfacial features, as originally created, the upper units of stratification are younger and the lower are older, for each must have been deposited on, or created by the removal or, a pre-existing mass of archaeological stratification.

MNI *minimum number of individuals* Minimum number of individuals. The smallest number of individuals necessary to account for all of the skeletal elements of a taxon in a faunal collection.

NISP *number of identified specimens* Number of identified specimens. The total number of identified fragments of any part of the anatomy of a taxon in a faunal collection.

‘ōpelu Hawaiian name for the finfish, mackerel scad, *Decapterus macarellus* (Carangidae).

palolo Samoan name for the marine polychaete worm, *Eunice* sp. (Polychaeta, Eunicidae).

stratigraphic sequence The stratigraphic sequence is the order of the deposition of layers and the creation of feature interfaces on an archaeological site through the course of time. On many sites these sequences are multilinear, due to separate areas of development that may have taken place, e.g. in the different rooms of a building.

synchronic Concerned with the complex of events existing in a limited time period and ignoring historical antecedents.

tautai Fishing specialist.

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