SANTA BARBARA AND SAN DIEGO: CONTRASTING ADAPTIVE STRATEGIES ON THE SOUTHERN CALIFORNIA COAST

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ABSTRACT

During the last 3500 years, hunter-gatherer toolkits in the Santa Barbara region of southern California were formal early on, increasing further after the bow and arrow arrived at approximately A.D. 500 and during a period of intensification shortly thereafter. Technological specializations (e.g., circular fishhook, decorated mortars and pestles, etc.) are evidence of large amounts of time spent making tools used in the intensive exploitation of acorns and marine foods. In contrast, hunter-gatherer toolkits over the last 3500 years in the San Diego region are informal throughout much of the Holocene, becoming more expedient after the bow arrives and during intensification at around A.D. 1400. Subsistence in the San Diego region is generalized, with a focus on terrestrial foods and underutilization of marine foods. Indeed, acorns and marine fisheries were of sufficient abundance and quality to support an intensified economy like hunter-gatherers in the Santa Barbara region. This research interprets the divergence in technological investment as evidence of vastly different evolutionary stable strategies that have divergent socioeconomic goals that are stabilized by social institutions. The Santa Barbara pattern approximates an energy maximizing (Emax) strategy in which a strong preference for more energy at the expense of free time results in more time devoted to making specialized subsistence tools (i.e., more time devoted to subsistence). In contrast the San Diego pattern approximates a time minimizing (Tmin) strategy in which time saving tactics are used to offset diminishing returns and satisfy a strong preference for non-subsistence time. In the time minimizing-energy maximizing model, both Tmin and Emax are strongly stable adaptive equilibria, with Tmin resistant to change that favors

Emax behavior. The stability of a Tmin economy better accounts for the apparent long-term stability of adaptive strategy in the San Diego region despite environmental change.

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I completed a large amount of work on Vandenberg Air Force Base (VAFB) with the 2008 UC Davis Archaeological fieldschool with the intent of incorporating it into this dissertation. Unfortunately, the Vandenberg region proved much more complex and

unique than I, and many previous scholars before me, have considered. That is, hunter-gatherers in the Vandenberg region were socioeconomically distinct from those in the Santa Barbara Channel not far to the south, despite sharing certain technologies. My work on Vandenberg is available in a separate monograph that considers this regional specificity and the implications for understanding hunter-gatherer socioeconomic stability and change. Regardless of the fate of the Vandenberg data, I am indebted to Christopher Ryan, Archaeologist at VAFB, for his astounding support involving the logistics of holding a fieldschool on a military installation, and for generating substantial funds for radiocarbon dating and other special studies without hesitation. Chris Ryan, and the Environmental Flight, assumed a substantial risk by entrusting the evaluation of archaeological sites on VAFB for Section 106 (of the National Historic Preservation Act—NRHP) eligibility determinations to an archaeological fieldschool. My praise and gratitude for Chris and the Environmental Flight at VAFB cannot be understated.

The inspiration for this research originated with several individuals. Clearly, the time minimizing-energy maximizing concept as applied to anthropological problems has its roots in an article by Bettinger and Baumhoff (1982) and another by Winterhalder (1983). Both articles identified the essential elements of the model. Bettinger (1999) provided further clarity by considering time minimizing and energy maximizing as evolutionary stable strategies (ESS) even though the archaeological implications and model machinations were not specified. Going back a bit further, Peter Richerson at UC Davis had the clarity to suggest that I explore the rate limiting factors of cultural evolution by tracing the impacts of a radical new technology (i.e., the bow and arrow) into different adaptive strategies. Pete's ability to see the big picture, all the while commanding the simplest of details, makes archaeology fun. A reading course with Bruce Winterhalder played no small part in the development of this dissertation. Bruce's clarity of thinking sent me down the path of formal economics and directed me to my favorite book, "The Nature and Significance of Economic Science," by Lionel Robbins (1932). While researching economics and intensification under Bruce, I was exposed to the richness of knowledge regarding cultural evolution from many different perspectives. Out of this research came the modified Ideal Free Distribution used in this dissertation to predict discontinuous socioeconomic change. Jelmer Eerkens was instrumental in keeping me tied down to the material record—the ultimate master in archaeological research. What was clear to me is not always so to others and his ability to find new ways to make mountains of data into understandable molehills was fascinating. I know that I will improve on this dissertation in subsequent writings because of his guidance. Richard McElreath was somewhat of a silent dissertation committee member. Richard forcibly taught me the mathematics behind the time minimizing-energy maximizing formal model. His perspective of casting problems in life in mathematical terms brings order to seemingly chaotic situations and, ultimately, helped me understand the dynamics of human economies.

The chair of my dissertation committee, Robert Bettinger, is a true archaeologist. By that I mean that Bob has the ability to make impossibly complex theoretical problems simple, and understandable from the material record. His attention to the history of archaeological thought and methodology is unparalleled and allows him to discern what is known and what needs to be known. However, the greatest lessons I learned from Bob did had less to do with the material record and more to do with the practicality of doing

meaningful archaeology day in and day out. The lessons are best summed up in one word: discipline.

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commitment, and honor. I wish there was a better way to express how much her love and support means to me. On that note, I dedicate this dissertation to Tara, Maile, and Sky.

CHAPTER 1. INTRODUCTION

During the last 3500 years, hunter-gatherer adaptive strategies in the Santa Barbara region changed frequently and significantly, culminating in the complex sociopolitical formations of Chumash ethnography. During the same 3500 years adaptive strategies in the San Diego region remained quite stable even as population grew and resources were used more intensively. Environment fails to account for this contrast. The intervening Los Angeles region was environmentally similar to San Diego but developed like Santa Barbara, in this case culminating in the complex sociopolitical formations of Gabrielino ethnography. This research addresses the question: Why did hunter-gatherers in the San Diego region not follow the socioeconomic trajectory that characterizes hunter-gatherers in the Santa Barbara (and Los Angeles) region? It argues that the San Diego – Santa Barbara contrast is due to the presence of two fundamentally different adaptive equilibria, one more, the other less, resistant to change.

Variation in hunter-gatherer behavior is popularly described in terms of continua (e.g., forager-collectors, simple-complex, mobile-sedentary; Binford 1980, Kelly 1995, Keeley 1988), implying that individual cases are simply local expressions of a basic pattern, differing in degree but not kind, owing to techno-environmental circumstances. Change in these circumstances produces adaptive responses that are transformational and continuous, groups becoming, for example, more forager-like or more collector-like but never irrevocably one or the other. In evolutionary terms, hunter-gatherer continua consist of an infinite number of local equilibria that are only weakly stable, i.e., to the extent local conditions do not change. Archaeological evidence in southern California suggests an alternative possibility. At minimum, the San Diego – Santa Barbara contrast hints that instead of a myriad of metastable equilibria there may be a few strongly stable equilibria – qualitatively different socioeconomic strategies that do not respond quickly to techno-environmental change. On this view, variation in hunter-gatherer socioeconomic behavior would be qualitatively varied and discontinuous, groups at different equilibria responding differently to identical techno-environmental stimuli.

The San Diego – Santa Barbara contrast approximates the difference between what have been termed time minimizers and energy maximizers – different evolutionary stable strategies with divergent socioeconomic goals that are stabilized by social institutions (Bettinger 1999, Winterhalder 1983). Time minimizers minimize time spent on subsistence, opting to invest more time in such non-subsistence activities as leisure, finding mates, maintaining social ties, sleeping, etc. Social institutions that value such preferences inhibit behaviors that favor food storage and resource privatization, land tenure, etc.—activities that would promote adaptive change. Energy maximizers maximize time spent on subsistence, choosing to acquire more calories at the expense of investing it in non-subsistence activities. As such, energy maximizing economies are inherently more dynamic, in terms of adaptive change, as long as the preference for more energy is satisfied. In these terms, over the last 3500 years hunter-gatherers in the San Diego region display a range of behaviors consistent with a conservative time minimizing adaptive strategy while Santa Barbara hunter-gatherers resemble a dynamic energy maximizing adaptive strategy.

This research supports the time minimizing-energy maximizing (hereinafter Tmin-Emax) explanation by presenting data regarding the socioeconomic response in the San Diego and Santa Barbara regions to the introduction of a major late Holocene technological innovation—the bow and arrow—and the response to diminishing returns brought on by population growth and possibly environmental shifts. In the Tmin-Emax model, time minimizing and energy maximizing are modeled as evolutionary stable strategies, inherently resistant to structural change due to strong social institutions that govern the allocation of scarce resources. Hunter-gatherers of the San Diego and Santa Barbara regions are expected to respond differently to new technologies. Hunter-gatherers in each region should intensify differently, if they are characterized by such divergent adaptive strategies. Time minimizers should use more efficient new technologies to save subsistence time, holding energetic intake constant and maintaining a conservative time minimizing economy. Energy maximizers should use the bow to increase energetic yield, increasing subsistence time and promoting adaptive change that maintains a strong preference for more energy. In these terms, time minimizing economies are conservative and resistant to change while energy maximizers are more dynamic—open to adaptive shifts that increase energetic yield. If the Tmin-Emax model is not correct, new technologies should generate relatively rapid change along a similar socioeconomic trajectory among the hunter-gatherers of both regions.

An analysis presented here of subsistence technology and general assemblage data from a large number of archaeological sites in the San Diego and Santa Barbara regions documents strong differences in the manufacture and use of subsistence technologies. In the San Diego region, assemblage formality is generally low prior to A.D. 500, declining further after the introduction of the bow and arrow, and again during a period of intensification. In comparison with the San Diego region, assemblage formality in Santa Barbara is relatively high prior to introduction of the bow, increasing thereafter with the adoption of the bow and during intensification after A.D. 1350. These results support the concept that during the last 3500 years, hunter-gatherers in the San Diego region were time-minimizers, choosing to save time in subsistence by reducing investment in tool formality when a costly technology (i.e., the bow complex) is adopted and during intensification. The increases in tool formality across the board in Santa Barbara are consistent with an energy-maximizing strategy, increasing time spent in subsistence-related activities to maximize energetic yield.

The results of this research help clarify the archaeological signature of socioeconomic divergence and carry strong implications for the widespread application of behavioral continua to explain socioeconomic change. The contrasting trajectory of technological investment evident in the San Diego and Santa Barbara archaeological records implies that conservative social institutions that manage subsistence can inhibit the development of more complex socioeconomic arrangements, despite changes in technological or environmental conditions. This research also helps clarify how different adaptive strategies respond to new technology, an area of great interest in current culture evolutionary research (see Arnold 2007, Henrich 2004, Richerson and Boyd 2005:242, Schiffer 2005).

This dissertation is divided in to several sections. Following this introduction, Chapter 2 presents a brief overview of the regionally distinct archaeological record in the Santa Barbara and San Diego regions, along with alternative explanations for the distinction, and theoretical considerations relating to the Tmin-Emax model. Chapter 3 is a detailed description of two models that provide the explanatory framework for interpreting the archaeological record. First, a formal model of the Tmin-Emax concept by Hale et al. (n.d.) is reviewed deriving predictions for socioeconomic change and subsequent archaeological patterning. Second, a modified version of the Ideal Free Distribution (IFD) is used to derive socioeconomic predictions for the shift from Tmin to Emax and subsequent archaeological expectations. Methods used to gather and interpret assemblage data are provided in Chapter 4. Data generated in support of this research are presented in three chapters. Chapter 5 considers datasets relevant to the Tmin-Emax explanation of socioeconomic divergence in the San Diego region, and Chapter 6 does the same for the San Diego region with respect to the modified IFD model. Chapter 7 explores model predictions for an Emax economy in the Santa Barbara region. A brief comparison of the two regions, with respect to model predictions, is provided in Chapter 8. Finally, Chapter 9 is a discussion of the overall research results and implications for broader theoretical and archaeological problems. Several comprehensive data tables and site descriptions can be obtained by contacting the UC Davis Department of Anthropology, or the author.

CHAPTER 2. RESEARCH CONTEXT

2.1 ARCHAEOLOGICAL CONTEXT

The archaeological context is late Holocene southern California during the last 3500 years. Specific areas include the greater San Diego and Santa Barbara regions. Excluding the intervening area (part of Ventura, Los Angeles, and Orange counties) simplifies the problem, putting the focus on just these two spatially discontiguous and geographically unique regions. Each area of analysis is large enough to capture the range of variability of aboriginal economies along the coastal plain, while circumscribed enough to exclude spatially overlapping adaptive strategies that cloud an understanding of local socioeconomic processes.

The San Diego region is defined as the area south of San Mateo Creek and north of San Elijo Lagoon, extending west of the Peninsular Ranges to the Pacific coast (Figure 2.1). This region is centered in the area traditionally attributed to the ethnohistoric Luiseño but it also circumscribes an area that is archaeologically distinct. The upper and east-facing slopes of the Peninsular Ranges were excluded from this analysis due to a heavy interior desert influence that complicates definition of regionally distinct economic patterns. North of San Mateo Creek, the archaeological record is a mixture of assemblages—some like the ethnohistoric Gabrielino, and others like the Luiseño. Just 40 km north of San Mateo Creek north of the Aliso Creek watershed, archaeological patterning is fully distinct from the northern San Diego region, assemblages there are characterized by mortars and pestles, circular fishhooks, beads and stone items, abundant fish and sea mammal remains, etc (Cite). Assemblages south of San Mateo Creek generally lack these indices.

Figure 2.1. Vicinity map showing the Santa Barbara and San Diego study areas.

The southern boundary, at San Elijo Lagoon, is less distinct, partly because early development prior to state mandated studies destroyed archaeological sites, and also because archaeological trends are slightly different. The southern boundary is consistent with what other local researchers have drawn based primarily on the timing of certain assemblage changes, such as the earlier appearance of the bow and arrow and ceramics, and greater proportions of marine foods near the coast in the southern San Diego Region (Carrico and Taylor 1983; Gallegos and Kyle 1986; Hector 1986; Kyle et al. 1998; Moriarty 1967; M. Rogers 1966; Warren 1968). Kroeber (1925), Rogers (1939), Warren (1968) and host of others suggest these differences are due to different migrations of people speaking different languages. The Luiseño are Uto-Aztecan speakers, like the Gabrielino to the north, and Kroeber (1925) suggests that a "Shoshonean" intrusion from the desert and Great Basin occurred sometime around A.D. 500. A second "Yuman Intrusion" is proposed by Rogers (1945, 1966) as an influx of population from the Colorado Desert to the east of San Diego. These linguistic models have been the traditional structure behind all cultural chronologies attempting to order archaeological materials in the last 2000 years or more (see Bean and Shipek 1978).

Small differences in archaeological patterning between northern and southern San Diego are also the product of early development in the southern part of the county near the city of San Diego. A general lack of well-dated deposits after A.D. 1400 along the littoral in southern San Diego County is certainly the result of intensive development before cultural resource management regulations were instituted in the 1960s and 1970s (i.e., California Environmental Quality Act, National Environmental Protection Act). Indirect evidence of this is the abundance of small and large shell middens that dot the coastline on Camp Pendleton in northern San Diego County, protected from development since the late 1940s.

The Santa Barbara region is defined here as the area north of Rincon point, east/southeast of Point Conception, and south/southwest of the Santa Ynez mountains (i.e., Transverse Ranges). This area was primarily occupied by the ethnohistoric Barbareño Chumash (Glassow 1996). Distinguishing the Santa Barbara mainland channel area from north of Point Conception is justified archaeologically by extensive research conducted on Vandenberg Air Force Base that has documented important differences in the timing and character of adaptive strategies (see Glassow 1996; Glassow et al. 2007). Much less work has been done in the Santa Ynez mountains to the north and east of the coastal plain, although a few archaeological sites from near Lake Cachuma are included in this research. South of Rincon Point, archaeological assemblages continue to resemble those near Santa Barbara but this marks an ethnohistoric boundary with the Ventureño that is geographically distinct as well.

That hunter-gatherer adaptive strategies in the Santa Barbara and San Diego regions were different has been known since the first systematic archaeological work was conducted in southern California by Owen (1967), D. Rogers (1929), M. Rogers (1945), Wallace (1955), Warren (1968), and others. In the same way, ethnohistoric accounts of the Chumash in Santa Barbara region and of the Luiseño in the San Diego region clearly show fundamental differences in sociopolitical complexity (Bean and Shipek 1978; Gamble 2008; Grant 1978). These differences were muted before about 3500 B.P.

Some of the earliest archaeological sites in southern California belong to what is called the Millingstone Horizon (Wallace 1955). Millingstone assemblages display large numbers of millingstones, handstones, and crudely shaped cobble tools but very few finished flakedstone tools (e.g., projectile points). Subsistence was based primarily on plants and shellfish. Oak Grove is a regional expression of the Millingstone Horizon in Santa Barbara region (Owen et al. 1964, Warren 1968), the La Jolla complex its regional manifestation in San Diego (M. Rogers 1945; Warren 1968). The Millingstone Horizon ended much earlier in Santa Barbara (5500-3500 B.C.) than in San Diego, persisting there well into the late Holocene, ca. A.D. 0-500 (Glassow et al. 2007; Hale 2001; M. Rogers 1945; Warren et al. 2004; Yohe and Chase 1995).

The Millingstone Horizon is one of few commonalities between the Santa Barbara and San Diego regions. Its earlier termination in Santa Barbara signifies fundamental shifts in settlement and subsistence that did not occur in San Diego. These differences are most visible in the last 3500 years. By 3500 BP, Santa Barbara assemblages have large numbers of shaped mortars and pestles relative to the older millingstone and handstone forms (see Erlandson and Rick 2002, Glassow et al. 1988). The growing number of shaped mortars and pestles likely reflects greater use of acorns relative to small seeds and tubers. Alternatively, Glassow (1996) suggests that the observed increase in the more costly to make mortars and pestles simply reflects more intensive plant processing in general, i.e., of acorns, roots, and small seeds collectively. However, intensive, broad spectrum plant processing is already apparent in Millingstone Horizon sites—such as Glenn Annie Canyon (SBA-530)—predating 3500 BP (Hale 2001). Since millingstones and handstones never disappear, this suggests that the growing fraction of mortar-pestle technology reflects a processing specialization on high cost/high yield resources, probably acorns.

Once a high cost processing economy is evident in Santa Barbara, several technological innovations appear, including the j-shaped fishhook (600 B.C.), plank canoe (A.D. 400), bow and arrow (A.D. 500), circular fishhook (A.D. 1300), and microlithics (A.D. 1300) (Arnold 1992; 1997; Gamble 2002; Glassow 1996; Kennett 2005; C. King 1990; Rick et al. 2002; Strudwick 1985). Dates of arrival for each of these technologies are more and less certain. Rick et al. (2002) develop a strong chronology for single-piece fishhooks drawing on a number of direct radiocarbon dates. Microlithics are also reliably dated from contexts on Santa Cruz Island (Arnold et al. 2001). However, the plank canoe and bow complex are less reliably dated. The plank canoe is known ethnographically and from pieces of wood planks (Gamble 2002), but its early arrival date is also based on inferences from changes in subsistence remains. Likewise, inception dates for the bow complex are complicated—its A.D. 500 arrival date also somewhat tenuous. Glassow (1996) presents a strong argument for small leaf-shaped points as the first arrow tips, appearing at around A.D. 500, then transitioning to the Canalino (i.e., Cottonwood Triangular) tips later in time, at around A.D. 1300 or so.

Subsistence appears to change gradually and in step with the arrival of new technologies including an increase in fish remains beginning after 3500 BP and rapidly accelerating after 650 BP (Kennett 2005), a shift in shellfish exploitation to emphasize California mussel (Glassow et al. 1988), and higher frequencies of traditional resources including terrestrial game and seeds. Settlement also changes at 3500 BP, becoming characterized by large coastal and interior villages with multiple semi-subterranean houses and large communal features (Erlandson 1997; Gamble and Russell 2002). Reconstructions of settlement and subsistence for the Santa Barbara region is based on archaeological data from sites on the mainland and from several of the Channel Islands, especially Santa Rosa and Santa Cruz islands (see Kennett 2005). Island occupation may have been episodic prior to 3500 years ago but after this time, evidence for stable island occupation (even if seasonal) and a strong economic relationship with the mainland is apparent from archaeological sites.

The archaeological record in San Diego is much different. From before 3500 BP until 250 BP, it is uniformly characterized by a generalized processing and gathering economy (see True and Waugh 1983, Warren et al. 2004; York 2006). Although much debated, the terminus of the San Diego Millingstone Horizon is usually equated with the disappearance of lagoon and estuary sites at around 3500 years ago, when erosion and flooding destroyed or decreased the bio-productivity of many lagoons (see Warren 1968; Warren et al. 2004). However, there are coastal and inland sites with Millingstone-like assemblages (i.e., dominated by ground and battered stone tools) post dating 3500 BP (see Gallegos and Kyle 1986; Yohe and Chase 1995) indicating that the Millingstone pattern in the San Diego region was not specifically a lagoonal / estuarine adaptation. Indeed, True's (1974) Pauma Complex is an inland expression of the Millingstone pattern. Subsistence throughout the late Holocene continues to feature generalized processing without additional subsistence specializations, despite regional variance in specific kinds of resources used—i.e., more fish were taken in southern San Diego County.

With the exception of the bow and arrow, most of the new technologies used in Santa Barbara were largely ignored in San Diego. The timing of the introduction of the bow is a subject of debate—some scholars proposing introduction of the bow at around

A.D. 500 (Glassow 1996; Koerper et al. 1996) and others suggesting it arrived later, at about A.D. 900 (Warren 1984). Koerper et al. (1996) document a relatively large number of Cottonwood projectile points in the Newport Bay area (ethnohistoric Gabrielino territory) dating to A.D. 600. Newport Bay is less than 40 km from the northern edge of this study area. Presumably, this distance was not so great as to inhibit exposure of the bow to hunter-gatherers in the San Diego region—even though factors other than distance may have hindered its spread. The depositional context of most early dates for arrow points is less than ideal. In the San Diego region, large numbers of Cottonwood and Desert Side Notched arrow points (some of these were labeled as preforms) were identified at SDI-4765A, dating as early as A.D. 490 to 650 (see Byrd and Serr 1993), and another 11 arrow points dating as early as A.D. 690 from SDI-10723 (Hale and Becker 2006). Despite these early dates, arrow points (i.e., Cottonwood Triangular, Desert Side Notched, etc.) only appear in large numbers after A.D. 1000. The paucity of arrow points between A.D. 500 and 1000 in the northern San Diego region may be a lag effect as more and more hunters learned how to make and use bows, and as social units responded to the bow's increased efficiency. For the purposes of this analysis, however, it is assumed that the bow was available to inhabitants of the San Diego region as early as A.D. 500.

With the availability of the bow and arrow after A.D. 500, older settlement and subsistence patterns shift slightly, large habitation sites being positioned with direct access to the most productive seasonal resources. This is accompanied by an increase in small temporary camp frequency (see Hale and Becker 2006). No formal residential or communal structures are known from either kind of site in the San Diego region. An intensive acorn economy does not take hold until around A.D. 1700, when ceramics also appear in massive quantities (Griset 1996, True and Waugh 1983, Hale and Becker 2006, York 2006). Acorns were most likely used intermittently during the Late Holocene but they were not paramount in the local economy as they were in the Los Angeles or Santa Barbara regions, implying that San Diego hunter-gatherers did not incorporate the social organizational imperatives of an acorn economy, i.e., pronounced division of labor (see Warren et al. 2004:96).

In summary, separated by less than 150 miles, the Santa Barbara and San Diego regions display vastly different socioeconomic trajectories over the last 3500 years. The Santa Barbara economy is dominated by high cost processing (probably acorns) and specialized fishing, with several periods of subsistence and settlement intensification, and increasing technological specialization. In contrast, the San Diego region is relatively static, characterized by a generalized processing and gathering economy from before 3500 BP until about 250 BP.

2.2 ENVIRONMENTAL CONTEXT

Environment has always been the stock explanation for adaptive and cultural differences between the Santa Barbara area and San Diego area further south. Prehistoric socioeconomic development in the Santa Barbara channel region is typically laid to a combination of topography and marine upwelling that produced a uniquely productive environmental setting vastly more favorable than that in the San Diego area (Arnold 1997, Kennett 2005, Raab and Larson 1997). There is some merit to this idea. The south-facing Santa Ynez Mountains terminate abruptly on a narrow Santa Barbara coastal plain, trapping moisture and creating a cool, temperate climate with about 20 inches of annual precipitation. Rock reefs dot the Santa Barbara shoreline, providing superb habitat for shellfish, kelp-dwelling fish, and occasional marine mammal colonies sustained by nutrient-rich deep water upwelling generated by offshore winds, conditions that are replicated on the adjacent Channel Islands.

The coastal mainland further south in Los Angeles, Orange, and San Diego counties is less productive in comparison. The coastal topography of the Santa Monica and Santa Ana Mountains and Peninsular Ranges is gentler and receives less precipitation (about 10-15 inches), producing a desert-like environment dominated by drought tolerant chaparral. The availability of marine foods varies, but except in the vicinity of the Santa Monica Mountains where they are steep and rocky, shorelines are generally a mixture of flat, sandy beaches and cliffs interspersed with rocky outcrops and reefs. As a consequence, while pelagic and schooling fishes are widely available in the waters off Los Angeles, Orange, and San Diego counties (Allen 1985; Achmeyer et al. 1983), sea mammals and kelp-dwelling fish are noticeably less abundant than in the Santa Barbara Channel. The kelp dwelling nearshore and schooling species that constitute the majority of identified archaeological specimens from the Santa Barbara area (Glassow et al. 2007), were exploited the San Diego area, but in much smaller quantities more heavily biased toward schooling species.

This north vs. south environmental contrast goes only so far. Certain aboriginally important resources were uniformly abundant along the whole of the southern California coast, the most notable being the acorn. The coast live oak (*Quercus agrifolia*) so highly preferred because of its oil-rich nut meat (Pavlik et al. 1991) was widely available in inland and coastal settings from Santa Barbara to San Diego (Griffin and Critchfield

1982). The equally valued black oak (*Quercus kellogii*) is actually more common to the south, in San Diego County, and decreases in productivity as one moves north despite increasing rainfall (Koenig 2007).

Prehistoric San Diegans had access to acorn crops at least as productive as those of their neighbors in the Santa Barbara and Los Angeles areas. The intensive, acorn dominated adaptation present in the San Diego region after A.D. 1700 shows beyond any doubt that the region had sufficient terrestrial resources to sustain much denser hunter-gatherer populations earlier in time. In addition, while inferior to that of Santa Barbara, marine environments off San Diego are nearly the equal of those off Los Angeles (Goodson 1988), which sustained intensive offshore fishing from plank canoes by the ethnographic Gabrielino. Pelagic and schooling fishes are common to the mild waters of both (Allen 1985; Achmeyer et al. 1983; Goodson 1988), their sea bottoms equally broken by reefs supporting stable kelp forests and diverse nearshore fish communities. In comparison to that of Los Angeles, however, the offshore San Diego fishery remained under-exploited.

Environment provides a ready-made explanation for regional differences in hunter-gatherer adaptation because hunter-gatherers are so clearly tied to their environment, no two of which are ever exactly alike. Environmental explanations may be frequently less convincing when closely scrutinized, however, and the Santa Barbara-San Diego comparison is surely one of these. It is quite clear that, relative to the Santa Barbara area, the San Diego area was disadvantaged on the marine side of the equation, which might explain its lesser development of marine resources and offshore fishing. That the intervening Los Angeles area was equally disadvantaged but nevertheless developed an intensive marine emphasis approaching that of the Santa Barbara Channel makes this environmental explanation implausible, however. Because they were on a par with those of Los Angeles, the marine resources off San Diego could have been, but were not, developed into an intensive fishing adaptation akin to that of the Gabrielino.

The terrestrial side of the equation is even more damaging to the environmental explanation. While the Santa Barbara Channel was somewhat better watered, producing more seeds and roots, acorn resources were similar to those in the San Diego area. Acorns bulked large in the Santa Barbara diet, probably acting as a source of carbohydrates and fat to offset heavy use of protein-rich but fat-poor marine fish (Cordain et al. 2000). From this perspective, intensified fishing in the Santa Barbara Channel had to develop in step with intensive exploitation of terrestrial plants (the acorn in particular). If environment were all that mattered, then, whether or not it was capable of developing an intensive marine fishery, the San Diego region had productive acorn crops and should have developed an acorn-intensive adaptation as early as the one that ended up paving the way for intensive marine fishing in Santa Barbara. The hunter-gatherers of the San Diego region did, in fact, intensify acorn exploitation, but only around A.D. 1700 (Hale 2005; Hale and Becker 2006; see also True and Waugh 1983), and never developed a marine fishery comparable to that in the Los Angeles area where the fishing was equitable.

Environmental explanations for differences in behavior hinge on showing a clear connection between variation in a specific aspect of environment and variation in a specific form of behavior. On this view, there is little merit in the received wisdom that differences in cultural trajectory between the Santa Barbara and San Diego areas can be laid to environment. There are environmental differences between the two, to be sure. The marine fishery of San Diego area was surely inferior. But its terrestrial resources were not, and its marine fishery was certainly sufficient to sustain substantial intensification, as the Gabrielino show. In short, environmental differences do not explain why marine intensification never occurred in the San Diego area, and acorn intensification was delayed to around A.D. 1700. Differences in the structure of adaptive strategy provide a more plausible explanation.

2.3 THEORETICAL CONTEXT

2.3.1 Behavioral Continua

In the last 30 years or so archaeologists—dissatisfied with stereotypes—have increasingly turned to behavioral continua to explain hunter-gatherer adaptive strategies (see Kelly 1995). Traditional research focused on finding a definition of pristine hunter-gatherers, i.e., unaffected by contact with foreign societies—of course this is an impossible venture. Ethnographic work in the 20th Century continued to document societies whose primary mode of production was hunting and gathering and existing definitions of hunter-gatherers failed to account for an increasing range of behavioral variability. Models of behavioral continua (e.g., foragers-collectors, travelers-processors; Binford 1980; Bettinger and Baumhoff 1982) emerged with the goal of better understanding the range of behaviors exhibited by hunter-gatherers, rather than coming up with a new definition.

Currently, behavioral continua are some of the most popular models used in hunter-gatherer research, and rightfully so because they account for most ethnographic cases and are easily adapted to archaeological problems (see Binford 1980). Continua are bounded by dichotomous poles characterizing either extreme, between these poles are an infinite number of behavioral combinations. Adaptive strategies are described as more or less similar to one of the poles (i.e., forager-like or collector-like) but never completely one or the other.

The purpose of behavioral continua is to provide a range of possibilities for describing combinations of social organization, demography, subsistence, mobility, and other factors that influence hunter-gatherer adaptation. Within behavioral continua, adaptive strategies are optimal solutions to local conditions. As conditions change, adaptive strategies must also change to reach local equilibria. In the forager-collector continuum, a forager-like adaptive strategy might respond to decreased abundance of high-ranked prey by practicing the collector-like strategy of storage, which can be abandoned as soon as conditions favoring storage disappear. This example illustrates the flexibility ascribed to hunter-gatherers in behavioral continua and shows that, in this model, local equilibria are weak—only as stable as local conditions.

If local hunter-gatherer adaptations are unstable and respond closely to techno-environmental change, as models cast in terms of behavioral continua (i.e., forager-collector) suggest, San Diego hunter-gatherers should have intensified acorn and marine resource exploitation. This is the scenario used explain archaeological patterning in southern California hunter-gatherer groups, the evolution from less intensive foragers to intensive collectors (Byrd et al. 1993, Glassow 1997, Kennett 2005) and from egalitarian foragers to complex fisher-processors (Arnold 1992, 1997, Raab and Larson 1997). In these accounts, subsistence intensification pushes hunter-gatherers from foragers to collectors, or from simple to complex hunter-gatherers, as the result of various combinations of environmental stress, resource availability, and population density. If this were universally true, archaeological patterning should reflect gradual socioeconomic transformation over the late Holocene in the San Diego region as well. It does not.

The apparent stability of hunter-gatherer adaptive strategies in the San Diego region highlights the limits of models based on behavioral continua; they cannot account for situations in which adaptive strategy does not transform under changing techno-environmental circumstances. Hunter-gatherers in the San Diego region were exposed to the same technological innovations available in Santa Barbara but none of the rapid and substantial changes that occurred in Santa Barbara happened in San Diego.

2.3.2 Time Minimizing-Energy Maximizing

The Time Minimizing-Energy Maximizing model (Tmin-Emax) provides an alternative framework for explaining contrasting socioeconomic trajectories in southern California. The idea itself is not new. Several researchers outlined earlier versions. Winterhalder (1983) proposed a formal model based on indifference. He began with the premise that human survival and reproductive success is primarily limited by time that can be devoted to either subsistence or other (non subsistence) fitness-enhancing activities. Winterhalder predicted that strong preferences for either non-subsistence time or more energy (food) affect the way hunter-gatherers make subsistence decisions. Unfortunately, his model did not explain the basis for the preferences themselves. Bettinger and Baumhoff (1982) take a different approach. Assuming that hunter-gatherers are limited by time and energy, they distinguish between time limited travelers and energy limited processors. Traveler and processor strategies are adaptive peaks because travelers are time limited and processors are energy limited. Since intermediate strategies are less productive, shifting from one peak to the other (i.e., from traveler to processor) is difficult. Unfortunately, their model was rooted in the contingency form of optimal foraging theory (diet breadth and patch choice), in which cost and benefits (time and energy) are treated as a ratio (energy relative to time or time relative to energy). This makes it impossible to examine the effect of time or energy independently, and equally impossible to separate time-limited from energy-limited strategies.

To distinguish the two, Bettinger (1999) proposed a model that defines time minimizing and energy maximizing as evolutionary stable strategies (ESS). By adaptive strategy is meant a combination of tactics for subsistence, settlement, organization, and demography developed within an overarching value system (see Bettinger 1999). An evolutionary stable adaptive strategy is one that resists invasion by competing strategies (McElreath and Boyd 2007). By definition, once established, an ESS cannot be invaded by another strategy. In this context, evolutionary stability is provided by mutually beneficial, and thus self-enforcing, coordination (e.g., driving on the right side of the road) and by value-reinforcing social institutions. In time minimizing economies, for example, the social institution of tolerated theft works as a disincentive to subsistence intensification (Why work hard if lazier individuals will eat just as well?). In the same way, norms valuing leisure time, decorative craftwork, or other non-subsistence pursuits reduce the perceived benefits of foraging, dampening the potential for population growth (Riches 1982; Winterhalder 1993). In energy maximizing economies, on the other hand, privatized resources, positively sanctioned resource hoarding, and punishment for resource theft act as incentives to resource intensification, permitting storage, with ensuing population growth (Blurton Jones 1987, Gurven 2002, Winterhalder 1996). The social forces that discourage resource intensification under time minimizing make a shift to energy maximizing impossible absent wholesale social re-coordination – a fundamental shift in values and behavior (see Bettinger 1999).

This research uses the time minimizing-energy maximizing concept to explain the dichotomous patterns in the archaeological record of southern California. To facilitate this explanation, a formal economic model of time minimizing-energy maximizing (Hale et al. 2008) is used to derive predictions for changes in subsistence technology. Further implications derive from a modified form of the Ideal Free Distribution model (Fretwell and Lucas 1970) that incorporates time minimizing and energy maximizing as distinct socioeconomic modes of production. The archaeological implications of both formal models are relatively straightforward, the prediction being that the two strategies will exhibit contrasting subsistence and technological trajectories and respond differently to new technology.

3. MODELING HUNTER-GATHERER TRANSITIONS

The primary goal of this research is to account for socioeconomic divergence visible in the archaeological record of southern California. In this chapter, two models—Time Minimizing-Energy Maximizing, and the Ideal Free Distribution—generate predictions for changes in adaptive strategy that can be measured in the archaeological record. Specifically, the models generate predictions for changes in the amount of time allocated to the manufacture of subsistence tools, measured by a flakedstone formality index, a debitage index, and a groundstone formality index.

3.1 TIME MINIMIZING-ENERGY MAXIMIZING

This section describes a formal model of the time minimizing-energy maximizing concept (Tmin-Emax) developed by Hale, McElreath, and Bettinger (2009). This model was developed as a tool to better understand how adaptive strategies respond to changes in critical variables. The general model illustrates changes in time allocated to the competing pursuits of subsistence and non-subsistence activities. A key component of the formal Tmin-Emax model is that response to changes in each variable are constrained by social institutions that stabilize a preference for either more time or more energy.

The Tmin-Emax model is grounded in formal economics and Darwinian evolution. The formal economic perspective is that humans have a tendency to make rational decisions about the allocation of scarce resources to achieve desired ends (Robbins 1932). Scarce resources can be many but there are two that strongly affect human survival and reproduction: time and energy. There are only 24 hours in a day and humans require a minimum energetic intake per day; more energy is needed to maximize reproductive potential. Desired ends are potentially infinite and are both individually and culturally determined. In formal economics, preferences—and changes in preferences—are only considered data (Robbins 1932). Decisions to allocate resources to specific ends are rational if they match socially defined preferences.

A formal economic perspective argues that decision making is rational but it does not account for why this is true. Darwinian evolution, based on the principle of Natural Selection, provides the theoretical framework that justifies rationality. Natural Selection is a culling process; variants that have a lower survivability and reproductive potential contribute less heritable variation to subsequent generations, resulting in a population that is better suited to a given set of conditions (see Brandon 1990). It is then reasonable to think that humans have been shaped by natural selection so that behaviors relating to survival and reproduction will be maximized (see Winterhalder 1983). At the most fundamental level, the success of humans depends on getting food and reproducing. It can be assumed that fertility and survivorship are maximized by getting more food, and that minimizing the time spent on subsistence frees up time for participation in other behaviors that enhance fitness (social networking, mating, etc.) (Kaplan and Hill 1992). It follows that strong selective forces work to optimize the allocation of scarce resources—time and energy—to alternative fitness-enhancing behaviors (see Alvard 1993, Stephens and Krebs 1986).

Darwinian evolution is concerned with changes in preference structures in as much as they affect the maximization of scarce resources. Hale et al. (2009) build the formal model of time minimizing-energy maximizing based on Bettinger's (1999) assumption that social institutions evolve to stabilize existing preference structures—i.e., either more non-subsistence time or more energy. Adaptive strategies cannot exist if social rules do not reinforce participation. Changes in local conditions (technology, environment, etc.) elicit qualitatively different responses from each strategy consistent with stable preferences; time minimizers should save more time on subsistence with the adoption of more efficient extractive technologies and energy maximizers should get more energy. Thus, changes in preference structures (i.e., from Tmin to Emax) are not continuous; they are abrupt, comprehensive changes in social coordination and adaptive mechanisms. The formal model of time minimizing-energy maximizing is based on stabilized preferences, rather than gradation from one strategy to the other.

3.2 MECHANICS OF THE MODEL

The model by Hale et al. (2009) assumes that individuals will maximize the total utility of time—a scarce resource—to the alternative required pursuits of energy acquisition and leisure. Leisure is defined as any non-subsistence activity such as sleeping, finding mates, social networking, decorative craftwork, etc., that contributes to human success. This is represented by the equation:

$$U(t) = E(t) + L(1-t)$$

The functions of energy and leisure—E(t) and L(t), respectively—must be represented by a continuous function. It is assumed that allocation of time to energy and leisure follows a diminishing returns curve; or that each additional unit of time applied to either pursuit will produce less utility than the previous unit of time invested. Research into hunter-gatherer time allocation generally supports this assumption (see Sahlins

1972). Diminishing returns can be modeled by a negative exponential such that the allocation of time to energy and leisure are analogous functions (Figure 3.1):

$$E(t) = b_E\left(1 - \exp\left(-a_E t + c_E\right)\right)$$
$$L(t) = b_L\left(1 - \exp\left(-a_L (t + alpha * t) + c_L\right)\right)$$

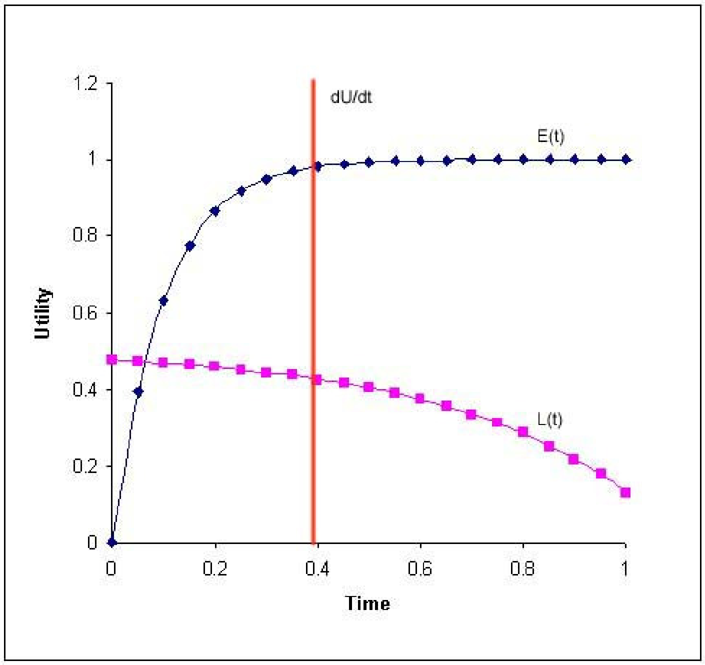


Figure 3.1. Analogous functions representing time invested in subsistence (E(t)) and leisure (L(t)).

There are four parameters that affect the maximization of time devoted to either E(t) or L(t) in these functions: *a*, the rate of return (a proxy for efficiency); *b*, the maximum utility of the activity; *c*, the minimum time required before gaining positive returns; and, *alpha*, the proportion of utility gained in L(t) while participating in E(t) activities (i.e., social coordination). Individuals are expected to optimize the time invested in both required activities represented by:

$$\max_t U(t) = E(t) + L(1 - t + alpha * t)$$

The value of the maximized equation can be estimated if the sum of both functions, E(t) and L(1-t), is plotted to find the maximum value (Figure 3.2). Formally, the problem is solved by taking the derivative of U(t) when t=0 (shown graphically as a vertical line at the derivative value). The derivative is represented by the equations:

$$\frac{dU(t)}{dt} = 0, \frac{d^2U(t)}{d^2t} < 0$$

and,

$$t^* = \frac{a_L - c_L + \ln\left(\frac{a_E b_E}{a_L(-1+alpha)b_L}\exp(c_E)\right)}{a_E + a_L - a_L(alpha)}$$

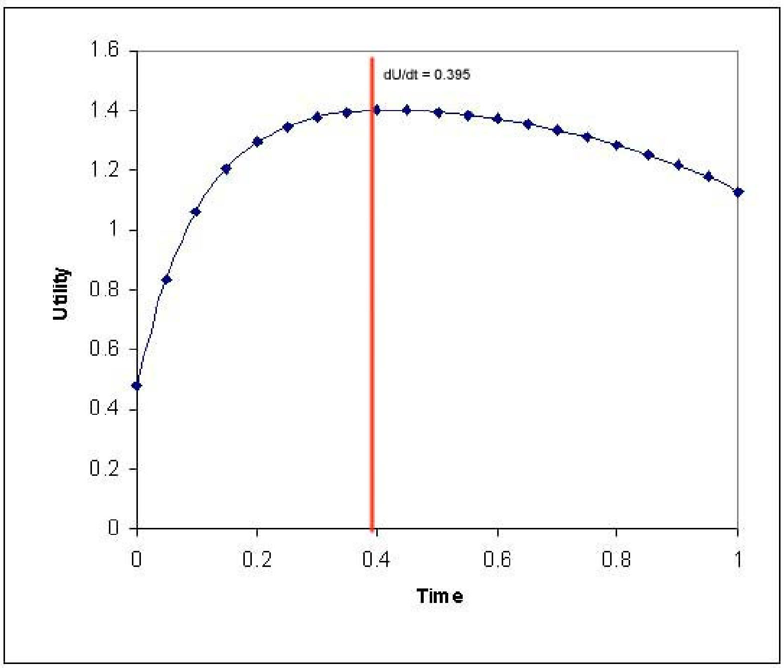


Figure 3.2. This is a graphical estimation of the derivative (dU/dt) of both E(t) and L(t) by adding the two functions together and plotting the values.

The final solution, solved for *t**, is used to estimate the effects of changes in efficiency (*a*), maximum yield (*b*), minimum investment (*c*), and social coordination (*alpha*) caused by various factors such as technology, environment, etc.

3.2.1 Efficiency, *a*

A single utility function, U(t), is defined by the continuous functions of E(t) and L(t) such that changes in the efficiency, *a*, of one will affect the other. The structure of these functions—both are diminishing returns curves—is such that less time will be spent in the activity with the greatest efficiency (highest value of *a*), because more time is required for less efficient activities. Graphically, a high efficiency value translates into a steeper curve with relatively high returns achieved in a short amount of time. Time allocation depends on the difference in efficiency and maximum utility between each function. Higher efficiency values result in greater differences in time allocation between each activity. Variation in efficiency between activities can be modeled as the adoption of new technologies, changes in the abundance of high ranking prey, increases in population density, etc.

3.2.2 Maximum Yield, *b*

In the utility function, U(t), maximum yield, *b*, is the upper limit of the efficiency curve and affects time allocation. It is a proxy for the relative productivity between energy and leisure activities. More time will be spent in the activity with the larger *b*-value to maximize total utility. Changing the value of maximum yield can represent the introduction of more efficient technologies and strategies, resource abundance, environmental change, etc.

3.2.3 Delayed Returns, *c*

The delayed returns constant, *c*, models the effects of minimum time required to achieve positive returns. Minimum investment, *c*, is a factor of time (*t*) and does not affect the total amount of time devoted to each activity because the rate, *a*, and maximum yield, *b*, are unchanged. However, an increasing value of *c* decreases the value of time spent on the activity at any given point in time. Graphically, the entire curve is shifted down the y-axis (either E or L axis) and has an x-intercept (or T intercept) at which positive returns begin. Delayed returns can increase search or processing time in E(t) activities, or increased social networking time in L(t) activities.

3.2.4 Social Coordination, *alpha*

Social coordination is modeled by integrating the constant, *alpha*, into L(t) as the proportion of leisure utility gained while spending time in subsistence. In many hunter-gatherer societies, this is known as social foraging, where social and political activities are completed during daily subsistence routines or seasonal feasting traditions. The constant, *alpha*, is a proportion and varies between 0 and 1; 0 representing no leisure utility gained during subsistence and a value of 1 indicating that leisure utility is fully satisfied during subsistence (both extreme values are not likely to occur). As the value of *alpha* increases, the initial utility of L(t) increases resulting in more time spent in E(t) activities.

3.3 MODELING TMIN AND EMAX RESPONSE TO MORE EFFICIENT TECHNOLOGIES AND INTENSIFICATION

Documenting the response of Tmin and Emax adaptive strategies in the archaeological record to the introduction of new technologies—or any other changes in efficiency—requires a measure of time allocation. Fortunately, tools used during subsistence show evidence of time invested during manufacture and maintenance. The details of generating data on time spent manufacturing and maintaining tools are reviewed in a description of analytical methods provided in Chapter 4. Briefly, these data are used to assign tools to functional categories whose basic criteria distinguish between formal tools (i.e., tools that required more time to manufacture and maintain but were retained longer) and expedient tools (i.e., tools that required little investment of time in manufacture or maintenance, but were not curated). The time invested in subsistence technology is quantified by indices that measure the proportion of formal tools in assemblages (i.e., formal flakedstone tools/total flakedstone tools, formal groundstone/total groundstone tools), and the degree of care taken in flakedstone tool manufacture (i.e., non-diagnostic shatter/total debitage). Relative changes in the time invested in tool manufacture are direct evidence of changes in time allocated to subsistence overall. While the true proportion of time devoted to subsistence can never be determined archaeologically, the formality indices act as a strong proxy because they are based on material data. The following models cast predictions in terms of changes in each formality index.

3.3.1 Initial Parameters

Setting up the model requires translation of key assumptions about each adaptive strategy—time minimizers and energy maximizers—into values for each constant: *a, b, c,* and *alpha*. Basic assumptions about time minimizers and energy maximizers are summarized in Table 3.1. Given similar environments, time minimizers are expected to have a higher *initial* rate of return, *a*, than energy maximizers because time minimizers are generally expected to practice low cost/immediate return subsistence rather than high cost/delayed return subsistence such as energy maximizers. The maximum utility of subsistence time is lower for Tmin, however, because they are not expected to coordinate efforts to ramp up energetic intake. Instead, Tmin should have social mechanisms inhibiting increased food production (see Bettinger 1999). Energy maximizers lack controls on subsistence intake and should actively try to increase maximum yield. Because of the difference in subsistence tactics, Tmin should have very low minimum time investment requirements on subsistence while Emax often experience noticeable delayed returns.

The maximum utility of non-subsistence time, L(t), is assumed to be lower and should increase at a slower rate for Tmin than it does for Emax (see Table 3.1). In foraging economies, populations are generally less dense, have less frequent individual social encounters, and do not have the coordination requirements of Emax economies.

Table 3.1. Assumptions for Each Model Parameter for Tmin and Emax

Constant	**Energy**	**Tmin**	**Emax**
a	initial rate of return	higher	lower
b	maximum utility	lower	higher
c	minimum time required	small	larger

Constant	**Leisure**	**Tmin**	**Emax**
a	initial rate of return	lower	higher
b	maximum utility	low	high
c	minimum time required	little to none	moderate to high
alpha	proportion of leisure gained during subsistence	small	large

Emax economies, on the other hand, do have coordination requirements, are more dense, and have more frequent individual social interactions implying that the rate of return on L(t) will be faster with a higher maximum utility since there are more social coordination problems that require attention. Emax economies are also expected to have higher *alpha* values indicating integration of leisure and subsistence time through social coordination. The converse is true for Tmin, who are expected to have low *alpha* values—at least initially—because of a lack of large-scale coordination in subsistence.

Table 3.2 translates the assumptions listed in Table 3.1 into parameter values, and provides an estimation of the derivative value, proportion of time spent on energy and leisure, and utility gained. The parameter values are proxy measures intended to illustrate the conceptual differences between Tmin and Emax.

Table 3.2. Model Parameters Translated Into Proxy Values

Utility	**Constant**	**Tmin**	**Emax**
	a	10	4
Energy	b	1	2.5
	c	0	0.2
	a	3	6
	b	0.5	1
Leisure	c	0	0
	alpha	0.1	0.2
dU/dt		**0.395**	**0.788**

Graphically, the differences between Tmin and Emax are visible in the shape of efficiency curves, maximum yield, and delayed returns. From Figure 3.1, it is clear that the proportion of time spent in subsistence for Tmin is approximately 39 percent, in contrast to roughly 78 percent for Emax. In both examples, parallel changes in individual parameters elicit a similar response. For instance, increasing the rate of return in E(t) results in less time spent in subsistence—the derivative value shifts left on the graph.

Increasing the maximum utility in either energy or leisure results in more time devoted to that pursuit. Increasing minimum time investment for positive returns necessarily results in more time spent in that activity. Finally, an increase in social coordination in L(t) results in more overall time spent in subsistence—the derivative line moves to the right on the graph. Despite the similar response of both Tmin and Emax models to changes in individual constants, each behaves according to theory when the constants are considered together. This is clarified when considering the introduction of new technologies and intensification.

3.3.2 Introduction of New Technologies

This research is specifically concerned with the socioeconomic response of hunter-gatherers in southern California to new technologies. In the Santa Barbara region, this includes the bow and arrow, circular fishhook, and plank canoe. Of these, only the bow complex appears in the San Diego region. The bow and arrow complex is considered a major technological innovation vastly superior in accuracy to its predecessor—the atl atl (see Bettinger 1999; Hrdlicka 2002). The atl atl is most effective in close range with several individuals and it is sufficient to bring down large game. However, the bow and arrow makes individual hunters more successful by increasing the range of accuracy and the chances of killing both large and small game (greater penetration) (Hrdlicka 2002). The simple mechanism of the bow makes it easier to use than the atl atl (see Hrdlicka 2002) and reduces variation between hunters that vary in skill. These factors make the bow and arrow a significant technological innovation that should elicit response in both Tmin and Emax economies.

Modeling introduction of the bow is as simple as increasing the energetic return rate (*a*). The bow increases the energetic return rate because it is more efficient (i.e., requires less time) at taking the same amount of game that can be acquired by the atl atl. In both Tmin and Emax models, *aE* is hypothetically increased by 20-percent, resulting in a decrease in the amount of time spent on subsistence (Table 3.3, Figures 3.3, 3.4a and 3.4b).

Table 3.3. Parameter Changes for Tmin and Emax after Introduction of the Bow

Utility	Constant	Tmin	Emax	Emax, Second Order Changes
Energy	a	12	5	5
	b	1	2.5	4
	c	0	0.2	0.2
Leisure	a	3	6	6
	b	0.5	1	1
	c	0	0	0
	alpha	0.1	0.2	0.2
dU/dt		**0.353**	**0.73**	**0.778**

The initial response fits with theoretical expectations of the Tmin conceptual model because the bow allows time minimizers to spend more time in much-preferred leisure activities. However, the conceptual model dictates that social institutions in an Emax economy should quickly require the time saved by using the bow to be spent on increasing overall energetic yield (see Table 3.3). In the Emax model, increasing maximum energetic yield—*bE*—combined with the bow's enhanced efficiency—*aE*—drives the time spent in subsistence back up.

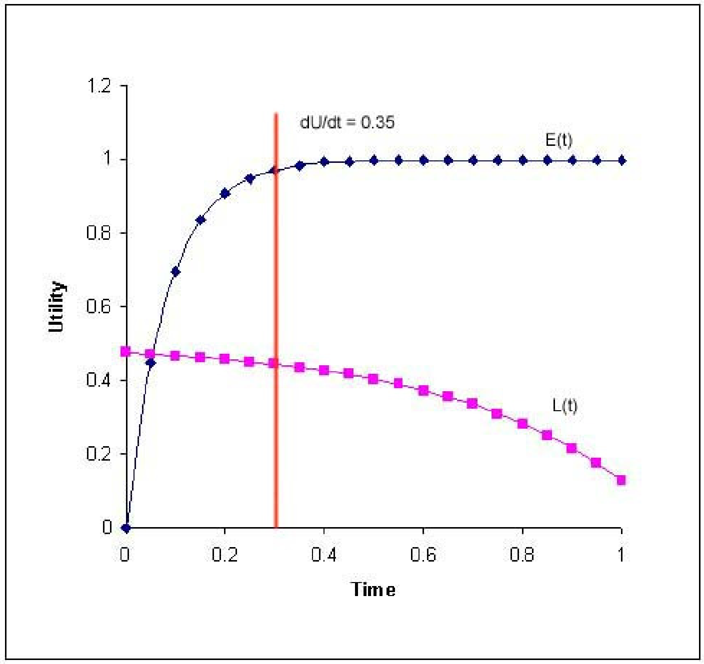
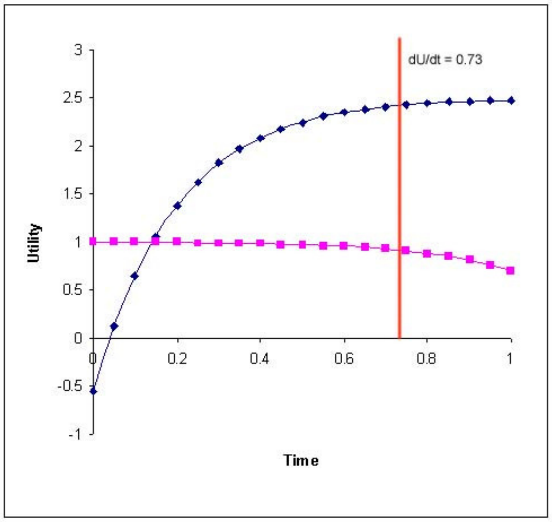


Figure 3.3. Tmin response to introduction of the bow and arrow. Note the derivative value changed from 0.39 to 0.35, indicating less time spent in E(t).

Predictions of the model are summarized in Table 3.4. The model predicts that a Tmin economy should spend less time in subsistence overall. This should translate into a decrease in the flakedstone formality index, lithic waste index, and groundstone formality index (see Table 3.4). Since Tmin prefer more leisure time over more energy, the increased investment required for bow and arrow manufacture should be offset by decreased investment in the manufacture of other subsistence tools—flakedstone and groundstone. Regarding debitage, more care is necessary for arrow point manufacture resulting in a higher proportion of finishing flakes (i.e., biface thinning and pressure flakes) relative to undiagnostic shatter.

For an Emax economy, introduction of the bow and arrow should have the opposite effect. Preferring more energy at the expense of free time, Emax economies should invest more in subsistence technology to increase reliability, resulting in an increase in the flakedstone formality and groundstone formality indices (see Table 3.4). A decrease in the lithic waste index is also expected, given more care needed in making arrow points.



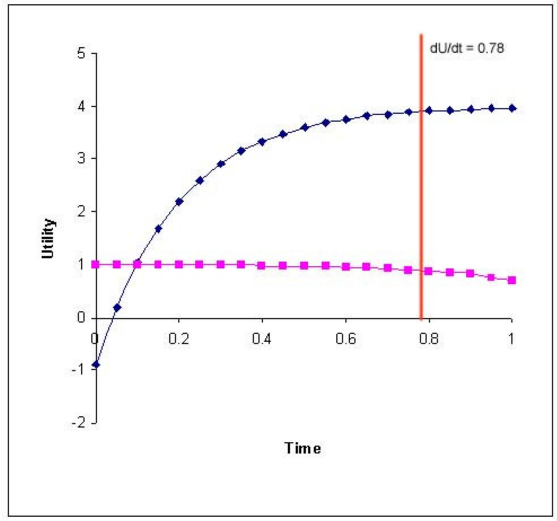


Figure 3.4a (left) exhibits the Emax initial response to introduction of the bow and arrow. Figure 3.4b (right), is the second-order Emax response, applying time saved by using the bow to increase maximum yield. Note the derivative value initially decreases from the initial value of 0.78 to 0.73 after the bow, and then increases again to 0.78 after more energy is harvested.

Table 3.4. Predictions of the Tmin-Emax Model Regarding Response to the Bow and Arrow

	Tmin	**Emax**
Model Prediction	Spend less time in subsistence	Use time saved by using bow to get more energy
Archaeological Prediction		
Flakedstone Formality Index	⇩	⇧
Lithic Waste Index	⇩	⇩
Groundstone Formality Index	⇩	⇧

Introduction of the bow and arrow is only one example—albeit one of the most important—of how new technologies can impact different adaptive strategies. Measuring the impact of other novel technologies is accomplished in the same way, but changes in each constant must be justified by theory. With the bow, a simple increase in the energetic return rate has different theoretical consequences for Tmin and Emax. Tmin simply save additional time on subsistence. Emax initially save time on subsistence but quickly use these savings to extract higher levels of energy.

Another new technology considered in this research includes the circular fishhook, which is expected to increase *aE*; circular fishhooks are much better at capturing single fish in open water than earlier hooks and gorges (Salls 1988). The role in subsistence of the circular hook is similar to the bow can facilitate a specialization on fishing. It is already known that the circular hook was not put to use in the San Diego region, but is a common constituent of Santa Barbara assemblages. If circular hooks drive the development of a fishing specialization, other related cultural material should also appear in the material record, such as manufacturing tools (i.e., drills/borers), that would lead to an additional increase in the flakedstone formality index. Eating more protein-rich fish would also result in an increase in the groundstone formality index in order to maximize yield from processing carbohydrate-rich plant foods needed to balance nutrition.

3.3.3 Intensification

Modeling the effects of intensification in Tmin and Emax economies illustrates the interrelatedness of each constant. Intensification in subsistence is a process where incrementally less utility is gained from additional inputs of labor. This is commonly referred to as diminishing returns, which is partially accounted for in the negative exponential of both energy and leisure utility functions.

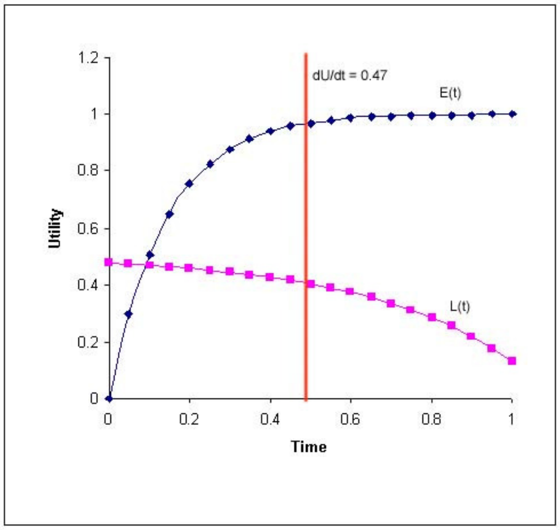
Understanding the response of Tmin and Emax models to intensification requires changing the value of certain constants to reflect changes in return rate, maximum yield, and social coordination. This is best undertaken in a stepwise fashion. Diminishing returns is initially accounted for by reducing *aE* (Table 3.5).

Table 3.5. Parameter Changes for Tmin and Emax to Model Intensification

Utility	**Constant**	**Tmin**		**Emax**	
		1st Order	2nd Order	1st Order	2nd Order
	A	7	3	3	3
Energy	B	1	1	2.5	2.5
	C	0	0	0.2	0.2
	A	3	3	6	6
Leisure	B	0.5	0.5	1	1
	C	0	0	0	0
	Alpha	0.1	0.25	0.2	0.3
dU/dt		**0.479**	**0.758**	**0.852**	**0.941**

For ease, this example begins with the parameters for Tmin and Emax following introduction of the bow (see Table 3.3). A hypothetical reduction in *aE* by 40-percent results in a greater than 12-percent increase in time devoted to subsistence for both Tmin and Emax (see Table 3.5, Figures 3.5 and 3.6). The reduction in energetic returns (i.e., diminishing returns) can be due to several factors such as increases in population density or environmental degradation, either of which can make food harder to come by.

The archaeological implications for this first stage of intensification are different for Tmin and Emax (Table 3.6). Time minimizers, now spending more time on subsistence for the same energetic yield, should attempt to save time by reducing manufacturing costs in secondary subsistence technologies. This should be visible as a decrease in the flakedstone formality index and an increase in the lithic waste index. However, intensified subsistence in a Tmin economy would likely involve greater regularity and intensity of vegetal processing, leading to an increase the groundstone formality index.



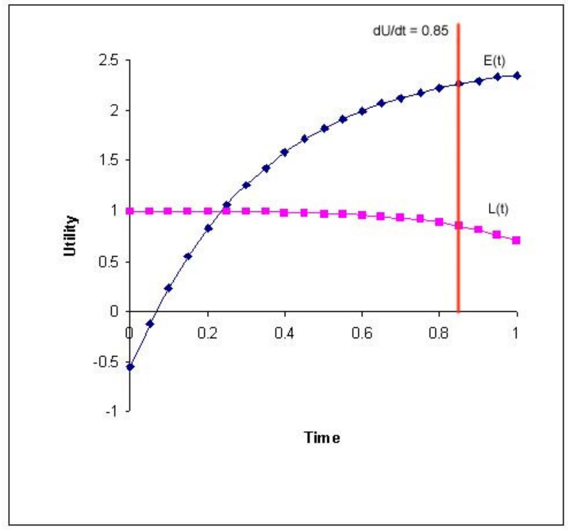


Figure 3.5 (left) is a Tmin economy undergoing intensification (note the derivative line shifted right from 0.35 to 0.47, indicating more time spent on subsistence). Figure 3.6 (right) is an Emax economy undergoing intensification—the derivative line also indicates more time spent on subsistence.

Table 3.6. Predictions of the Tmin-Emax Model Regarding Intensification

	Tmin	**Emax**
Model Prediction	Spend more time in subsistence	Spend more time in subsistence
Archaeological Prediction		
Flakedstone Formality Index	⇩	⇧
Lithic Waste Index	⇧	⇩
Groundstone Formality Index	⇧	⇧

Diminishing returns in an Emax economy should appear archaeologically as an increase in the flakedstone formality and groundstone formality indices, and a decrease in the lithic waste index (see Table 3.6). Decreased efficiency should prompt energy maximizers to produce more efficient and reliable tools, increasing the proportion of formal flakedstone and groundstone and increasing the proportion of diagnostic finishing flakes relative to shatter.

There are several reasons for this. First, a strong preference for energy at the expense of leisure time should elicit a desire for greater tool reliability and this should be manifest as increased shaping effort. Second, the increased preference for energy might be manifest conceptually in tool design or decoration (i.e., decorated mortars, etc.). Investment in subsistence tools for reliability and ideological purposes reflects the importance of those items in everyday life.

The second-order effects of intensification relate to social coordination. When *alpha* is increased, the model predicts that more time will be spent in subsistence (see Table 3.5). This fits with expectations for Emax; increasing social coordination—alpha—in this model results in almost all time spent in subsistence activities (see Table 3.5). A strong preference for energy should structure social relations so that energy acquisition is maximized (i.e., greater division of labor, communal work efforts, etc.).

An increase in *alpha* is counter-intuitive for Tmin economies; it is expected that the integration of leisure and subsistence activities should remain relatively low for Tmin even during intensification. Tmin should exhibit greater integration of energy and leisure activities—i.e., increase *alpha*—only if the energetic return rate dropped dramatically due to high population densities or decreased resource availability. Both circumstances can be expected to cause groups of hunter-gatherers to rely more heavily on their neighbors for provisioning and thus facilitate coordination of non-subsistence activities (i.e., political alliances, etc.). To model this, *aE* is hypothetically decreased from 7 to 3 and *alpha* is increased from 0.1 to 0.25 (see Table 3.5). This results in a dramatic increase in time devoted to subsistence (see Figure 3.7a and 3.7b).

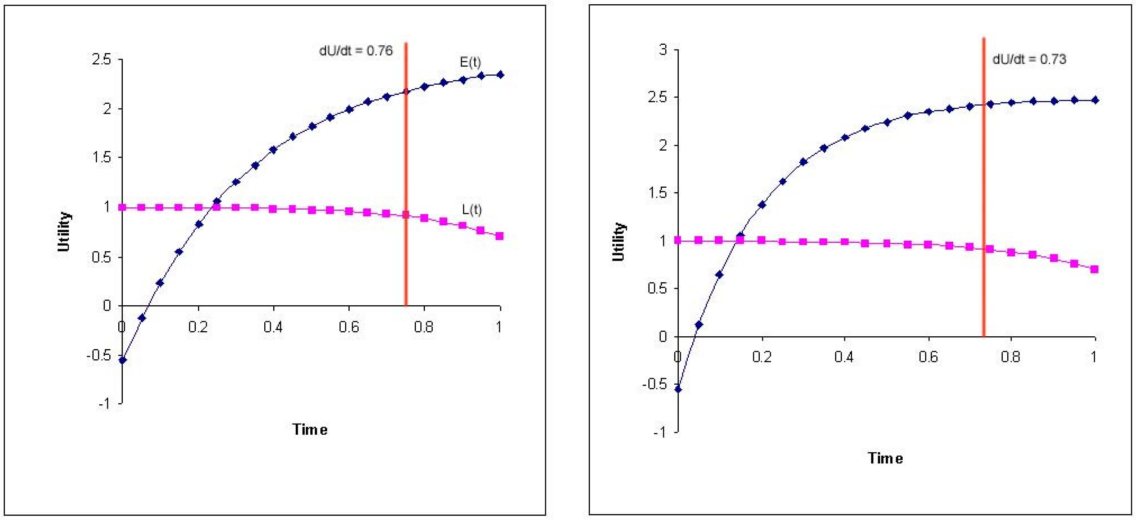


Figure 3.7a (left) is an intensified Tmin economy with increased social coordination (alpha). Figure 3.7b (right) is an Emax economy equipped with the bow and arrow. Note that the intensified Tmin economy spends more time on subsistence setting up the conditions for socioeconomic change from Tmin to Emax strategies.

Under these conditions, the amount of time invested in subsistence is roughly equal to that of an alternative Emax acorn economy after introduction of the bow, however, the energetic returns in the alternative Emax economy are 2.7 times greater (see Table 3.5). At this point, when overall conditions are poor in a Tmin economy (i.e., energy and leisure yields), a coordinated shift may occur that mobilizes enough individuals to begin the alternative Emax strategy; simply because it satisfies the immediate preference for more free time. Eventually, the coordination required to run the Emax economy will be reinforced by the evolution of new social institutions to stabilize the adaptive strategy leading to an overall shift in preference structures to favor energy over free time.

The archaeological implications for greater social coordination are less straightforward. An Emax economy should exhibit higher formality indices while a Tmin economy should continue to discount time invested in subsistence technology in any way possible without sacrificing efficiency. However, when conditions in a Tmin economy significantly deteriorate, an abrupt shift to the alternative Emax economy should occur. Thus, the Tmin-Emax models predict that both strategies should diverge in their response to intensification and that the shift from Tmin to Emax is abrupt. The details of this shift are portrayed more clearly in the modified Ideal Free Distribution.

For the Tmin-Emax model, it is important to remember that the concept of time minimizing and energy maximizing as ESS's is what guides the modification of model parameters and provides some insight into the nature of change in the utility of time spent in subsistence and leisure. For instance, the rate of energetic return and maximal level of energetic gain are strongly linked such that the instantaneous time savings predicted for energy maximizers after introduction of the bow would be immediately translated into a higher maximum energetic yield. Additionally, social foraging/processing is a significant component of Emax economies that embeds L_t in E_t. That is, the real difference between Emax and Tmin is that Emax provides a social benefit between the subsistence return rate and its maximal energetic yield through greater coordination in non-subsistence activities.

3.4 IDEAL FREE DISTRIBUTION

The Ideal Free Distribution (IFD) is a model that can be modified to make useful comparisons between different adaptive strategies and to better understand socioeconomic transitions. First, the basic structure of the original model by Fretwell and Lucas (1970) is reviewed. This is followed by a discussion on modifications to some of the assumptions to model the transition between Tmin and Emax adaptive strategies.

3.4.1 The Original Ideal Free Distribution (Fretwell and Lucas 1979)

Fretwell and Lucas (1970) developed the Ideal Free Distribution (IFD) to explain why birds congregate in habitats that differ in quality. The IFD model assumes that individuals have an ideal capacity to perceive of variability in habitat quality and select the most suitable habitat. The model also assumes that individuals are free to occupy any available habitat. Thus, the distribution of individuals across habitats is a behavioral phenomenon.

Intrinsic quality of a habitat refers to the availability and distribution of resources necessary for survival and reproduction. Habitats are not contiguous but represent discrete areas. The difference between habitats is perceived by individuals as relative goodness, or suitability for occupation. In the original model, habitat quality is a proxy for average foraging return rates because it is assumed that incremental population growth diminishes food supply, etc. Refer to Fretwell and Lucas (1970) for original algebraic derivation of habitat suitability.

There are two perspectives on the maximum suitability of a given habitat. The most basic perspective assumes that maximum habitat suitability occurs as the density of occupants approaches zero (Fretwell and Lucas 1970:20). That is, with lower densities, more resources are available to newcomers increasing their potential to maximize fitness. In this scenario, individuals first congregate in the habitat with the highest initial suitability (at zero individuals) (Figure 3.8).

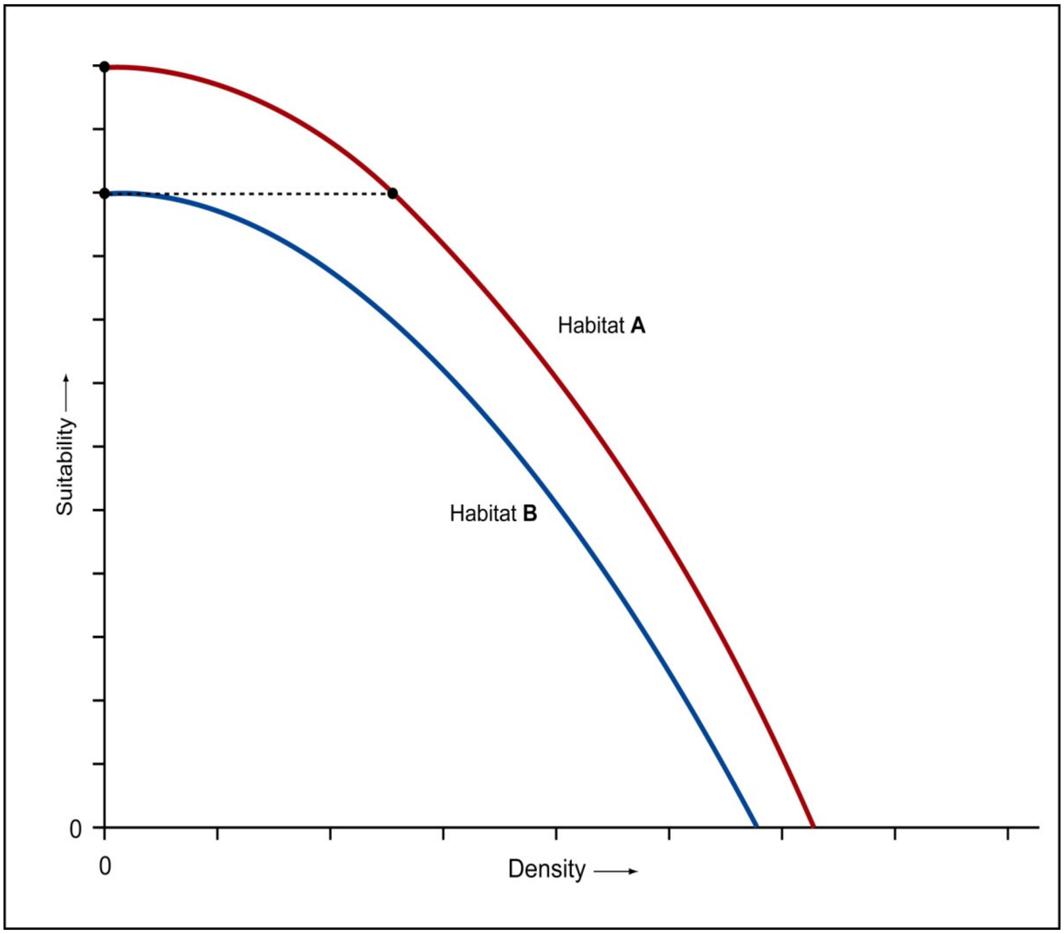


Figure 3.8. A model of the standard Ideal Free Distribution. Individuals colonize Habitat A first because it has a higher initial suitability, and only populate Habitat B when the suitability in Habitat A diminishes with each additional individual to the point that suitability in Habitat A is equal to Habitat B. Both habitats then have the same mean suitability as habitats are filled evenly.

As individuals continue to colonize the original habitat through migration and endogenous population growth, its suitability declines until it is equal to the initial suitability of another habitat with a lower intrinsic quality. Habitat quality is now perceived as equal and individuals fill both habitats evenly resulting in an equilibrium population structure. Suitability in both habitats remains equal and continues to decline, even though the original habitat maintains a higher population density.

There are a number of reasons why this perspective might not be realistic among social animals. Individuals might choose to congregate with conspecifics to spread the risk of predation over the group, to cope with risk of starvation by sharing food, or to cooperate in food acquisition or other social activities. For example, maximizing reproductive success is density dependent because it requires access to mates. Such frequency dependent problems are accommodated by the Allee effect (Fretwell and Lucas 1970:19, see also Allee et al. 1949). The Allee effect occurs when survival and reproduction increase with population size. The Allee effect will increase habitat suitability when population densities increase to some optimal size and then decline thereafter with each additional newcomer (Fretwell and Lucas 1970:23-25). When the suitability of alternative habitats is characterized by the Allee effect, changes in population structure are discontinuous because the habitat with higher intrinsic suitability is depopulated until its suitability is equal to the lower quality habitat at its maximum density (Figure 3.9).

When individuals vary in competitive abilities, they may become despotic and attempt to restrict access to resource patches to prevent incremental habitat degradation. When territoriality is incorporated into the IFD, it is typically referred to as the Ideal Despotic Distribution (IDD) (see Fretwell and Lucas 1970). If an individual or group restricts access to a habitat, newcomers and individuals/groups with lower competitive ability will be forced to occupy poorer habitats. This will result in the best competitors occupying the best habitats in lower densities and inferior competitors aggregated in poorer habitats at higher densities (see Sutherland 1996). Despotism decreases the perception of habitat quality to newcomers or inferior competitors such that habitats with lower intrinsic suitability are perceived as better alternatives.

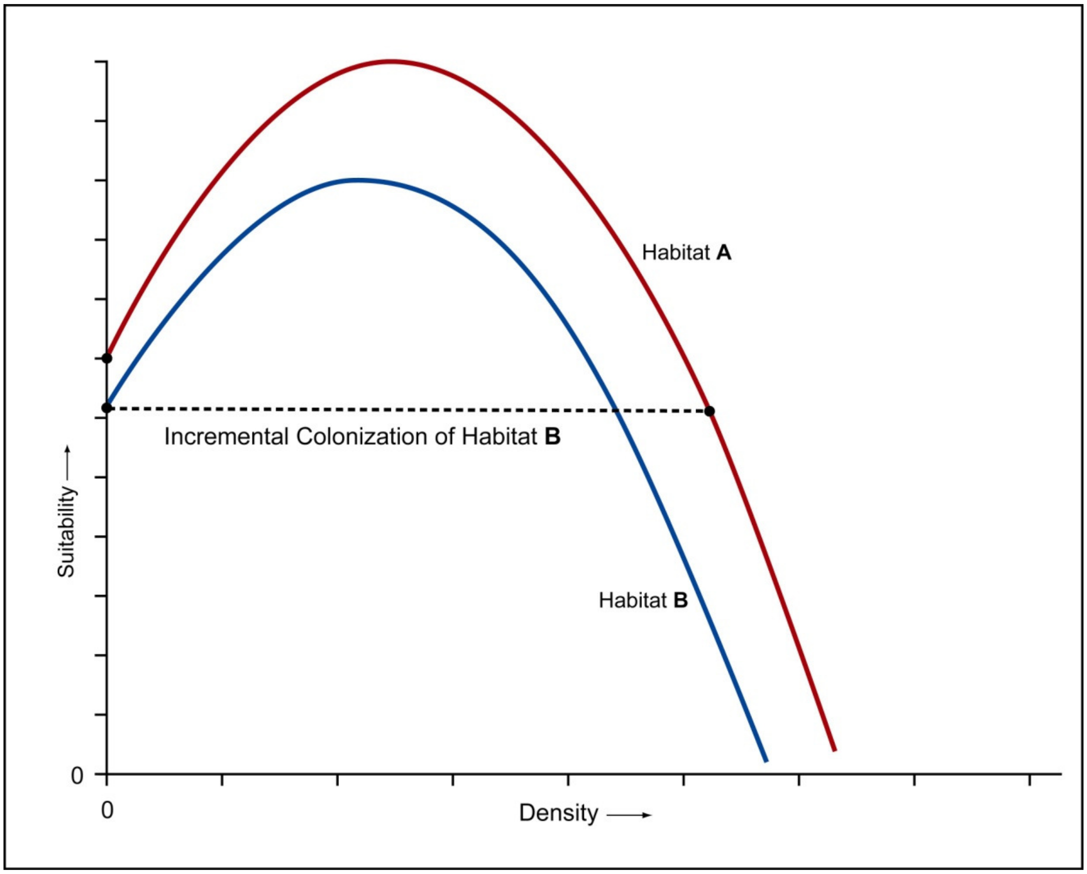


Figure 3.9. Allee-based Ideal Free Distribution model. The Allee effect causes maximal habitat suitability to be achieved with some minimum number of individuals populating the habitat. The habitat with a lower initial suitability, Habitat B, is only populated after the population in Habitat A grows large enough to surpass its maximum suitability, declining to the point that it is equal to the initial suitability of Habitat B.

When the mean population strategy is to achieve an ideal free distribution, it can become an Evolutionary Stable Strategy (ESS) (Quijano and Passino 1995:5). At an IFD, newcomers to the population with a different strategy will not fare as well—i.e., have lower fitness—and will be out-competed. When these conditions are true, the population is at Nash equilibrium (see Maynard Smith and Price 1973; McElreath and Boyd 2007). In a population structured by the IFD, individuals share a mean fitness, whether in the habitat with highest or lowest intrinsic suitability. Comparing populations structured according to the IFD model, despotic behaviors can be stabilizing controls making it even harder for competing strategies to invade.

3.4.2 Modifying the Ideal Free Distribution to Model Changes in Human Populations

The IFD model is convenient for explaining a wide range of problems pertaining to human population structure (see Kennett et al. 2008, Kennett and Winterhalder 2006; Lessells 1995). However, with modification of certain parameters, the IFD model is particularly well-suited to understand discontinuous socioeconomic shifts.

It is probably safe to assume that the Allee effect characterizes all human societies since much of what humans do is socially coordinated. However, the justification of other factors is theoretically distinct from Fretwell and Lucas (1970). First, the concept of habitat can be replaced with niche to account for spatial overlap in economic strategy, even if they closely track geography—i.e., deep water fishing or acorn processing. In this sense, a niche can be a socioeconomic mode of production as well as a geographically discrete habitat. The assumption that habitats must be spatially distinct is not necessary to describe human populations, except in the most extreme or risky environments. Human occupation is more likely characterized by adaptive strategies that dictate which niches are economically important. It is possible to have spatially overlapping niches when different resources are exploited.

Second, the concept of ideal niche selection capability is more direct among humans than non-human foragers because of the effect of cumulative (cultural) knowledge. The IFD is a model of aggregate individual-level decisions regarding behaviors that affect fitness. Niche suitability can be thought of as a proxy for average fitness benefits, especially since a niche—whether a physical habitat or mode of production—yields resources critical for human survival and reproductive success. In Darwinian evolution, it is generally assumed that humans have an evolved capacity for rational behavior that tends to maximize fitness. In the IFD, this would equate to relatively ideal niche selection capabilities—the ability to perceive of average changes in potential fitness within and between alternate niches. This could be as simple as understanding that a particular mode of production requires a minimum number of coordinated laborers. Such an understanding is much more likely among humans that bank information on particular environments, foods, and economic strategies than non-human societies (Richerson and Boyd 2005).

Third, humans (and non-humans) are not always free to occupy any available niche, especially when newcomers face a despotic resident population, or when an unoccupied niche requires a minimum number of individuals for successful colonization. When newcomers encounter resident populations, they may perceive occupation of that niche as risky—this is accounted for in the Ideal Despotic Distribution. Despotic residents can threaten newcomers with violence or simply outcompete them by controlling resources. In addition, minimum density requirements can be prohibitive to occupation of a niche, also negating the assumption of free niche selection.

Since humans tend to coordinate their subsistence behavior with others, density dependent problems are especially relevant. In the IFD, changes in population structure are density dependent; higher population densities affect niche suitability and colonization. Economies of scale are a good example of density dependent problems among human populations. Eric Alden Smith (1991) provides a clear example of how the density of a group of hunters affects the overall per capita rate of return on hunting efforts. In certain kinds of hunting, the per capita return rate increases until a certain group size is reached where the cooperative efforts of multiple individuals are more efficient than smaller groups or the individual hunter. After this optimal group size is reached, the return rate diminishes with each additional hunter added to the group. Smith noted that groups will continue to allow additional hunters to join, to a certain limit, while experiencing a drop in the overall return rate. Excluding a hunter might hinder social relationships between groups and inhibit reciprocal group membership in the future (c.f. Kelly 1995:219-220). However, it is not likely that a hunter will join a group if the overall per capita return rate of the group is relatively the same as or lower than that attained by hunting alone. This example closely parallels the conceptual framework provided by the Allee-based IFD since hunting groups can be considered alternative niches with varying return rates.

Frequency dependent problems also affect how humans occupy different niches. Considering sexual division of labor, if women are the primary processors or acorns, the frequency of women in a population would strongly affect the success of a burgeoning acorn economy among that population. This could determine the degree to which men could specialize on fishing, for example.

3.4.3 Time Minimizing-Energy Maximizing: Density-Dependent Modes of Production in the IFD

Time minimizing and energy maximizing adaptive strategies can be incorporated into the IFD model as separate modes of production that vary with respect to initial and maximum suitability, return rate, and population density. To set up the model, the suitability curves of Tmin and Emax must reflect the assumptions of each strategy outlined in the Tmin-Emax model (Table 3.8).

Table 3.8. Expectations of Tmin and Emax Economies in the Same Physical Environment

	Time Minimizers	**Energy Maximizers**
Initial Suitability	Higher	Lower
Minimum Density	Very Low	Higher
Allee Effect	Smaller	Larger
Population Density at Maximum Suitability (height of curve)	Lower	Higher
Rate of Diminishing Returns (steepness of curve)	Faster	Slower
Overall Density	Lower	Higher

Figure 3.10 illustrates two curves representing the Tmin (niche A) and Emax (niche B) modes of production. The major differences between the two curves are that niche B has a minimum density threshold, lower initial suitability, and a higher maximum suitability at higher densities. Assume that niche A represents a Tmin foraging economy without specialized subsistence and niche B is an Emax acorn economy. The intrinsic suitability of niche A (SiA) is higher than that of niche B (SiB) because foraging in a low density population has relatively high returns—i.e., foragers are able to pursue higher quality, less abundant resources (see Figure 3.10). Individualized or sporadic acorn processing is very costly and not expected to occur (see Bettinger et al. 1997). The initial suitability of an acorn economy cannot be attained without a minimum density of individuals because of labor requirements. However, once people coordinate labor to exploit acorns in mass quantities, energetic and nutritional yield is amplified.

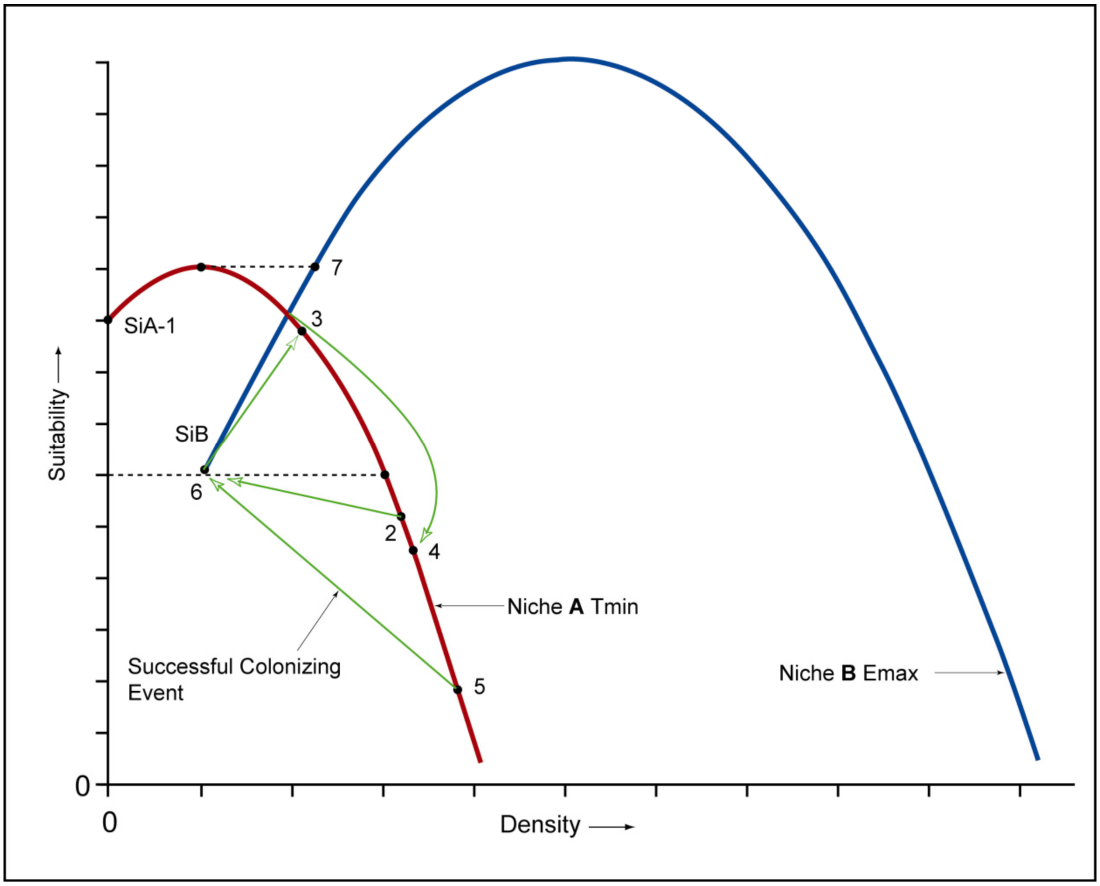


Figure 3.10. Allee-based Ideal Free Distribution model, modified to compare Tmin and Emax economies as distinct niches. The shape, height, and position of each curve in relation to population size can be modified to accommodate the effects of new technologies, environmental change, etc.

Individuals will first occupy niche A and continue to do so experiencing diminishing suitability until it is equal to SiB. With a small increase in the density of niche A (point 2, Figure 3.10) its suitability slightly decreases and the number of individuals necessary to colonize niche B are expected to coordinate and migrate as a group. The migrating group will occupy the new niche with greater suitability than if they stayed in niche A. Consequently, the suitability in niche A will significantly increase (point 3) with the emigration of this group (see Figures 3.10). In this scenario, coordination can occur as long as the payoff for coordination is greater than the payoff of remaining in the initial niche with lower suitability; it does not have to be greater than the maximum payoff of niche A (see Bettinger 1999).

Complex and non-intuitive population dynamics occur after the new niche is colonized because the suitability of the previous niche is higher. If a commitment to coordination in niche B is weak, the colonizing population will split resulting in some members defecting to niche A with a higher suitability. This will reduce the mean suitability (return rate) of the remaining individuals forcing them to switch to niche A as well (point 3, Figure 3.10). If the overall population is assumed to have an intrinsic growth rate, each time defectors reoccupy niche A the suitability in that niche decreases below the initial suitability of niche B (point 4, Figure 3.10). This results in a cycle of colonizing groups to niche B that perpetually fail. To stop the cycle, the overall population must increase such that suitability in niche A is significantly diminished below SiB (point 5). If this occurs, migration of a group to colonize niche B will result in relatively equal suitabilities between both niches stabilizing the population in niche B (point 6).

When suitabilities are eventually equal (point 6, Figure 3.10) newcomers settling in niche B will foster incremental migration from niche A resulting in its eventual depopulation after suitability in niche B passes the maximum suitability of niche A (see point 6). With the depopulation of niche A all newcomers continue to fill niche B until suitability diminishes to the point that it equals SiA. A second non-intuitive prediction is reached when the Allee effect causes an incremental migration to niche A until maximum suitability in niche A is achieved. After this occurs suitability is again at equilibrium between both niches with incremental population growth.

This model anticipates multiple non-intuitive discontinuities in the distribution of a population across Tmin and Emax economies. When shifting to an Emax economy, the model revealed that founding populations in a density dependent economy will often fail until average fitness (suitability) in a Tmin economy degrades dramatically. At that point, an Emax economy should successfully begin and the Tmin economy should depopulate. It is probably true that the number of founding events would be limited, given that Tmin know the cost of an acorn economy (see Richerson et al. 1997), in addition to stable social institutions that actively campaign against such a shift. A second unexpected prediction is that fringe Tmin populations can occur when suitability in a stable Emax economy declines until it is again equal to the initial suitability of a Tmin economy.

Other factors can be incorporated in the model to better understand the dynamics of each mode of production. The introduction of technological innovations can increase energetic returns, thereby increasing suitability, maximum density, etc. The bow and arrow might increase the maximum suitability of a Tmin economy, prolonging its viability in the face of competing Emax economies. Environmental factors could also affect suitability curves. Environmental degradation would drop the maximum suitability and density of a Tmin economy. This would either hasten the transition to an Emax economy, or preclude it altogether if not enough individuals could be mobilized to meet minimum density requirements of the alternate Emax strategy.

Comparing Tmin and Emax as modes of production in the IFD carries significant implications for the archaeological record (Table 3.9). The model predicts that conditions in the Tmin economy should greatly deteriorate before a successful Emax economy begins. An obvious aspect of deteriorating conditions is declining return rates; a condition predicted by the Tmin-Emax model. In the Tmin-Emax model, social institutions are expected to stabilize a strong preference for free time to the point that intensification actually makes time minimizers allocate a majority of time to subsistence—similar to Emax. Deteriorating conditions in a Tmin economy should be manifest as intensification tactics—low flakedstone formality index, higher lithic waste index, and higher groundstone formality index (i.e., more intensive use of groundstone tools for processing).

Table 3.9. IFD Model Predictions and Archaeological Expectations for the Transition from Tmin to Emax

	Archaeological Signature		
Model Prediction	Flakedstone Formality Index	Lithic Waste Index	Groundstone Formality Index
Deteriorating Conditions of Tmin Economy	⇩	⇧	⇧
Cyclical Emax Founding Events	⇧	⇩	⇧

The second major archaeological implication of the IFD when comparing Tmin and Emax economies is that Transitional sites should appear before the Emax economy takes root and supplants the time-minimizing adaptive strategy. Transitional sites are attempts to start an Emax acorn economy. These sites should be small residential sites with relatively diverse assemblages and a significantly larger proportion of formed tools than traditional Tmin residential sites. Specifically, the model predicts that assemblages should exhibit higher flakedstone and groundstone formality indices and lower lithic waste indices. They are small because founding groups are limited in size. Tools should be formalized because Emax economies value energy over time and formalized tools are more reliable than expedient tools.

It is important to remember that social institutions stabilize widely divergent preference structures of the Tmin and Emax adaptive strategies. For Tmin, such institutions might involve male prestige hunting that results in large amounts of time spent pursuing game at the expense of supporting women's gathering and processing roles, inhibiting the development of Emax behaviors and the social institutions that support them (see Bettinger 1999). Additionally, once the shift to Emax has occurred, it is difficult to practice time minimizing without a drop in population, or depopulation of the Tmin niche, due to the density dependent nature of Emax strategies. Considering the fact that the shift from Tmin to Emax occurs in the same geographic area, shifting back to Tmin from Emax would be impossible, absent large scale depopulation, because energy maximizers should exploit available resources more intensively, disallowing time minimizing behavior to take root.

3.5 SUMMARY

The main goal of this chapter was to provide a theoretical context for evaluating the proposition that hunter-gatherers in the San Diego region were characterized by a time-minimizing ESS during the last 3500 years until recent times, and that hunter-gatherers in the Santa Barbara region practiced an energy-maximizing ESS during the same time period. The formal Tmin-Emax model predicts that time-minimizers should respond differently than energy maximizers to various influences, such as the introduction of new technologies, environmental change, population growth, etc. This research focuses on the socioeconomic response of Tmin and Emax to the introduction of new technologies because several major innovations, such as the bow and arrow and circular fishhook, were available in both regions at approximately the same time. The general prediction is that San Diego assemblages should become less formalized, aside from arrow point manufacturing, and Santa Barbara assemblages should exhibit increasing formality. If the Tmin-Emax model is correct, time invested in tool manufacture and use should have different archaeological signatures in each region.

Additionally, subsistence intensification should elicit divergent responses in each region; San Diego assemblages continuing the trend of decreasing tool formality and Santa Barbara assemblages exhibiting subsistence specializations aided by ever-increasing tool formality.

The Ideal Free Distribution model was incorporated to help understand the dynamics of Tmin and Emax as ESS's and the conditions that would lead to a shift from Tmin to Emax. Compared as modes of production, the modified IFD predicts that conditions in a Tmin economy should significantly deteriorate before a comprehensive coordinated shift to Emax would occur. Before such an abrupt shift occurs, however, the model predicts that there should be a series of founding events. These Emax founding events should appear archaeologically as small, diverse residential sites with signatures of the competing Emax economy—in this case, acorn processing and greater tool formality.

The concept behind the Tmin-Emax model is that hunter-gatherers can be defined by completely different adaptive strategies, stabilized by social institutions. If this model does not apply to the San Diego-Santa Barbara contrast, then the converse should be true: hunter-gatherer socioeconomic behavior is instead characterized by a continuum with multiple, weakly-stable equilibria that change when technological and environmental conditions change. If the Tmin-Emax model is not correct, there should be parallel changes in both regions with hunter-gatherers of the San Diego region following the same socioeconomic trajectory as groups in the Santa Barbara region. It is apparent from general overviews of the archaeological record in each region that this does not appear to be true—the main argument being that resources such as acorns and fish were of adequate quality and abundance in the San Diego region throughout the Holocene to support the early development of energy-maximizing tendencies and complex socioeconomic institutions. As such, population growth and environmental change in the San Diego region should have resulted in socioeconomic transformation of the kind that characterized the Los Angeles and Santa Barbara regions, resulting in similar technological trajectories.

4. RESEARCH METHODS

This research is based on the assumption that the organization of subsistence technology reflects the fundamental goals of an adaptive strategy relating to the allocation of time and energy in the manufacture and use of tools. Thus, evaluating the Tmin-Emax concept requires data relating to changes in the frequency and proportion of tool types that vary with respect to manufacturing effort. Specifically, this research focuses on changes in flakedstone and groundstone tool formality. While other aspects of the toolkit in southern California are equally important, flakedstone and groundstone are the most common assemblage constituent in both regions facilitating regional comparison. Other artifact categories (i.e., fishhooks of organic material, subsistence remains, etc.) are considered but only summarized from existing documentation.

4.1 DATA SOURCES

To identify archaeological sites with the potential to address relevant research themes, published and unpublished excavation reports (i.e., evaluation and data recovery) on file at regional information centers and from private libraries were examined. Specifically, archaeological manuscripts were reviewed at the South Coastal Information Center (SCIC), California State University San Diego, and at the Central Coastal Information Center (CCIC), University of California Santa Barbara. While all data were generated from existing collections, I directed field excavations at several of the sites sampled in the San Diego region (e.g., SDI-10714, -10723, and -14571), and participated in fieldwork at many of the other sites (see Hale and Becker 2006).

No rigid method or sampling protocol was instituted for this research. At the regional level, site assemblages were selected for inclusion based on a few simple criteria, including dating, minimal mixing of distinct components, and quality of the curated assemblage. However, some sites with strong data potential were not used because they only added redundancy, or because the assemblage was not in a condition facilitative to this research (i.e., unprocessed, could not be relocated, monographs never produced, etc.). Finally, the sample of sites was intended to capture broad socioeconomic trends in each region; it was not intended to be a comprehensive documentation of archaeological sites. Despite these qualifications, the sample of sites is considered to be representative of each regional site population, with the exception of very small temporary camps that, even if better understood, would be unlikely to clarify temporal trends in subsistence and settlement due a lack of chronological control.

Sampling within specific site assemblages was also done on a case-by-case basis. Some assemblages were analyzed in full. Others were subject to sampling due to the large size of the assemblage. For most assemblages, all available flakedstone tools were analyzed while debitage was sampled. When debitage was sampled for analysis, the sample was drawn from well-dated deposits with the highest data potential.

4.2 ARTIFACT CLASSIFICATION

Artifact frequency data was compiled for all sites. The problem of differential artifact classification schemes was resolved by accessing the collections and examining tools. This provided a better understanding of the artifact categories used by previous analysts and allowed for the reclassification of tools according to the current artifact class definitions. It was not the intent of this research to analyze, in detail, all of the stone tools from each site but to reclassify tools under a consistent framework with the goal of differentiating between formal and expedient tools—formal tools are those requiring greater manufacturing investment (i.e., time and energy). For some assemblages, particularly those with difficult access issues, published analytical protocol (i.e., artifact descriptions, photos, etc.) were sufficiently detailed to reassign artifacts according to the current scheme without physically examining all of the artifacts (see Schroth and Gallegos 1991). It was often true that whole artifact classes could be reassigned to the current categories, give or take a few reassignments (i.e., utilized flakes reclassified as simple flake tools, domed scrapers as formed flake tools, etc.). However, the scraper category from many assemblages were often comprised of items that, for this research, were separated into formed flake tools, retouched flakes, and simple flake tools.

Descriptions of the artifact categories used in this analysis are provided in Table 4.1. These categories have been refined through extensive research on flakedstone and groundstone tools from multiple regions in California and they are supported by detailed studies of manufacture and use (see Basgall 1993; Basgall and Giambastiani 1995; Basgall and Hall 1990; Becker and Iversen 2006; Giambastiani 2003; Hale 2001; Levulett et al. 2000). The biggest difference between the current classification scheme and others used in southern California is that flake-based tools are separated according to the kind and degree of edge modification rather than morphological typologies.

Overall, the different kinds of artifacts are distinguished by morphology and function. Some overlap exists between tool categories. For instance, Formed Flake Tools (FFT) (Figures 1a and 1b) are distinguished from Simple Flake Tools (SFT) (Figure 4.2) by having an intentionally manufactured working edge that has completely modified the original flake form; SFT's are flakes with an edge damaged by use only.

Retouched Flakes (RET) (Figure 4.3) are modified versions of SFTs, having minimal retouch and little to no usewear—the parent flake form still recognizable. All three of these—FFT, SFT, and RET—were used for similar cutting, scraping, chopping, and battering tasks, but each differs with respect to the level of manufacturing investment.

The tool categories described in Table 4.1 contain a mixture of what some analysts would consider formal and expedient tools. For instance, the biface category can contain finished knives or early stage preforms—with the latter being discarded early in the process of manufacture (Figures 4.4 and 4.5). However, unfinished bifaces are considered evidence of high levels of manufacturing effort because a bifacial reduction trajectory is much more intensive, due to platform preparation, than simply using a minimally modified flake or cobble for similar tasks. In general, bifaces were categorized by stage according to Callahan 1979. Note that the biface category does not include flake or cobble-based tools with a single bifacial margin.

Figures 1a and 1b. Formed Flake Tools with bifacially modified convex edges and hafted bases (note traces of asphaltum on the base of each FFT) (SBA-117, artifacts 183-570 and 183-442).

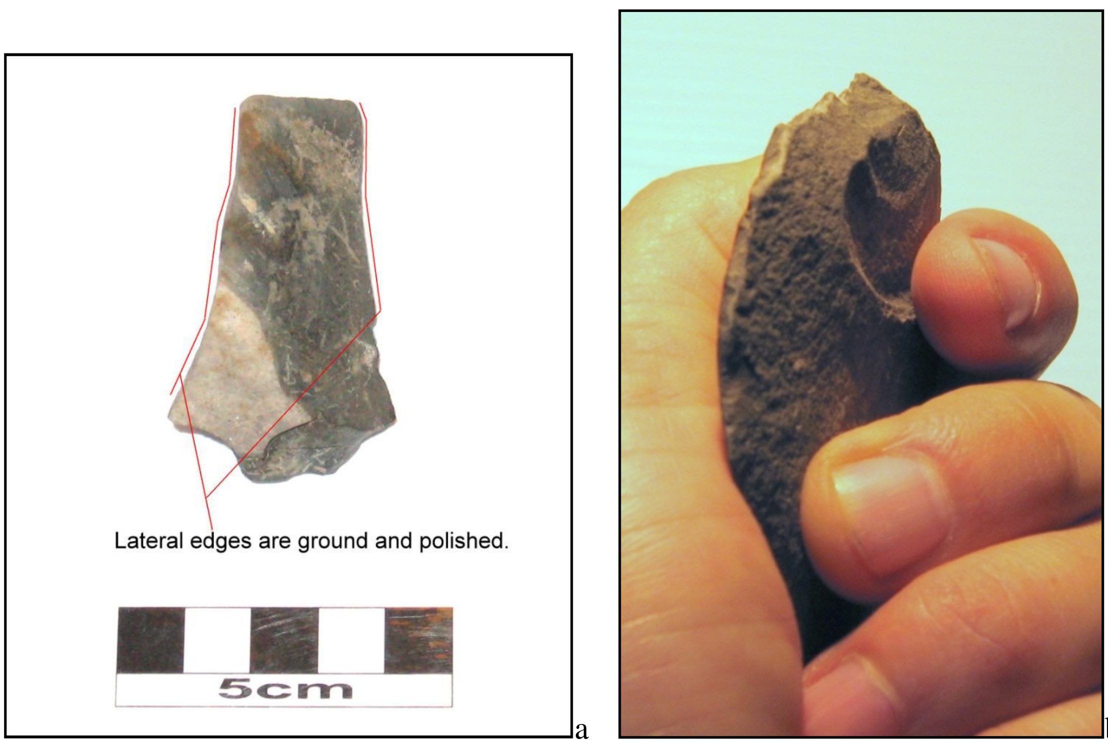


Figure 4.2. Simple Flake Tools: A, SDI-X, catno. X, exhibiting grinding and polish from the use of unmodified edges; B, SBA-72, catno. 448-386, exhibiting edge damage in the form of microchipping and polish.

Figure 4.3. Retouched Flake exhibiting multiple, irregular notches (SDI-691, unprovenienced).

Figure 4.4. A finished bifacial knife with a single, convex working edge (SBA-71, artifact 447-57).

Table 4.1. Descriptions of Artifact Categories

Artifact Category	Formal or Expedient?	Description
Projectile Point (PPT)	Formal	spear points, atl atl dart points, arrow points; an implement fastened to the end of a shaft to facilitate penetration. These are typically made of stone, but can be made from bone, wood, and shell. All projectile points in this analysis are made from stone and are probably either dart or arrow points. Recognized types include Elko, Pinto, Cottonwood, Desert Side-Notched, Saratoga Springs, Dos Cabezas, Canalino, and various other leaf-shaped and corner notched forms. These are formal flakedstone items.
Biface (BIF)	Formal	A flakedstone item with flake detachments from either side of a single margin. This category only includes items that have been fully modified by bifacial flaking, such as knives and other cutting implements, and generic bifaces (unknown function). Bifaces are considered formal. This category does not include items with modification to a single edge only (some flake tools have bifacially-modified edges, but are not included here). Projectile points and preforms are not included in this category.
Formed Flake Tool (FFT)	Formal	A flake with intentional flake detachments from one or more edges to the extent that the parent flake form is unrecognizable. These are formal tools that include traditional categories such as thumbnail and domed scrapers, among others.
Retouched Flake (RET)	Expedient	A flake with intentional flake detachments from one or more margins; flake detachments are irregular in length and spacing. These artifacts typically show little to no use-wear and are considered expedient tools or items rejected during artifact manufacture.
Simple Flake Tool (SFT)	Expedient	A flake with modification to one or more edges caused by use only. These are expedient flake tools.
Core	NA	A mass of flakedstone raw material from which flakes have been detached.
Core/Cobble Tool (CBLTL)	Expedient	A core or flaked cobble (including excessively large flakes) that exhibits damage on one or more margins. This category includes the traditional scraper plane and chopper categories.
Scraper	Expedient	A flake that has been unifacially modified along one or more edges, or that exhibits extensive edge damage. This is a traditional artifact class that primarily overlaps RET and SFT. The category was only retained when the full artifact collection could not be accessed for analysis.
Hammer	NA	A stone used for pulverizing various materials or for flakedstone reduction.
Debitage (DEB)	NA	Debris leftover from reduction of flakedstone raw material for the production of flakedstone tools. This includes flakes (identified by a platform with a bulb of percussion) as well as shatter (chipping debris with no identifiable platform or bulb of production).
Mortar	Formal	A relatively deep concave surface, oval or circular, used as a basal surface for vertical pulverization and grinding. These surfaces are intentionally manufactured and imply a higher degree of manufacturing effort than millingstones.
Pestle	Varies	The counterpart to a mortar, this hand-held stone used for vertical pulverization and grinding. Stones used as pestles typically exhibit wear on the ends. Formal pestles are shaped.
Millingstone (MS)	Varies	A basal stone used primarily for horizontal grinding. Millingstone surfaces can be slightly convex, flat, or concave (including basins).

Artifact Category	Formal or Expedient?	Description
		Millingstones are used for grinding as well as pulverization, though the surface is thought to attain its shape primarily through use-related attrition and maintenance-related pecking. Formal millingstones are shaped.
Handstone (HS)	Varies	The counterpart to a millingstone, this is a handheld stone used primarily for horizontal grinding with the primary wear facets being located on the broad faces of the stone rather than on the ends. Handstones commonly exhibit use on ends, including battering and grinding. Formal handstones are shaped.
Gorge	Formal	Typically made from bone, these are long, thin items that are sharpened into points on opposing ends. Gorges were primarily used for fishing.
Single Piece Hook	Formal	These resemble modern-day hooks with a shaft and a curved hook. In the southern California region, these hooks are either j-shaped or circular and were tied to the end of a line to catch single fish in open water.
Composite Hook	Formal	Used in a similar manner to the single piece hook, composite hooks consist of two pieces—a shaft and a barb—secured at the base by line and/or asphaltum and tied to the end of a line.
Ceramic	Generally formal, but can be expedient	Ceramics, or pottery, include baked clay items that integrate various kinds of temper (i.e., shell, sand, etc.). Ceramics were used in southern California for storage and cooking and imply a relatively high degree of manufacture investment when present in large quantities. Some ceramics are figurines or other decorative and/or functional items.

Some traditional tool categories, such as scraper planes and choppers (i.e., core/cobble tools), debitage, mortars, pestles, handstones, and millingstones (the latter two define a horizontal orientation of grinding) were left as-is with the exception that subtypes were ignored in exchange for detailed use wear analyses. Core/cobble tools (see Figure 4.6) refer to scraper planes and cobble based choppers; both were probably used to resharpen millingstones and process fibrous materials such as yucca or agave. Suffice it to say that these two tool types decline sharply after appearance of the bow and probably signal declining importance of a root/tuber processing regime.

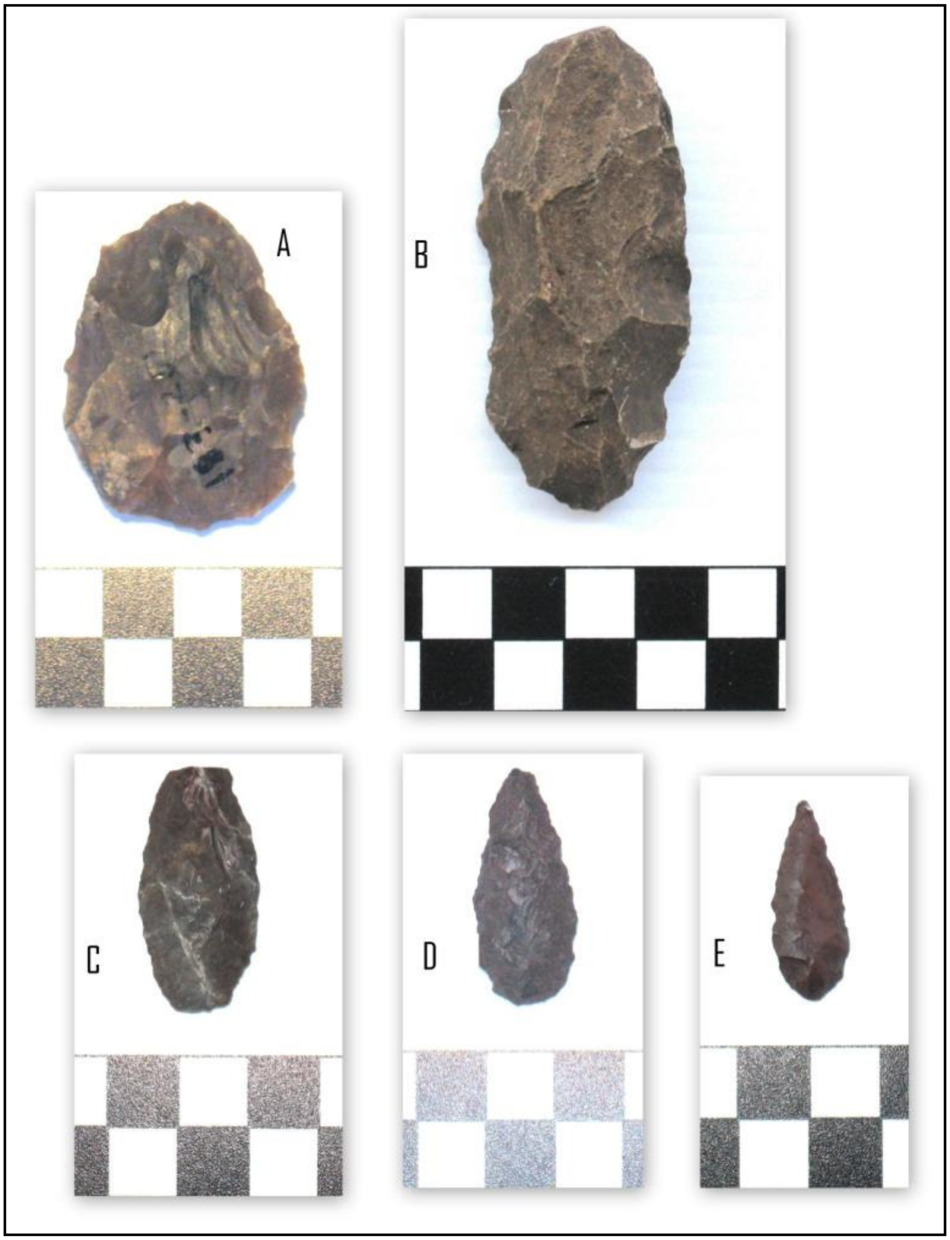


Figure 4.5. Examples of bifaces from each stage, following Callahan (1979): A, Stage 1; B, Stage 2; C, Stage 3; D, Stage 4 preform; E, Stage 5 finished projectile point.

Figure 4.6. Example of a core-cobble tool; this specimen consists of a split cobble with flake detachments along the broken end; the edge also exhibits battering (Specimen is unprovenienced).

4.3 DETAILED ARTIFACT ANALYSIS

Detailed analyses were conducted to evaluate the formal or expedient characterization of each artifact class, and to sample variability in manufacturing effort and use. These efforts were most valuable for understanding groundstone formality since categorization of these tools as formal or expedient is less obvious than for flakedstone. Manufacture and use-related attributes were analyzed on projectile points, bifaces, FFT, RET, SFT, debitage, and groundstone (mortars, pestles, millingstones, and handstones). A brief description of each attribute is provided in Table 4.2.

The attributes chosen for analysis of formality and use derive from the same body of research that defined the artifact categories themselves. There are numerous published justifications of the current approach to flaked and groundstone analysis and the complete rationale will not be recounted here (Andrefsky 1998; Basgall and Giambastiani 1995;

Basgall and Hall 1990; Bleed 1986; Bamforth 1991; Cook 1979, 1985; Hale 2001; Horsfall 1985; Keeley 1982; Nelson and Lippmeier 1993; Schott 1995). It is sufficient to state that the general approach considers tool manufacture and use an economic activity that requires input of time and energy.

Table 4.2. Manufacture and Use-Related Attributes Measured for each Artifact Category

Artifact Category	Analyzed Attributes
Projectile Point (PPT)	Material, condition, basic metrics (weight (WT), maximum length (ML), width (MW), and thickness (MTH)), axial length (AL), stem length (SL), basal width (BW), neck width (NW), distal shoulder angle (DSA), proximal shoulder angle (PSA), notch-opening angle (NOA), basal depth (BD), spine-plane angle (SPA), shape (pointed, rounded, square, etc.), type (arrow or dart sized, generic, etc.), form (made from a flake, biface, or nodule blank), stage (1-5), and observed edge damage.
Biface (BIF)	Material, condition, basic metrics, spine-plane angle (SPA), shape, type, form, stage, edge damage, and number of flake detachments per edge (see Callahan 1979 for a description of biface stage).
Retouched Flake (RET)	Material, condition, basic metrics, flake type, edge frequency, edge shape, edge damage, and edge angle.
Simple Flake Tool (SFT)	Material, condition, basic metrics, flake type, edge frequency, edge damage, edge use wear, and edge angle.
Formed Flake Tool (FFT)	Material, condition, basic metrics, flake type, edge frequency, edge shape, edge damage, and edge angle.
Debitage (DEB)	Material, size, and type.
Mortar	Material, condition, basic metrics (including rim diameter and mortar depth), exterior shaping (type and degree), number of surfaces, surface type, surface shape, and polish, striations, pecking, battering, etc.
Pestle	Material, condition, basic metrics, # of Surfaces, surface type, surface shape, and use polish, striations, pecking, battering, etc..
Millingstone (MS)	Material, condition, basic metrics, number of facets, surface type, surface shape, polish, striations, pecking, and secondary modification.
Handstone (HS)	Material, condition, basic metrics, number of facets, surface type, surface shape, polish, striations, pecking, and secondary modification.

The intent of tool use is reflected in tool morphology and the condition of tools at discard. More expedient items exhibit less shaping and less attrition from use than formal tools—these being better made and maintained in toolkits for longer periods of time (i.e., curated and expedient, see Binford 1979).

For flakedstone artifacts, changes in attributes are discussed according to frequencies or proportions. However, groundstone tools lend themselves to description using a Groundstone Use Intensity index (GUI).

- *Groundstone Use Index (GUI)* = (total sum of present and regular attribute states) / (total possible value of all present and regular attribute states).

This index, developed by Stevens and Hale (n.d.), considers each attribute of a wear facet as a scaled value: 1=absent/irregular, 2=present/regular. These values are added together and divided by the total maximum value (occurring with all present/regular measurements). The resulting GUI value (varying from 0 to 1) is a reflection of use intensity—more intensively used surfaces have a higher GUI value than less intensively used surfaces. The benefit of this approach is that the GUI can be calculated for each groundstone artifact class, or the values from all artifact categories can be combined for a measure of use intensity for the overall groundstone assemblage. While the degree of shaping can be incorporated (see Stevens and Hale n.d.), shaping is treated separately by the Groundstone Formality Index (GFI), described below in section 4.5. An example of a shaped handstone is provided in Figure 4.7, and its counterpart, a millingstone, is Figure 4.8.

4.4 DEBITAGE ANALYSIS

There are two main approaches to debitage analysis commonly used in southern California. The first approach, exemplified by Bamforth (1991), Eerkens (2001), and Becker and Iversen (2006), intensively describes many different morphological attributes of each piece of debitage. This approach is the most accurate in terms of determining the specific style of reduction and place along the reduction trajectory for each piece of debitage. However, the drawback with this approach is that it is very difficult to employ on a large scale and typically involves smaller samples, because it is much more intensive.

The second approach—used in this analysis—is a semi-detailed flake typology. It has been extensively employed throughout California—i.e., Levulett et al. (2000) at SBA-54 (see also Basgall and Giambastiani 1999; Giambastiani 2003). In this scheme, flakes are sorted by material and size in one centimeter increments, and then assigned to a particular category (Table 4.3). Compared to the descriptive approach (i.e., Bamforth 1991), this typology is less intensive and does not facilitate analysis of platform configuration as it relates to platform or dorsal cortex, metrics, or other such attribute comparisons. Instead, the current typology is intended to make generalizations about the kind of reduction trajectory employed and how extensively raw material was reduced to produce finished artifacts. Prior to initiation of the debitage analysis, a test was conducted on several assemblages from the San Diego region (e.g., SDI-10714, SDI-14571). These assemblages were originally analyzed using the descriptive method (see Becker and Iversen 2006), and were reanalyzed for this research using the debitage typology. Results from the typology were generally consistent with those from the descriptive analysis. Both were able to identify a basic cobble-core reduction trajectory with very little platform preparation. The utility of the debitage typology is that it cuts down on analysis time and can be used to make basic comparisons between assemblages regarding the trajectory and intensity of flakedstone reduction.

Table 4.3. Debitage Types.

Debitage Type	Description
1-Early Cortical	Any percussion flake with more than 70% dorsal cortex
2-Late Cortical	Any percussion flake with less than 70% dorsal cortex
3-Early Interior	Percussion flake, generally greater than 3 cm in diameter and thick, straight in cross section, with one dorsal arris and with either a cortical or interior platform; platforms tend to be simple with two or less facets
4-Late Interior	Percussion flake, generally smaller than 3 cm, straight in cross section, with more than one dorsal arris, and either a cortical or interior platform; platform can be multi-faceted or prepared
5-Linear Interior	Percussion flake, straight in cross-section, twice as long as it is wide, with one or two dorsal arrises running the length of the flake, and with an interior platform that can either be single or multi-faceted
6-Early Biface Thinning	Percussion flake, curved in cross-section, with one or two dorsal arrises, and with a prepared platform that has more than one facet
7-Late Biface Thinning	Percussion flake, curved in cross-section, with more than two dorsal arrises, and a prepared, multi-faceted platform
8-Finishing	A small flake, generally less than 1 cm in diameter, with a simple or complex dorsal surface, a small platform varying in facets, and variable shape; pressure flakes fall into this category, but small flakes detached by percussion also occur
9-Bipolar	A small, straight-sided flake deriving from small nodules with or without cortex, and may show opposing platforms and/ or evidence of percussion on the same faces
10-Cortical Chunk	A large, chunky or angular piece of stone exhibiting cortex
11-Cortical Shatter	A piece of a broken cortical flake, cortical chunk, or cortical bipolar flake
12-Percussion Shatter	Piece of a broken flake of any kind that could not be classified, and general debris resulting from percussive reduction

Figure 4.7. An example of a shaped handstone (SDI-8303, catno. 212).

Figure 4.8. An example of a basined millingstone (Unprovenienced).

4.5 EVALUATING MODEL PREDICTIONS: FORMALITY INDICES

The broad regional scale of this research requires simplification of assemblage data to provide a clear evaluation of predictions generated from the Tmin-Emax and IFD models. Mentioned in Chapter 3, there are three indices that reflect changes in time allocated to the manufacture of subsistence tools: Flakedstone Formality Index (FFI), Lithic Waste Index (LWI), and Groundstone Formality Index (GFI). Each index is a value that varies between 0 and 1 and is primarily calculated at the regional assemblage level for each temporally distinct sample, rather than calculating the index by site and averaging these values. While the latter method can be argued to minimize the bias of exceptionally large or small samples on the formality index, it also places the focus on individual assemblages. The focus of this research is region-wide trajectories in tool formality, placing emphasis on total regional assemblage formality. Thus, calculating formality indices at the regional assemblage level (i.e., ignoring site-specific indices) allows for the consideration that tool manufacture and use was the product of an overarching adaptive strategy. Regardless of the approach, formality indices calculated for each site and then averaged for a regional value vary little from the formality index values that do not take into account individual site biases. A description of each index is provided below:

- *Flakedstone Formality Index (FFI)* = (Total # Formal Flakedstone Tools: BIF and FFT) ÷ (Total # Formal and Expedient Flakedstone Tools: BIF, FFT, RET, SFT). This index does not include arrow points, dart points, or projectile preforms because the intent of the index is to measure impact of the bow and arrow on other flakedstone tools.

Concerning the introduction of new flakedstone technologies, changes in the FFI do not include that technology since the index is intended to measure changes in the manufacture of all other flakedstone tools. For example, measuring change in assemblage formality after the bow and arrow compares FFI values that do not include arrow points or arrow point preforms. Including arrow points clouds an understanding of how a Tmin and Emax economy respond by investing in other tools. This is especially true in the San Diego region where arrow points are essentially the only formal flakedstone tools present in assemblages after the introduction of this technology. To simplify the index, all projectiles or projectile preforms are excluded. This allows other formal flakedstone tools (i.e., bifaces and FFT) to be compared to their expedient counterparts.

The FFI does not include core/cobble tools and heavy scrapers for two reasons. First, these tools resist the formal versus expedient dichotomy because each category (i.e., scraper planes, scrapers, etc.) shares a fundamental form but varies widely in the amount of initial manufacturing and maintenance that affects the formality of the tool or working edge (see True and Beemer 1982). Hale (2001) demonstrated this with an extensive study on scraper plane edge morphology. Parsing out such tools into formal and expedient categories detracts from their economic significance as multi-function tools that could be used situationally or for long periods of time. Second, including core/cobble tool and scraper categories in the FFI hides underlying patterns that occur among less robust flakedstone tools. It is sufficient to note changes in the proportion of large cobble tools and heavy scrapers when discussing overall assemblage change.

- *Lithic Waste Index (LWI)* = (Total # Non-Diagnostic Shatter) ÷ (Total # All Debitage). This index measures the amount of debitage that was too fragmentary to assign to a particular debitage category in relation to diagnostic flakes.

The lithic waste index is a gross measure of the care taken in flakedstone reduction. The LWI is based on the assumption that, on average, larger amounts of non-diagnostic shatter compared to diagnostic flakes represents greater expediency in raw material reduction. The more tool finishing that occurs, the greater number of smaller, controlled flake detachments are expected, reducing the proportion of shatter. This index is complicated by variation in flakedstone raw material. Poor quality raw materials, or those that are excessively hard, should produce more shatter in general than higher quality materials that are more plastic. However, raw material type was recorded during this research for all debitage, allowing for the identification of a raw material bias in the proportion of different debitage types. This was only a problem with poor quality Monterey chert and most quartz. One source of error in the LWI index is trampling or other post depositional breakage, potentially contributing to an overrepresentation of shatter. However, these effects would be similar at sites in both regions—all sites being reoccupied over time—thereby allowing comparison between LWI values of each region.

- *<u>Groundstone Formality Index (GFI)</u>* = (Total # Formal Groundstone Tools: All Mortars and Shaped Pestles, Millingstones, and Handstones) ÷ (Total # Formal and Expedient Groundstone Tools: Mortars, and Shaped and Unshaped Pestles, Millingstones, and Handstones). All mortars are considered formal, given the relatively high cost associated with manufacturing the mortar surface, regardless of exterior condition or if it is a bedrock feature.

Determining the formality of groundstone tools can be as simple as determining whether an item has been extensively shaped or not. Mortars are considered formal because of the large amounts of time required to make a mortar surface. However, mortars also vary in formality if they are non-stationary tools since the exterior can either be unshaped, moderately shaped, or decorated (Figures 4.8 and 4.9). For other groundstone tools, some items, such as handstones, can become shaped through use on the margins and mimic a tool that has been intentionally shaped—the two are very difficult to distinguish. Nevertheless, extensive research by Hale (2001, 2003, 2006) has shown that shaped groundstone tools are almost always associated with intensively used wear facets while unshaped specimens vary to a large degree in use intensity. This means that using shaping as a measure of groundstone formality is generally accurate. In many cases, however, intentional shaping is clear; note the intentionally pecked margin on the informal pestle in Figure 4.11.

The general expectations of each formality index are implicit. Increases in FFI and GFI indices are representative of increasing assemblage formality, and declining values reflect less time spent making and finishing tools. Regarding lithic waste, an increase in the LWI value implies less care taken in tool manufacture while a drop in the LWI implies more time spent finishing flakedstone tools.

While the primary method of addressing model predictions is the use of formality indices, other supporting evidence is also summarized, including a description of the detailed analysis of flakedstone and groundstone. Subsistence data are summarized to varying degrees by time period, however, regional differences in reporting standards and interpretation complicate a comprehensive summary.

4.6 SUMMARY

The artifact classification system employed in this research distinguish between fundamental differences in tool formality. Essentially, tool categories reflect differential allocation of time to the manufacture of tools used during subsistence. Three formality indices are used to simplify evaluation of model predictions by collapsing large amounts of artifact frequency data into a single quantity. In addition, detailed analyses of tools and debitage provide evidence that validates each formality index. Finally, other published information (i.e., subsistence data) is summarized to support interpretations where applicable.

Figure 4.9. A bowl mortar with moderately shaped exterior (SBA-1, unprovenienced).

Figure 4.10. A flower pot mortar; note the formal interior and exterior design and rim detail (Santa Barbara general accession).

Figure 4.11. Informal pestle. Note the pecking along margin—evidence of minimal shaping effort.

5. THE SAN DIEGO REGION DATASET

The San Diego dataset is drawn from 51 archaeological sites that collectively span the last 8,000 years until after A.D. 1700 (Table 5.1; Figures 5.1 and 5.2). The sample of assemblages derives from both large and small habitation sites located in coastal, inland, and upland settings. I directed excavations at three sites used in this research (SDI-10723, -10714, and –14571) (see Hale and Becker 2006) and directed or participated in fieldwork at another thirteen sites (SDI-10726, -10728, -14417, -16780, and all nine of the Case Springs sites).

While thousands of archaeological sites are known for the San Diego region, those selected for this analysis are characteristic of the San Diego coastal plain and foothills. In general, sites in the mountains are poorly dated and few have been extensively studied. The selected sites are not intended to be a random sample; they have been carefully chosen based on chronology, assemblage composition, and location. This research is not focused on resolving potential early Holocene transitions (i.e., San Dieguito versus La Jolla cultural traditions), thus excluding sites of the "San Dieguito Tradition" (see Warren et al. 2004). Other important sites, such as SDI-5130 (see Moratto et al. 1994), were not included because extensive depositional mixing precludes delineation of chronologically distinct components. The same can be said for many of True's (1980) Frey Creek sites in the upper San Luis Rey watershed.

Numerous chronologies have been proposed for the San Diego region over the last century. No attempt was made to refine any of these or to propose a new chronology. This research only required analysis of archaeological material before and after the introduction of new technologies. The only novel technology that had an immediate impact on adaptive strategy was the bow and arrow; economically significant ceramic use lagged by more than a thousand years, present only in trace amounts in northern San Diego County prior to about A.D. 1450 (see True 1980). Circular fishhooks are also rare throughout prehistory in the San Diego region, and there is no evidence that the plank canoe was used this far south in southern California. For these reasons, a simple chronological scheme was created to group sites before and after the appearance of the bow (as early as A.D. 500). This research also revealed important changes at around A.D. 1400, necessitating a separate grouping of sites that generally post date this age.

The sample datasets are defined as follows:

- *Sample I, Pre A.D. 500*: The pre A.D. 500 sample includes sites that predate the arrival of the bow and arrow; *n* = *21 sites*.
- *Sample II, A.D. 500-1400*: This sample includes sites that postdate the arrival of the bow and arrow and that generally predate a period of intensification from A.D. 1400-1700; *n = 17 sites*.
- *Sample III, A.D. 1400-1700*: Sites in this sample reflect a period of intensification and are further separated into *Traditional* and *Transitional*.
    - *Sample IIIA, Traditional*: These sites follow the same general trajectory that defines the region in Sample II; *n = 9 sites*.
    - *Sample IIIB, Transitional*: Transitional sites are distinguished by having higher assemblage formality, among other important characteristics; *n = 4 sites*.

Sample I, Pre A.D. 500: Sample I comprises 21 sites that predate the arrival of the bow and arrow (see Table 5.1; Figure 5.1). Eleven sites are located on lagoonal margins, two are coastal, one is in a deeply buried river valley, one is among the interior mountains, and six are on ridge tops or low hills within 10 km of the coast. In the northern San Diego region, there is a general lack of assemblages that date between 1000 B.C. and A.D. 500, and just a few that have dates as late as 500 B.C.. Warren (1968) postulates a depopulation of the coast in favor of inland areas after closing of most lagoons by about 1000 B.C.. However, a few radiocarbon dated sites deeply buried in floodplains indicate that settlement probably shifted to the floors of major drainages after 1000 B.C. (see Byrd 1996; Reddy 2005; Rasmussen and Woodman 1998; York 2006). Exploration for buried sites in major drainages in northern San Diego County is a recent endeavor whereas accelerated development to the south has led to the discovery of multiple buried deposits postdating 1000 B.C.. To fill this radiocarbon gap, several sites have been selected from the southern part of San Diego County. The Ballast Point site (SDI-48) and SDI-10945 are two sites located on Point Loma on the margin of San Diego Bay that collectively date between 4000 B.C. and A.D. 500 (see Gallegos and Kyle 1998; Pigniolo et al. 1993). SDI-11767 is a buried archaeological site in the San Diego river valley that dates between 180 B.C. and A.D. 500, and another site located on Sweetwater Mesa, SDI-4765 Locus B, has an age range of 1200-200 B.C. (see Cooley and Mitchell 1996; Byrd et al. 1993). Inclusion of these sites in the pre-bow category is justified because assemblages from the whole of San Diego County that predate A.D. 500 differ mainly in subsistence remains—i.e., more shellfish remains at coastal sites, more arrow points at interior sites. This assertion can be confirmed by comparing assemblage constituents from sites in the northern versus southern San Diego region included in this sample (see Table 5.1).

Sample II, A.D. 500-1400: Sample II is well represented in the San Diego region, containing 17 sites that date between A.D. 500 and A.D. 1400. One of the sites is located on a coastal bluff, four are lagoonal, five are in upland environments (i.e., low coastal mountains), and seven are located at various elevations on the coastal plain (see Table 5.1 and Figure 5.1). The dearth of littoral sites in this sample is due to a combination of factors. Many sites have been destroyed due to development and others are poorly dated. There are numerous radiocarbon dated sites along the littoral in the San Diego region, but many of these are small shell middens with meager artifact assemblages, contributing little to an understanding of adaptive response other than basic presence/absence and subsistence information. Indirect evidence that coastal bluff sites have been destroyed includes at least three large habitation sites on the either side of the mouth of Las Flores Creek on undeveloped Camp Pendleton (SDI-10723, SDI-10728, SDI-10728) postdate A.D. 500. Only one of these—SDI-10723—is included in Sample II because parsing out assemblage content before and after A.D. 1400 is difficult at the other two sites. Other, similar sites exist on the coastal bluffs of Camp Pendleton but have yet to be extensively studied.

Sample IIIA, Traditional, A.D. 1400-1700: Sample IIIA, Traditional sites, comprises nine sites that generally postdate A.D. 1400 and predate A.D. 1700. These sites include three each in upland and inland settings, two at the coast, and one lagoonal (see Table 5.1; Figure 5.1). Generally, Sample IIIA sites have substantial midden deposits and were reoccupied frequently. The age and geographic position of Sample IIIA sites are perhaps the best indications that these sites are different, representing more intensive occupation of coastal bluffs (e.g., SDI-10726) and low elevation inland areas (e.g., SDI-8303), than in previous periods. Sample IIIA sites have relatively large assemblages—

given the short time span of occupation—and show increased use of bedrock milling facilities.

Sample IIIB, Transitional, A.D. 1400-1700: Sample IIIB, Transitional sites, consists of just four sites that generally date between A.D. 1400-1700, and are distinguished from their contemporary Sample IIIA sites by having higher assemblage formality and other unique characteristics. The four Transitional sites include SDI-10712/713, SDI-10714, SDI-14571, and SDI-16780 (see Table 5.1). All of these are located on Camp Pendleton among low inland hills next to bedrock outcrops in an area characterized by oak woodland vegetation. Reddy (2000) excavated SDI-10712/713, Reddy et al. (2006) excavated SDI-16780, and I excavated SDI-10714 and SDI-14571 (see Hale and Becker 2006). Each site is characterized by a relatively small, single-component midden typically no deeper than 30-50 cm. Given the prominent location of each Transitional site on low knolls, it is not surprising that they have been disturbed to varying degrees from military activities such as camping and use as staging areas. These disturbances are minor, for the most part, leaving midden deposits mostly intact. Bedrock milling facilities are present at each site and generally contain a large number of mortars in addition to flat and basined milling surfaces. One site, SDI-10714, also has a boulder containing numerous small cupule petroglyphs and red ochre staining (see Hale and Becker 2006).

Table 5.1. Assemblage Data by Site and Sample for the San Diego Region

Sample I Site South San Diego	SDI-4765-B	SDI-48	SDI-11767
Age	1200-200 B.C.	4000 B.C. - A.D. 500	180 B.C. - A.D. 500
Distance From Coast	24 km	Coastal	5 km
Flakedstone			
Arrow Point			
Dart Point			
Point Preform/ Frag.			
Biface	12	2	2
Formed Flake Tool	6	7	16
Retouched Flake	1	12	28
Simple Flake Tool	2	26	17
Core	2	36	6
Core/ Cobble Tool		8	68
Scraper			13
Hammer	3	7	25
Miscellaneous	1		
Debitage	3366	2199	1877
Groundstone			
Mortars			
Pestles			
Millingstones	1	8	14
Handstones	17	73	18
Handstone Pestle			
Miscellaneous		1	
Indeterminate			
Ceramics			
Bone Tools			
Miscellaneous		20	7
Gorge		3	
Composite Hook		5	
Miscellaneous			
Ornaments			
Shell		7	52
Stone			
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample I Site South San Diego	SDI-10945A	**Total South San Diego**
Age	750-0 B.C.	
Distance From Coast	Coastal	
Flakedstone		
Arrow Point		
Dart Point		
Point Preform/ Frag		
Biface	1	**17**
Formed Flake Tool		**29**
Retouched Flake	10	**51**
Simple Flake Tool	22	**67**
Core	32	**76**
Core/ Cobble Tool	6	**82**
Scraper		**13**
Hammer	5	**40**
Miscellaneous		
Debitage	1904	**9346**
Groundstone		
Mortars		
Pestles		
Millingstones	14	**37**
Handstones	59	**167**
Handstone Pestle		
Miscellaneous	7	**8**
Indeterminate		
Ceramics		
Bone Tools		
Miscellaneous		**27**
Gorge		**3**
Composite Hook	2	**7**
Miscellaneous		
Ornaments		
Shell	5	**64**
Stone		
Bone	1	**1**

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample I Site North San Diego	SDI-4558	SDI-6010	W-84, 95
Age	No dates	4848-4037 B.C.	8000-7000 B.C. uncalibrated
Distance From Coast	Upland	10 km; Valley	Lagoonal
Flakedstone			
Arrow Point			
Dart Point		2	2
Point Preform/ Frag	5		2
Biface	3	2	
Formed Flake Tool			90
Retouched Flake		6	46
Simple Flake Tool	23		96
Core	7	3	33
Core/ Cobble Tool	5	2	44
Scraper			110
Hammer	8	10	68
Miscellaneous			
Debitage	??	678	1288
Groundstone			
Mortars			1
Pestles	1		
Millingstones	15	1	57
Handstones	70	5	233
Handstone Pestle			
Miscellaneous			
Indeterminate		9	36
Ceramics			
Bone Tools			
Miscellaneous			
Gorge			1
Composite Hook			
Miscellaneous			11 charmstones
Ornaments			
Shell			24
Stone			
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample I Site North San Diego	W-131	SDI-4392	W-36
Age	8300-7000 B.C. uncalibrated	6410-4670 B.C.; A.D. 1240 uncalibrated	4890-3730 B.C.
Distance From Coast	Lagoonal	8 km Inland	Lagoonal
Flakedstone			
Arrow Point		2	
Dart Point	2	5	2
Point Preform/ Frag	5	3	
Biface	3	6	
Formed Flake Tool	19	216	5
Retouched Flake	4	63	
Simple Flake Tool	11	270	50
Core	7	260	8
Core/ Cobble Tool	9	171	31
Scraper	43		
Hammer	14	25	8
Miscellaneous	8 (4 crescent)	1 crescent	
Debitage	7732	6520	723
Groundstone			
Mortars			
Pestles			
Millingstones	1	14	11
Handstones	9	75	84
Handstone Pestle			
Miscellaneous			
Indeterminate	7		
Ceramics			
Bone Tools			
Miscellaneous	10	2	
Gorge			
Composite Hook			
Miscellaneous			
Ornaments			
Shell			
Stone			
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample I Site North San Diego	W-20	SDI-691	SDI-12814
Age	7285-2265 B.C.	4300 B.C., 6910-8310 B.C.	3000-1000 B.C.
Distance From Coast	Lagoonal	Lagoonal	4 km
Flakedstone			
Arrow Point			
Dart Point	10	4	5
Point Preform/ Frag	4		2
Biface	4	2	6
Formed Flake Tool	34	21	10
Retouched Flake	74	14	10
Simple Flake Tool	346	17	37
Core	58	163	6
Core/ Cobble Tool	183	54	29
Scraper	210	63	8
Hammer	104	211	22
Miscellaneous		3	4 (crescents)
Debitage	4330	2008	11517
Groundstone			
Mortars			4
Pestles	21		9
Millingstones	48	85	63
Handstones	451	189	96
Handstone Pestle	7		8
Miscellaneous	7		
Indeterminate		3	66
Ceramics			51 intrusive
Bone Tools			
Miscellaneous		1	
Gorge			
Composite Hook			
Miscellaneous			
Ornaments			
Shell	3		
Stone		5	
Bone		2	

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample I Site North San Diego	SEL 1,2,3,6,9	SEL 6928/6933 loci C-G	**Sample I Grand Total**
Age	6200-1970 B.C.	6300-2800 B.C.	
Distance From Coast	Lagoonal	Lagoonal	
Flakedstone			
Arrow Point			**2**
Dart Point			**32**
Point Preform/ Frag			**21**
Biface	2	1	**46**
Formed Flake Tool	2	6	**432**
Retouched Flake	13	13	**294**
Simple Flake Tool	3	42	**962**
Core	25	30	**676**
Core/ Cobble Tool	1	47	**658**
Scraper		31	**478**
Hammer	19	33	**562**
Miscellaneous			**16**
Debitage	1632	396	**46170**
Groundstone			
Mortars			**5**
Pestles			**31**
Millingstones	6	12	**350**
Handstones	43	115	**1537**
Handstone Pestle			**15**
Miscellaneous		24	**39**
Indeterminate			**121**
Ceramics			**51**
Bone Tools			
Miscellaneous	9		**49**
Gorge			**4**
Composite Hook			**7**
Miscellaneous			**11**
Ornaments			
Shell	22	8	**121**
Stone			**5**
Bone			**3**

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample II Site	SDI-14170	SDI-14748	SDI-4851-3
Age	A.D. 665-1565	70 B.C.-A.D. 1250	A.D. 780-980
Distance From Coast	Lagoonal	Lagoonal	5 km
Flakedstone			
Cottonwood Arrow			
Other Arrow Point			
Dart Point			
Point Preform/ Fragment			1
Biface		1	
Formed Flake Tool			
Retouched Flake		6	
Simple Flake Tool		1	
core/cobble tools		2	2
Core/ Cobble Tool			
Scraper			
Hammer			2
Miscellaneous		1	
Debitage	326	504	128
Groundstone			
Mortars			
Pestle			
Millingstone	3		6
Handstone	2	2	25
HSP			
misc			
indeterminate		1	
Bedrock Milling			
Mortars			
Slicks			
Basins			
Ceramics			
Tizon Brown			
Other Function			
Bone/Shell Tool			
Miscellaneous			1
Hook			
Ornaments			
Shell			
Stone		1	
Glass			
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample II Site	SDI-2739*	SDI-6142	SDI-6144
Age	A.D. 1050-1190	A.D. 1020-1150 uncorrected	A.D. 650-1630 uncorrected
Distance From Coast	4.8 km	4.8 km	4.8 km
Flakedstone			
Cottonwood Arrow	4		8
Other Arrow Point			
Dart Point			1
Point Preform/ Fragment	1		1
Biface			8
Formed Flake Tool			
Retouched Flake	2		4
Simple Flake Tool			
core/cobble tools	1	1	26
Core/ Cobble Tool		3	14
Scraper	1	5	49
Hammer	1	5	58
Miscellaneous			
Debitage	721	56	2521
Groundstone			
Mortars			
Pestle			
Millingstone	2	2	23
Handstone	9	7	70
HSP			
misc			
indeterminate			
Bedrock Milling			
Mortars			
Slicks			
Basins			
Ceramics			
Tizon Brown			29
Other Function			
Bone/Shell Tool			
Miscellaneous			
Hook			
Ornaments			
Shell	1		
Stone			
Glass			
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample II Site	SDI-6147*	SDI-4845-1*	SDI-10006
Age	A.D. 1305-1435 uncorrected	A.D. 1000-1260	A.D. 1325-1685
Distance From Coast	4.8 km	6.4 km	7 km
Flakedstone			
Cottonwood Arrow	1	9	1
Other Arrow Point			
Dart Point			
Point Preform/ Fragment		2	2
Biface		2	1
Formed Flake Tool		13	2
Retouched Flake	1		3
Simple Flake Tool		32	6
core/cobble tools	1	21	13
Core/ Cobble Tool	1	20	16
Scraper			
Hammer	1	18	
Miscellaneous		2	
Debitage	61	5442	729
Groundstone			
Mortars			
Pestle			1
Millingstone	1	12	
Handstone	2	68	2
HSP			
misc			2
indeterminate			
Bedrock Milling			
Mortars			
Slicks			
Basins			
Ceramics			
Tizon Brown	57	2	
Other Function			
Bone/Shell Tool			
Miscellaneous			
Hook			
Ornaments			
Shell		1	
Stone			
Glass			
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample II Site	Case Springs: SDI-5138, -5139, -5141, -5142, -5143	SDI-10723	W-143/146 Upper*
Age	A.D. 1200-1600	A.D. 690-960, 1260-1520	A.D. 0-1550**
Distance From Coast	12 km	Coastal	Lagoonal
Flakedstone			
Cottonwood Arrow	16	11	2
Other Arrow Point			
Dart Point			
Point Preform/ Fragment	31	2	
Biface	26	17	6
Formed Flake Tool	3		
Retouched Flake	13	110	23
Simple Flake Tool	8	8	17
core/cobble tools	13	29	15
Core/ Cobble Tool		31	28
Scraper			12
Hammer	2	25	2
Miscellaneous			
Debitage	3037	7860	6371
Groundstone			
Mortars	1		1
Pestle			2
Millingstone	5	15	11
Handstone	11	91	42
HSP		1	
misc	1	1	2
indeterminate			9
Bedrock Milling			
Mortars	16		
Slicks	4		
Basins	7		
Ceramics			
Tizon Brown	3	15	139
Other Function	1(pipe)		
Bone/Shell Tool			
Miscellaneous		10	15
Hook		1	
Ornaments			
Shell		5	10
Stone			
Glass	1		
Bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample II Site	SDI-8303 lower	**Sample II Total**
Age	A.D. 910-1400	
Distance From Coast	Lagoonal	
Flakedstone		
Cottonwood Arrow	6	**58**
Other Arrow Point		
Dart Point		**1**
Point Preform/ Fragment		**40**
Biface	3	**64**
Formed Flake Tool	1	**19**
Retouched Flake		**162**
Simple Flake Tool	13	**85**
core/cobble tools	2	**126**
Core/ Cobble Tool	9	**122**
Scraper		**67**
Hammer		**114**
Miscellaneous		**3**
Debitage	957	**28713**
Groundstone		
Mortars	1	**3**
Pestle	1	**4**
Millingstone	22	**102**
Handstone	17	**348**
HSP	5	**6**
misc	3	**9**
indeterminate	44	**54**
Bedrock Milling		
Mortars		**16**
Slicks		**4**
Basins		**7**
Ceramics		
Tizon Brown	16	**261**
Other Function		**1**
Bone/Shell Tool		
Miscellaneous	2	**28**
Hook		**1**
Ornaments		
Shell	20	**37**
Stone		**1**
Glass	2	**3**
Bone	1	**1**

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample IIIA Site	SDI-10726A Late	SDI-10728 Late	SDI-14417*
Age	A.D. 1450-1700	A.D. 1375-1675	A.D. 1385-1685
Dist. from coast	coastal	coastal	6 km
Flakedstone			
Cottonwood Arrow Point			1
Other Arrow Point			
Dart Point			
Point Preform/ Fragment			7
Biface	3	3	2
Formed Flake Tool	2	1	
Retouched Flake	6	3	2
Simple Flake Tool	5	8	1
Core	20		19
Core/ Cobble Tool	3	10	8
Scraper			
Hammer	4	7	
Miscellaneous			
Debitage	632	1321	1412
Groundstone			
Mortars			
Pestle			
Millingstone		9	
Handstone	4	16	5
Handstone Pestle			
Miscellaneous			
Indeterminate	24	1	
Bedrock Milling			
Mortar			
Slick			
Basin			
Cupule			
Ceramics			
Tizon Brown	29	13	
Colorado Buff			
Bone Tools			
Miscellaneous	3	5	
Gorge			
Hook			
Ornaments			
shell	1	2	
stone			
glass			
bone			

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample IIIA Site	SDI-11068 Lower	SDI-9824*	SDI-8303 Upper
Age	A.D. 1460-1700	A.D. 1645-1950	post A.D. 1400
Dist. from coast	19 km	8 km	Lagoonal
Flakedstone			
Cottonwood Arrow Point	19	6	10
Other Arrow Point		1	
Dart Point			
Point Preform/ Fragment	2	13	5
Biface	15	2	
Formed Flake Tool	1		
Retouched Flake	12		
Simple Flake Tool	34	3	19
Core	24	2	3
Core/ Cobble Tool	5	2	7
Scraper	2		
Hammer	48		
Miscellaneous	21		
Debitage	14094	1031	3272
Groundstone			
Mortars	4		
Pestle	21		
Millingstone	78		
Handstone	30	1	11
Handstone Pestle			
Miscellaneous	14		4
Indeterminate	42	3	
Bedrock Milling			
Mortar		7	
Slick		21	
Basin		2	
Cupule			
Ceramics			
Tizon Brown	877	53	423
Colorado Buff	24		
Bone Tools			
Miscellaneous	18		
Gorge			
Hook			
Ornaments			
shell	7		
stone			
glass	1		
bone	4		

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample IIIA Site	SDI-5144*	SDI-5145*	SDI-5146*	**Sample IIIA Total**
Age	A.D. 1550	A.D. 1490	A.D. 1600	
Dist. from coast	10 km Upland	11 km Upland	12 km Upland	
Flakedstone				
Cottonwood Arrow Point	1		2	**39**
Other Arrow Point				**1**
Dart Point		1		**1**
Point Preform/ Fragment	4		2	**33**
Biface		4	2	**31**
Formed Flake Tool			1	**5**
Retouched Flake		5		**28**
Simple Flake Tool		1	1	**72**
Core		6	2	**76**
Core/ Cobble Tool				**35**
Scraper				**2**
Hammer	2			**61**
Miscellaneous				**21**
Debitage	310	637	274	**22983**
Groundstone				
Mortars				**4**
Pestle				**21**
Millingstone				**87**
Handstone				**67**
Handstone Pestle				
Miscellaneous				**18**
Indeterminate				**70**
Bedrock Milling				
Mortar			3	**10**
Slick	7		2	**30**
Basin	3		3	**8**
Cupule				
Ceramics				
Tizon Brown				**1395**
Colorado Buff				**24**
Bone Tools				
Miscellaneous				**26**
Gorge				
Hook				
Ornaments				
shell				**10**
stone				
glass				**1**
bone				**4**

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

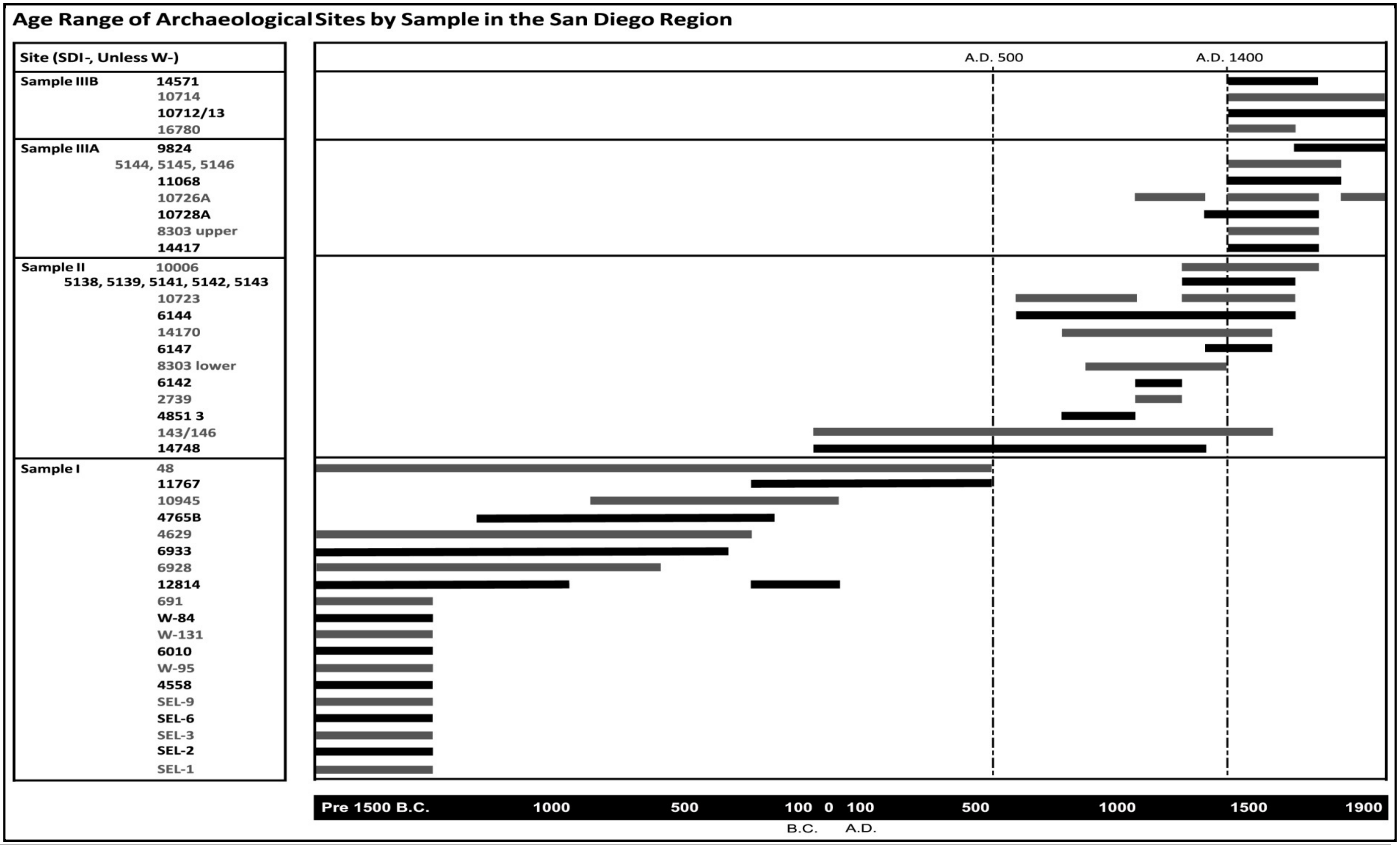
Sample IIIB Site	SDI-16780	SDI-10712/713	SDI-10714
Age	A.D. 1390-1575	A.D. 1420-1645 1650-1950	A.D. 1660-1900
Distance From Coast	8 km	8 km	9 km
Flakedstone	Inland	Inland	Inland
Cottonwood Arrow	10	10	
Point Preform/ Fragment	2		1
Biface	1	9	4
Formed Flake Tool	4	3	4
Retouched Flake	1		1
Simple Flake Tool		6	4
Core	8	6	1
Core/ Cobble Tool		4	
Scraper			
Hammer	4		
Miscellaneous			2
Debitage	1892	1553	554
Groundstone			
Mortar			
Pestle			
Millingstone		2	2
Handstone		5	5
Handstone Pestle			
Miscellaneous			1
Indeterminate		1	2
Bedrock Milling			
Mortar	7	20	
Slick	2	9	3
Basin		1	2
Ceramics			
Tizon Brown	10	6	165
Bone Tools			
misc	12		
Ornaments			
shell			1

Table 5.1, Continued. Assemblage Data by Site and Sample for the San Diego Region

Sample IIIB Site	SDI-14571	**Sample IIIB Total**
Age	A.D. 1440-1640	
Distance From Coast	9 km	
Flakedstone	Inland	
Cottonwood Arrow		**20**
Point Preform/ Fragment	1	**4**
Biface	2	**16**
Formed Flake Tool	3	**14**
Retouched Flake		**2**
Simple Flake Tool	3	**13**
Core	3	**18**
Core/ Cobble Tool	2	**6**
Scraper		
Hammer	1	**5**
Miscellaneous	2	**4**
Debitage	583	**4582**
Groundstone		
Mortar		
Pestle		
Millingstone	2	**6**
Handstone	8	**18**
Handstone Pestle	2	**2**
Miscellaneous	2	**3**
Indeterminate		**3**
Bedrock Milling		
Mortar	2	**29**
Slick	7	**21**
Basin	1	**4**
Ceramics		
Tizon Brown	13	**194**
Bone Tools		
misc		**12**
Ornaments		
shell		**1**

Note: *, Dates are approximate.

Figure 5.1. Map showing the locations of archaeological sites included in this sample, distinguished by color for each sample.



Age Range of Archaeological Sites by Sample in the San Diego Region
Site (SDI-, Unless W-)
Sample IIIB
14571
10714
10712/13
16780
Sample IIIA
9824
5144, 5145, 5146
11068
10726A
10728A
8303 upper
14417
Sample II
10006
5138, 5139, 5141, 5142, 5143
10723
6144
14170
6147
8303 lower
6142
2739
4851 3
143/146
14748
Sample I
48
11767
10945
4765B
4629
6933
6928
12814
691
W-84
W-131
6010
W-95
4558
SEL-9
SEL-6
SEL-3
SEL-2
SEL-1
A.D. 500
A.D. 1400
Pre 1500 B.C.
1000
500
100
0
100
500
1000
1500
1900
B.C.
A.D.

[illegible]

5.1 ASSEMBLAGE COMPOSITION

5.1.1 Artifact Proportions

Relative proportions of the major assemblage constituents provide a strong picture of changes in technological organization over time (Table 5.2). The following discussion highlights important shifts in assemblage composition between the different samples. Ceramics and debitage are excluded from the description of assemblage proportion because these two artifact classes are qualitatively different in terms of frequency. One ceramic vessel is more likely to produce hundreds of fragments whereas one diagnostic projectile point base can only be broken into a few identifying elements. Debitage frequencies are so high that inclusion in a discussion of assemblage proportion reduces other artifact categories to nearly insignificant quantities. Because of these factors, ceramics and debitage are discussed separately by sample.

Significant shifts in assemblage composition occur when comparing Samples I and II. Immediately apparent from Table 5.2 is the increase in projectile points, point preforms, and bifaces to 4.9%, 3.3%, and 5.3%, respectively, in Sample II—up from a total of 1.9% for these same categories in Sample I. Small arrow points essentially replace dart points and become much more frequent in Sample II. Changes in other tool categories reflect shifts in manufacturing investment. For instance, FFT drop from 8.0% in Sample I to 1.6% in Sample II; at the same time their expedient counterpart—retouched flakes—more than double in proportion (see Table 5.2). Simple flake tools, on the other hand, drop by two thirds from 17.8% to 7.0%. The increase in expedient RET and drop in SFT is explained further in the flakedstone analysis sections that follow.

Table 5.2. Relative Proportion of Assemblage Constituents by Sample for the San Diego Region

	Sample I Pre A.D. 500	**Sample II A.D. 500-1400**	**Sample IIIA A.D. 1400-1700**	**Sample IIIB Transitional A.D. 1400-1700**
Arrow Points	.0	4.8	7.5	12.7
Darts	.6	.1	.2	.0
Point Preforms/ Fragments	.4	3.3	6.2	2.5
Biface	.9	5.3	5.8	10.1
Formed Flake Tool	8.0	1.6	.9	8.9
Retouched Flake	5.4	13.3	5.2	1.3
Simple Flake Tool	17.8	7.0	13.5	8.2
Cobble Tool	12.2	10.0	6.5	3.8
Heavy Scraper	8.8	5.5	.4	.0
Hammerstone	10.4	9.4	11.4	3.2
*Millingstones	6.5	9.3	23.4	19.6
Handstones	28.4	28.6	12.5	11.4
*Mortars	.1	1.6	2.6	18.4
Pestles	.6	.3	3.9	.0
Total Stone Tools	**5410**	**1216**	**535**	**158**
Simpson Diversity Index	6.27	7.06	8.10	7.73
Evenness	.45	.50	.58	.70
Ceramics	51	262	1419**	194
Bone tool	60	29	26	12
Beads	129	42	15	1
Grand Total	**5650**	**1549**	**1995**	**365**

Note: *, Millingstone and Mortar categories include bedrock features; **, Much of the Sample IIIA ceramics likely derive from later, post A.D. 1700 components at two key sites—SDI-11068, and SDI-8303. The Shannon Diversity Index is based on: [SUM $(n_i(n_i-1))$]/N(N-1), where n_i = # artifacts in a category and N = total # of stone artifacts.

Interestingly, core-cobble tools (including scraper planes) decline by 2.2%, crude scrapers by 3.3%, and hammerstones decline by 1.0% percent. These heavy, expedient tools were hallmarks of Millingstone-era assemblages and their decline signals a shift in processing technique and subsistence emphasis. Relative proportions of groundstone items show only minor changes, with the exception of millingstones and mortars that actually increase by approximately 2.8% and 1.5%, respectively (see Table 5.2). The increase in millingstones and mortars is due to the increased use of bedrock milling facilities in upland regions. In Sample II, five sites in upland settings have 16 small, shallow bedrock mortars, and 11 millingstone surfaces, increasing the relative proportion of netherstones (i.e., millingstones and mortars) in general.

Shifts in assemblage composition in Sample IIIA are a continuation of those noted in Sample II. Arrow points and point preforms together nearly double in proportion (see Table 5.2). Concerning non-projectile formal flakedstone, bifaces remain stable while formed flake tools become even scarcer in Sample IIIA, dropping to less than 1.0% (see Table 5.2). While expedient RET drop by more than half, SFT double in proportion—the total proportion of both kinds of tools remaining stable at an average of 19.5%. Cobble tools and heavy scrapers together diminish by more than half, from 15.5% in Sample II to 6.9% in Sample IIIA. Groundstone tools show interesting shifts. Millingstones (including bedrock millingstone surfaces) more than double from 9.3% to 23.4% in Sample IIIA, while handstones are half as common. Mortars increase by 1.0%, given the increase in small, bedrock saucer mortars, while pestles comprise 3.9%. For the first time in the prehistory of the San Diego region, handstones are not the most common stone tool type—dropping by more than half to 12.5% of the overall assemblage.

Sample IIIB (Transitional) assemblages are smaller than those from Sample IIIA sites due to the small size and limited temporal span of Transitional sites. However, assemblage composition between the two samples differs markedly. While projectile points and preforms show a modest 1.5% gain, higher assemblage formality is reflected in greater proportions of FFT, increasing from almost zero to 8.9% of Transitional assemblages. These are shaped and maintained flakedstone tools, as opposed to minimally modified RET and unmodified SFT that are discarded shortly after use. RET are nearly absent in the Transitional sample and SFT drop in proportion to 8.2%, 1.5

times less than in Sample IIIA (see Table 5.2). Following the regional trend, cobble tools drop to negligible levels and bulky scrapers are absent in Transitional assemblages.

Turning to groundstone, a total of six millingstones, 19 handstones, and nine miscellaneous fragments were recovered from Transitional sites—a relatively typical milling kit. However, Transitional sites exhibit a sharp rise in all netherstones (i.e., basal grinding platforms), including milling features; mortars amount to 18.4% of the assemblage and millingstones comprise 19.6% (see Table 5.2). Mortar surfaces are more costly to manufacture than slicks or basins that require little to no initial modification prior to use. The much higher frequency of mortar surfaces compared to Sample IIIA is an indication of increased time invested in subsistence technology.

At first glance, ceramics from Sample IIIB (Transitional) sites comprise a smaller proportion of the overall assemblage (53.2%) compared to 71.1% for Sample IIIA sites (see Table 5.2). However, ceramic density at Transitional sites is actually higher. Comparing ceramics from control units (i.e., not including Shovel Test Pits—STPs—or surface artifacts), Sample IIIB (Transitional) sites have an average ceramic density of $88/m^3$ (n = 168, volume = 1.914). In contrast, Sample IIIA sites have an average ceramic density of $55/m^3$ (SDI-9824; SDI-8303 units 6-10, upper 50 cm; SDI-10728A; n = 463, volume = 8.35 m^3). Sample IIIB sites have more than 1.5 times the ceramic density than contemporary Sample IIIA sites; this is evidence of additional investment in technology and a shift in processing and storage technique. Moreover, there is strong reason to believe that the bulk of ceramics in Sample IIIA derives from post A.D. 1700 occupations at SDI-11068 and SDI-8303. Considering just SDI-11068, it can be argued that approximately 75.0% of the 877 ceramic sherds present in strata assigned to Sample IIIA likely derive from post A.D. 1700 occupations but have been transported to lower levels due to post-depositional processes. More than 10,000 pieces of ceramic vessels were recovered from the site, 91.0% of this from the upper 40 cm that postdates A.D. 1700 (see Schroth and Gallegos 1991). If only 25.0% of the ceramics from SDI-11068 are included in Sample IIIA, the overall assemblage proportion of ceramics drops to 53.0%, similar to Transitional sites.

To summarize, other than arrow points and preforms, assemblages show decreasing proportions of formal artifact classes over time from Sample I to Sample II and Sample IIIA. A high level of formal artifact classes in Sample IIIB (Transitional) sites, including bedrock mortars, reverses this pattern, indicating that Transitional sites are socioeconomically distinct. These patterns are best characterized by differences in assemblage formality indices discussed in the next section.

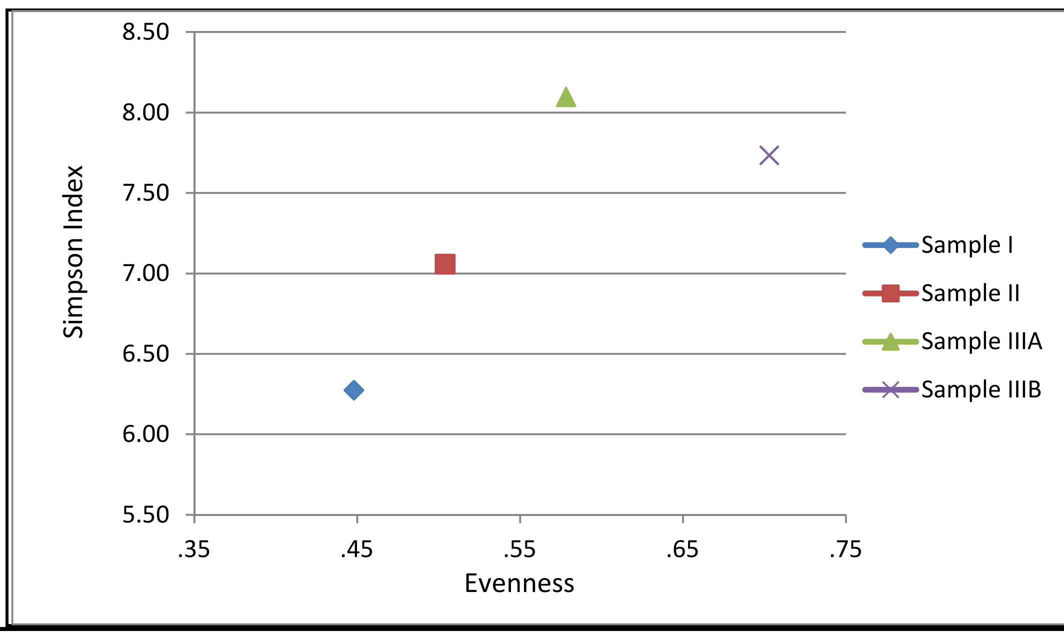
5.1.1.1 Shannon Diversity Index Values

Assemblage diversity for each sample was measured with the Simpson's diversity index (D) which is the inverse of the sum of the squared proportions for each artifact class:

$$D = 1/[\sum(n_i/N)^2]$$

where n_i = the number of specimens in a particular artifact category and N = the total number of specimens for all categories (see Bettinger 1980). Larger Simpson values reflect greater diversity, with the maximum value being equal to the maximum number of artifact categories. For the San Diego region, Samples I through IIIA had the same the same number of artifact classes represented (i.e., richness). Thus, the Simpson index is only measuring variability in evenness because richness is the same. To better estimate evenness across all samples, the Simpson's index value was divided by the maximum number of tool classes present. Equivalent richness betweens samples is reflected graphically as a straight line if Simpson's index is plotted on the y-axis and evenness on the x-axis (Figure 5.3).

The Simpson index value increases in step with evenness from Sample I to Sample IIIA, generally indicating an increase in diversity (Figure 5.3). However, the Simpson index decreases for Sample IIIB (Transitional), while evenness increases (see Figure 5.3). The drop in diversity in Sample IIIB is due to a the decreased reliance on heavy cobble-based pulverizing and chopping tools and increased use of task-specific tools (i.e., technological specialization).



	Sample I	Sample II	Sample IIIA	Sample IIIB
Simpson	6.27	7.06	8.10	7.73
Evenness	.45	.50	.58	.70

Figure 5.3. Simpson diversity index values (y-axis) and evenness (x-axis) for each sample from the San Diego region.

The inverse relationship between The Simpson index and the formality indices is not unexpected. The lack of a substantial increase in either the flakedstone or groundstone formality indices fits with an increase in expedient tools, fashioned for an immediate, local need. The large increase in FFI and GFI values for Sample IIIB is reflected here as a drop in the Simpson value (i.e., decreased diversity of artifact classes) and an increase in evenness. Larger amounts of formal tools are being manufactured at the expense of more expedient items.

5.1.2 Assemblage Formality Indices

Assemblage formality indices are considered a proxy for measuring the relative degree of investment in subsistence tools. Considering flakedstone, the FFI value is low in all samples except Transitional sites (Table 5.3). However, there is a slight decrease in the FFI value from 0.28 to 0.25 from Sample I to Sample II, after the bow arrives. Low flakedstone formality continues to characterize Sample IIIA, which has an FFI value of 0.26. On the other hand, Sample IIIB (Transitional) sites have a high FFI value (0.67); a more than 50.0% increase in flakedstone formality and a direct measure of increased manufacturing effort.

Turning to debitage, an increase in waste is anticipated when either less care is taken during the initial stages of reduction, or if tool finishing is less common. After the bow arrives, a drop in the LWI value from 0.53 in Sample I to 0.30 in Sample II supports the appearance of finished arrow points in massive quantities, despite the disappearance of FFT. This trend is reversed in Sample IIIA, having an LWI value of 0.49—nearly equal to that in Sample I (see Table 5.3). This reversal occurs despite an increase in arrow points and bifaces and suggests that less care is taken in flakedstone tool reduction. The subsequent low LWI value among Sample IIIB (Transitional) sites is also consistent with a sharp increase in formal flakedstone tools, implying more time spent finishing tools.

Groundstone formality index values behave much like flakedstone tools in the San Diego region (see Table 5.3). GFI values are relatively low among all samples, except Sample IIIB (Transitional) sites, which have high values. Samples I and II both have GFI values of 0.34, indicating that the aggregate time spent formalizing groundstone tools, including the manufacture of mortar surfaces, is consistent, regardless of whether the formal tools co-occur at the same site or if they are segregated between sites in different settings. The Sample IIIA GFI value is significantly lower at 0.23. While there are relatively equal proportions of shaped and unshaped handstones, unshaped millingstones and pestles, along with incipient bedrock slicks far outnumber mortars. The Sample IIIB (Transitional) GFI value of 0.50 is opposite that of Sample IIIA. High handstone formality and a large percentage of bedrock mortars condition the high GFI value for Transitional groundstone tools.

Table 5.3. Assemblage Formality Indices by Sample in the San Diego Region

Formality Index	**Flakedstone**	**Debitage**	**Groundstone**
Sample I	0.28	0.53	0.34
Sample II	0.25	0.30	0.34
Sample IIIA	0.26	0.49	0.23
Sample IIIB Transitional	0.67	0.37	0.50

Sample biases could certainly have an effect on the FFI and GFI values, but significant departures from the observed pattern are unlikely. Many more sites were analyzed for this research but not included because the assemblages had depositional mixing issues that could not be resolved. Despite these problems, nearly all of the excluded assemblages in the San Diego region match the pattern of low flakedstone and groundstone formality. That is, it is unlikely that any assemblage exists in the San Diego region, especially in Sample II, with exceptionally high tool formality such that the pattern documented herein would significantly change. The main point behind the formality index values for the San Diego region is that there are no significant increases in assemblage formality after the bow arrives or during intensification, with the exception of Sample IIIB (Transitional) sites.

5.2 FLAKEDSTONE AND GROUNDSTONE ANALYTICAL DATA

A sample of flakedstone and groundstone artifacts was analyzed as a second independent test of the hypotheses set forward. These analyses track manufacturing effort and use, and are compared to the assemblage-level changes above. Flakedstone artifacts are discussed first, followed by groundstone. Finally, available subsistence data are summarized to provide a more complete picture of overall economic change.

5.2.1 Flakedstone

A sample of 78 projectile points, 34 bifaces, 28 FFT, 26 RETS, and 70 SFT from 15 sites were analyzed to generate data on manufacturing and use (Table 5.4). In general, the results of the flakedstone analysis strongly support assemblage-level change characterized by the formality indices.

Though the frequencies of different flake-based items are relatively high in the tabulated assemblages, access for analytical purposes to the collections that contained high numbers of these items (i.e., SDI-4392, W-20, W-84, W-95) was limited, allowing only enough observation of reported artifact types to ensure correct reclassification. Additionally, in other collections revisited for analysis, items classified as one kind of flake tool or another did not meet the criteria to be classified as FFT, SFT, or RET. When this occurred, items not considered flake-based tools were excluded from tabulation. The end result was an overall reduction in the number of flake-based tools-especially SFTs (i.e., utilized flakes)—represented in the respective assemblage. A good example is the "teshoe (or teshoa) flake" consisting of a single flake struck from the end of a cobble retaining its entire cortex on the dorsal surface. Many of these items were not included in assemblage tallies because little to no evidence of use-related edge damage was observed. Another common occurrence was the reclassification of "scrapers" or "utilized flakes" as retouched flakes or debitage in this analysis.

Table 5.4. Lithic Tools Analyzed from the San Diego Region by Sample

	SITE	Projectile Point	Biface	Formed Flake Tool	Retouched Flake	Simple Flake Tool	Grand Total
Sample I	11767			1	3	4	8
	12814	3	6	10	5	17	41
Subtotal		3	6	11	8	21	49
Sample II	10006	3	1	2	3	6	15
	8303 lower	4					4
	5138	15	1	1	2	5	24
	5139		6				6
	5143	4		1	1	2	8
	5147					1	1
Subtotal		26	8	4	6	14	58
Sample IIIA	5144	5					5
	5146	4	2	1		1	8
	8303	11			5	7	23
	9824	17	2			3	22
	10726		1	2		5	8
	10728				6	6	12
Subtotal		37	5	3	11	22	78
Sample IIIB Transitional	10712/713	10	9	3		6	28
	10714	1	4	4	1	4	14
	14571	1	2	3		3	9
Subtotal		12	15	10	1	13	51
Grand Total		78	34	28	26	70	236

5.2.1.1 Projectile Points

Projectile points in Samples I through IIIB include stone dart (atl atl) and arrow points. Analyzed points from Sample I are rare (n=3), while Samples II, IIIA, and IIIB (Transitional) contain relatively large numbers of points (Table 5.5). Sample I predates A.D. 500 when the bow and arrow is thought to have arrived in the San Diego region.

That dart points are still found in low numbers in Sample II is most likely due to overlapping early and late occupations of the same site. However, the atl atl was probably used for a short period of time after the bow was introduced. Most dart points in the San Diego region are morphologically similar to Pinto points or Elko Eared points, and are categorized as such (see Reddy 1996). Other kinds of dart points include broad and narrow contracting stems and concave base points. Though the Pinto and Elko point chronologies were established in the Great Basin, they were probably used during the same time periods in the San Diego region, signifying a broad socioeconomic system characteristic of the Millingstone Horizon. In fact, Pinto period assemblages are known to have large numbers of ground and battered stone tools, similar to La Jolla period sites (Basgall and Hall 1990). It is not unreasonable to think that mobile groups from interior deserts could have temporarily settled in the San Diego region, or that technologies were transmitted between local residents and neighboring groups. Such a connection has been frequently cited in previous research (see Warren et al. 2004). Earlier point forms are also present. Carrico et al. (1983) report several projectile points from sites around Agua Hedionda lagoon that resemble Silver Lake and Lake Mojave forms—both of these date to the early Holocene in the Great Basin and Mojave.

The analysis of projectile points was conducted as a supplement to other stone tools. Most published reports and monographs give lengthy treatment to projectile points and neglect other kinds of flakedstone tools. Extensive summary data on projectile points from each sample can be found in the documents referenced for each site, and it will not be repeated in this section. The single goal of analyzing projectile points for this research was to separate them out from other bifacially modified items (i.e., early stage roughouts, knives, drills, etc.). Where applicable, each point was assigned to a typological category (i.e., Cottonwood arrow point) and metrics were recorded. Little time was spent recording incomplete measurements, unless it contributed to another metric, such as defining the depth of the concave base on a Cottonwood arrow point by measuring total length and axial length, regardless of whether the distal end was present or not.

Just three dart fragments were found during the flakedstone analysis for Sample I (Table 5.5). These were all made from high quality local materials (one each Monterey chert, Piedre de Lumbre (PDL) chert, and quartz) and were finely made (i.e., Stage 4 bifacial reduction). Each fragment was an end; two are pointed, one is rectangular (probably a base). One of these retained some characteristics of the parent flake blank, including the shape of percussion bulb, while the original mass of the other two fragments could not be determined. Interestingly, all three fragments exhibited impact fractures. Metrics on darts were largely incomplete. However, a thickness reading of 0.91 cm demonstrates that these points were robust compared to later arrow points average thickness is a common attribute of dart points and can be a loose proxy for distinguishing between dart and arrow points.

Table 5.5. Projectile Point Attribute Proportions by Sample

		Sample I	**Sample II**		**Sample IIIA***	**Sample IIIB (Transitional)**
		Dart	Dart	Arrow	Arrow	Arrow
Class	Arrow			.61	.58	.83
	Arrow Fragment			.22	.21	.17
	Dart		.67			
	Dart Fragment	1.00	.33			
	Blank			.17	.21	
	Total	3	3	23	37	12
Condition	Whole		.67	.39	.46	.41
	Distal	.33		.15	.14	
	Proximal		.33	.36	.32	.25
	End	.67			.05	.17
	Medial			.05	.03	
	Margin			.05		.17
Spine Plane Angle			77	53	48	43
Shape	Rectangular	.33		.05		.33
	Pointed	.67	.67	.64	.70	.50
	Rounded			.05	.03	
	Concave					
	Straight				.03	
	Indeterminate		.33	.26	.24	.17
Type	Arrow Size			1.00	.97	.92
	Dart Size	1.00	1.00			
	Preform				.03	.08
	Indeterminate					
Form	Nodule					
	Flake	.33	.67	.91	.92	1.00
	Indeterminate	.67	.33	.09	.08	
Stage	1					
	2			.09		
	3				.03	
	4	1.00	1.00	.04	.08	.08
	5			.87	.89	.92
Edge Modification	Bifacial Chips					
	Edge Ground					
	Battered/Dull					
	Step Fracture					
	Impact Fracture	1.00	0.67	0.44	0.43	.42
	Reject					

Note: *, does not include one dart fragment.

Sample II projectile points include three darts and 22 arrow points or fragments thereof. Another four are arrow point blanks (see Table 5.5). Dart points include one untypable quartz stemmed point (from SDI-1006), and two metavolcanic Pinto points (one base, one whole). As in Sample I, darts in Sample II were bulky, having an average thickness of 0.77 cm. An average spine plane angle of 67 degrees also indicates that these darts were thickest in the midsection, quickly tapering to sharp margins. All of the Sample II darts are finished (i.e., Stage 5), two were made from flake blanks (one was indeterminate for parent form) (see Table 5.5). Both Pinto points had impact fractures while the stemmed point was reworked on the distal end.

Sample II arrow points and blanks are mostly whole (46.0%) or proximal fragments (32.0%), with a few other distal, medial, and margin fragments (see Table 5.5). Arrow points were made from local metavolcanic (58.0%), PDL (26.3%), and quartz (15.7%). Despite the hardness and difficulty in flaking fine grained metavolcanic stone, the use of this stone for arrow points is similar to the manufacture of dart points in Sample I from these same materials. Sample II arrow points and blanks have an average thickness of 0.45 cm, roughly half that of dart points from this sample and from Sample I. A more acute spine plane angle of 53 degrees for Sample II arrow points is further evidence that these items are thin in cross section (see Table 5.5).

Given that all arrow points originated as flake blanks, the spine plane angle probably relates more to the parent flake shape, having a less pronounced percussion bulb and narrower platform. That is, although both dart and arrow points from Samples I and II were made from flake blanks, the flakes selected for arrow manufacture were smaller and thinner. In fact, the parent flake curvature is still visible on most arrow points from Sample II.

All arrow points from Sample II that could be assigned to an existing point type were consistent with the Cottonwood Triangular form. Sample II Cottonwood points are relatively narrow, having an average width of 1.51 cm. The basal concavity is also shallow, averaging 0.16 cm. As will be discussed below, Sample IIIA basal concavity and width measurements for Cottonwood forms is much more variable.

Sample IIIA analyzed projectile points consist entirely of arrow points or arrow preforms (n=37) (see Table 5.5). Like Sample II, most Sample IIIA points are whole (46.0%) or proximal fragments (32.0%). Whole average metrics for Sample IIIA points are a rough measure of variation in point shape. All typable arrow points are Cottonwood Triangular or a variant thereof (including Dos Cabezas Serrated), with one fragmented Desert Side Notch point (Figure 5.5). Sample IIIA Cottonwoods are more variable in form than those from Sample II. Average metrics for Sample IIIA Cottonwood points are 1.57 cm for width and 0.35 cm for thickness; compared to 1.51 cm for width and 0.45 cm for thickness on Sample II Cottonwood points. Additionally, the average basal concavity measures 0.37 cm for Sample IIIA Cottonwoods—this is nearly two and a half times the average concavity of Sample II Cottonwoods (0.16 cm). There are obvious differences in outline that account for some of this variation. Some Sample IIIA Cottonwoods are short and broad with a deep base and others have long serrated blades and narrow bases—serrations on these extending the length of the point from base to tip. All other attributes of Sample IIIA points are very similar to Sample II, the majority having pointed ends, being made from flakes, extensively retouched (i.e., Stage 5), and commonly exhibiting impact fractures (see Table 5.5).

Four arrow points from Sample IIIA are minimally retouched—edge flaking does not cross the entire flake and can be unifacial. These items (three from SDI-8303 and one from SDI-9824) are considered incipient arrow points because each had an impact fracture on the distal end, implying use as a projectile tip. These incipient points are narrower (1.2 cm wide) and thinner (0.29 cm thick), on average, than typical arrow points in the sample, indicating that small interior flakes were quickly fashioned as arrow tips.

The increase in arrow point morphological variability in Sample IIIA is widely recognized in the San Diego region (see Waugh 1986), but most forms are classified as variants of either Cottonwood or Desert Side-Notch types. The latter type is more common than Cottonwood forms in the southern part of the county and the opposite is true north of San Elijo Lagoon (see Pigniolo 2004). In fact, among Sample IIIA assemblages, 39 arrow points were classified as Cottonwood variants and only one as a Desert Side-Notch.

Sample IIIB (Transitional) arrow points are consistent in form and use with those from Sample IIIA (see Table 5.5). Out of 12 measured points, average metrics for Transitional arrow points are 2.49 cm long, 1.42 cm wide, and 0.47 cm thick, similar to those from Sample IIIA, though slightly thicker. The basal concavity on Transitional Cottonwoods is 0.14, similar to the 0.16 average concavity for Sample II Cottonwoods. Nearly all arrow points at Transitional sites (n = 20 out of 23, including the 12 analyzed arrow points) were identified as Cottonwood Triangular points. Three others were indeterminate types. The absence of variant point forms at Transitional sites may be an indication that Cottonwood and Desert Side-Notch point forms are culturally specific. If true, the lack of Desert Side-Notch forms in Transitional assemblages supports the notion that these sites represent local economic developments, rather than deriving from an influx of non-local groups.

Transitional arrow point raw material profiles show a greater use of lower quality materials. Most were made from quartz (40.0%), with 30.0% each made from PDL chert and metavolcanic stone. The increased use of lower quality metavolcanic and quartz probably resulted from the procurement of these materials in cobble form from coastal outcrops for manufacture of several kinds of tools at Transitional sites. All other attributes are similar to those for Sample II and IIIA arrow points (see Table 5.5).

In sum, the analysis of projectile points shows a transition from dart to arrow points between Sample I and II. Nearly all arrow points in Samples II, IIIA, and IIIB (Transitional) are classified as Cottonwood Triangular points, or variants on this form. Despite the consistency in arrow point form, morphological variability increases later in time, with Sample IIIA finished points exhibiting a wider range of metrics. Additionally, Sample IIIA includes several expedient points that exhibit use-related damage but are unfinished (i.e., unifacial, not completely retouched). Finally, all arrow points were made from thin flake blanks, rather than being reduced bifacially from a larger flake blank as were earlier dart points.

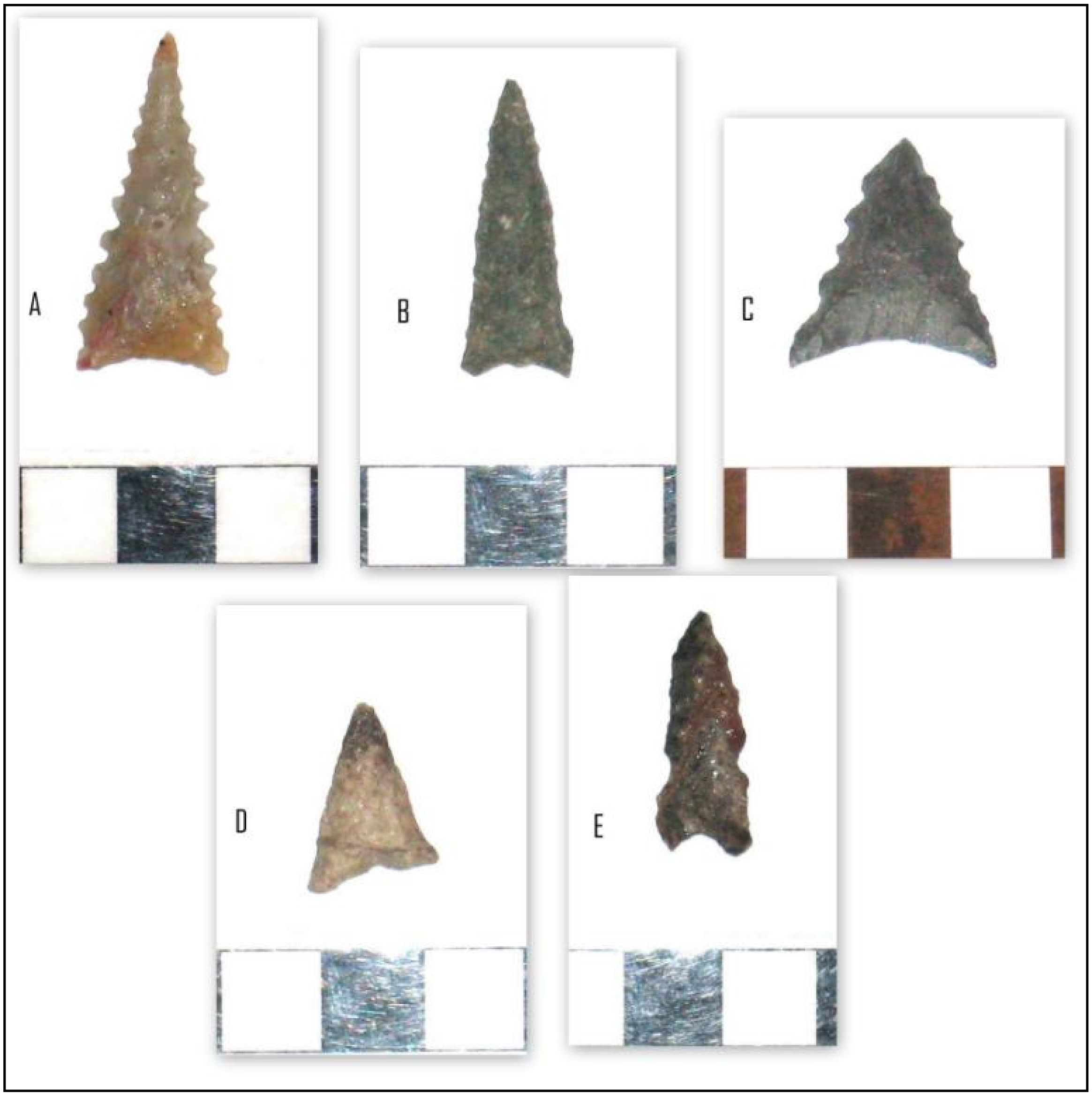


Figure 5.5. Some arrow point forms from the San Diego region. A-D, Cottonwood Variants (A may actually be a repaired Dos Cabezas Serrated); E, incipient Desert Side-Notch.

5.2.1.2 Bifaces

Bifaces analyzed from all samples total 30, with six from Sample I, eight from Sample II, five from Sample IIIA, and 15 from Sample IIIB (Transitional) (Table 5.6). Sample I bifaces were made from local stone, including metavolcanic, quartz, and quartzite; one was made from red chert. A third of these are drills and the rest are generic, nondescript roughouts. Despite the vagaries in form, most Sample I bifaces have pointed ends (66.0%). All bifaces are dart-sized or larger. This is confirmed by large average metrics for Sample I bifaces of 6.4 cm long, 3.4 cm wide, and 1.3 cm thick. An average spine plane angle of 64 degrees is another indication of thickness in cross section, and that these artifacts were made from bulky parent flakes—one drill was made from a biface blank (see Table 5.6). Half of Sample I bifaces are finished forms (i.e., Stage 4), with the rest classified as Stage 3 or lower—an indication of irregular margins and a lack of edge retouch. The finished state of bifaces suggests that they were manufactured as tools, rather than representing discarded tool blanks.

In Sample II, all bifaces are classified as generic roughouts; no tools were identified in the analyzed sample (see Table 5.6). These items are relatively thick and irregular in form. The 67-degree spine plane angle is slightly larger than the average of 64 degrees measured on Sample I bifaces. While not as large as bifaces in Sample I, Sample II bifaces are still bulky with average metrics of 3.2 cm long, 2.4 cm wide, and 0.97 cm thick. Interestingly, PDL chert makes up half the sample of analyzed bifaces from Sample II; the rest are metavolcanic. The increased use of PDL chert in the generic biface category is probably related to the increased occurrence of this material for arrow points in Sample II. While procuring PDL chert for arrow manufacture, it is not unthinkable that the same good quality material would be procured for bifacial tool manufacture as well. Similar to Sample I, bifaces from Sample II were primarily made from flakes; only one specimen was made from a nodule (see Table 5.6). A major difference between Sample I and II bifaces is that the latter are much more irregular in form. Most (75.0%) of Sample II bifaces are classified as Stage 2 with one other that is a Stage 1 biface.

Table 5.6. Biface Attributes by Sample

		Sample I	Sample II	Sample IIIA	Sample IIIB (Transitional)
Class	Tool	.33		.20	.13
	Generic	.67	1.00	.80	.87
	Total	6	8	5	15
Condition	Whole	.83	1.00	.80	.40
	Distal				.08
	Proximal				.26
	End			.20	.26
	Medial	.17			
	Margin				
Spine Plane Angle		64	67	68	54
Shape	Rectangular				.07
	Pointed	.66	1.00		.40
	Rounded	.17		.40	.07
	Concave				.13
	Straight			.60	.33
	Indeterminate	.17			
Size	Arrow Size				.07
	Dart Size	.33			
	Tool Blank	.17		.20	.53
	Indeterminate	.50	1.00	.80	.40
Form	Nodule	.17	.12	.20	.13
	Flake	.83	.76	.80	.74
	Indeterminate		.12		.13
Stage	1		.25	.60	.07
	2	.17	.75	.20	.67
	3	.33		.20	.26
	4	.50			
	5				
Edge Modification	Bifacial Chips			.20	
	Edge Ground			.20	
	Battered/Dull			.20	
	Step Fracture				
	Impact Fracture	.17			
	Reject			.20	

The lack of finished bifaces is not surprising given that no specific bifacial tools were identified. Cursory examination of bifaces from other, non-analyzed collections in Sample II are consistent with a decrease in bifacial tool finishing, a trend that is hinted at in an assemblage-wide trend of decreasing biface production overall from Sample I to Sample II and IIIA.

Five bifaces were analyzed from Sample IIIA assemblages (see Table 5.6). Most of these are generic roughouts and one is a tool. PDL chert remains the most commonly used material (n=3), while one is metavolcanic and the other petrified wood. Average metrics on Sample IIIA bifaces are 3.5 cm long, 2.3 cm wide, and 1.4 cm thick—similar to those from Sample II. The spine plane angle of 68 degrees is nearly equal to that of Sample II, indicating thickness in cross section (see Table 5.6). All other attributes of Sample IIIA bifaces are similar to those for Sample II, including a majority of bifaces made from large flakes and a bias toward early stage, unfinished margins (see Table 5.6). The increased incidence of use wear in Sample IIIA derives from the edge of a single wedge-like tool that was used intensively enough to exhibit macroscopic wear.

Sample IIIB (Transitional) bifaces are different than those from all previous samples. Of the fifteen Transitional bifaces, at least two bifaces are formal tools (i.e., knives), and the rest are generic tool blanks. While most Transitional bifaces were made from flakes, two were made from nodules, lacking flake attributes. The latter specimens are large, early stage (Stage 1 or 2, respectively) generic bifaces, with average metrics of 3.9 cm long, 3 cm wide, and 1.4 cm thick. In terms of reduction stage, another 67.0% were classified as Stage 2, and 26.0% as Stage 3, showing only a few flake detachments per side of each margin. All Stage 2 and 3 bifaces are also large, averaging 3.2 cm long, 2.3 cm wide, and 0.83 cm thick. These were made from late decortication flakes—cortical platforms or dorsal cortex was present to make this determination. No early stage biface exhibited use wear. The early stage bifaces were intended to be tools, such as the two bifacial knives. Remnant flake scars were too small to imply that flakes were being detached for arrow point or SFT production, given larger whole measurements of both arrow points and SFTs. Additionally, an average spine plane angle of 54 degrees indicates that Transitional bifaces were made from parent flakes that were thinner in cross section. As is described in the analysis of Transitional debitage (see Section 5.1.2.6), cobbles were procured off site and reduced on site for tool manufacture. Coupled with greater care taken in flakedstone reduction overall, it can be expected that flakes detached for the production of bifaces were more regular, and perhaps thinner. This inference is indirectly supported by the fragmentary nature of the Transitional biface assemblage (60.0% are fragments). However, the lower spine plane angle on Transitional bifaces could also derive from scavenging suitable flakes from a smaller sample of debitage overall.

The analysis of bifaces for each sample shows that bifaces form is generally irregular in Samples I, II, and IIIA. Transitional bifaces deviate from this trend, exhibiting greater formality in edge shape and a wider variety of edge shapes. Together with smaller average metrics, Transitional bifaces reflect greater emphasis on the manufacture and use of bifacial tools.

<u>5.2.1.3 Formed Flake Tools</u>

A total of 28 FFT was analyzed, including 11 FFT from Sample I, four from Sample II, three from Sample IIIA, and 10 from Sample IIIB (Transitional) sites (Table 5.7). The low frequency of analyzed FFT is mostly due to their general scarcity in assemblages from the San Diego region. Given that FFT are intentionally manufactured tools, general consistencies in FFT attributes across all samples is not surprising.

Sample I FFT exhibit a raw material profile shared with other flakedstone tools and debitage, with most (n = 8) specimens made from metavolcanic stone, and others made from chert, PDL, and quartzite (n = 1 each). FFT were manufactured from both cortical (45.0%) and early interior flakes (55.0%)—in all cases, the parent flake platform and bulb of percussion was visible. FFT shape is indicative of manufacturing effort and appears unrelated to parent flake size. Average metrics are 4.12 x 3.05 x 1.18 cm—somewhat round, thick objects.

Sample I FFT tended to have a single manufactured edge with a regular outline (82.0%) (see Table 5.7). Two FFT (18.0%) exhibited multiple edges (one had two edges, another had three edges) for a total of 14 tool edges. Only 14.0% of all edges were irregular in shape (n=2, both convex)—one each occurring on the two multi-edge tools. All other edges were regular in shape, including 65.0% convex, and 7.0% each concave, deeply notched, and denticulate (i.e., multiple, regular concavities along a single straight edge).

Macroscopic edge damage—a proxy for use wear—was observed on all Sample I FFT edges. All edges were unifacially flaked, 65.0% of these showing unifacial edge damage. Half of all edges exhibited small, but regular ground facets and 36.0% of these had a ground face (i.e., the underside of the flake tool). Some edges (14.0%) exhibited bifacial microchipping and 7.0% exhibited battering that dulled the edge. The bifacial edges were probably used for cutting and battering. Attributes of unifacial edges are consistent with scraping.

Sample II assemblages included four analyzed FFT. Half were whole and half were fragments. Most (75.0%) were made from metavolcanic cortical flakes, with one made from a PDL chert interior flake (see Table 5.7). Average metrics are 4.81 x 3.7 x 1.75 cm; these sizes are larger than those in Sample I. Sample II FFT tend to have a single edge (75.0%) but one specimen exhibited two edges—one of these characterized as straight and regular in shape, the other as concave-irregular. This multi-purpose tool had a drill bit end with bifacial retouch and microchipping, and a regular shaped convex edge with unifacial flaking and microchipping. Other FFTs include one drill, two scraping tools with convex-regular edges, and one unifacially flaked straight edge that has been ground down. Generally, FFT in Sample II are a lot like their Sample I counterparts, but were made on larger flakes and appear to have been used less intensively for scraping tasks, or against less abrasive materials, given the lack of grinding on planar faces.

Sample IIIA FFT reveal little about tool use, other than their limited occurrence after A.D. 1400. Only five formed flake tools were identified from Sample IIIA assemblages; three of these were analyzed in detail. All three analyzed FFT are whole and made from early and late cortical flakes (see Table 5.7). One FFT was used primarily as a drill, but also has a convex-regular edge, exhibiting unifacial edge damage and unifacial retouch; this edge was probably used for scraping. The drill bit is a natural protrusion off the flake that was minimally retouched on two sides to narrow the bit. This specimen measures 3.9 x 2.9 x 0.8 cm. The other two FFT are rather large; one measures 6.8 x 3.8 x 1.7 cm, and the other measures 7.8 x 7.2 x 3.4 cm. The larger specimen is also a drill with the bit being unifacially retouched on opposing margins. Grinding was observed on the drill tip indicating heavy use. The other FFT has a single, unifacially retouched edge but no use wear was evident. The edge angle is steep (82^0), consistent with scraping tasks. These tools are similar to those found in Sample I assemblages.

Table 5.7. Formed Flake Tool Attributes by Sample

			Sample I	**Sample II**	**Sample IIIA**	**Transitional Sample IIIB**
Condition	Whole		0.64	0.50	1.00	0.70
	Fragment		0.36	0.50		0.30
	Total	%	100%	100%	100%	100%
		N	11	4	3	10
Flake Type	Cortical		0.45	0.75	1.00	0.70
	Interior		0.55	0.25		0.30
#Edges	1		0.82	0.75	0.67	0.80
	2		0.09	0.25	0.33	0.20
	3		0.09			
	Total # Edges		14	5	4	12
Edge Shape	Concave	Regular	0.07			0.08
		Irregular				
	Convex	Regular	0.65		0.25	0.17
		Irregular	0.14		0.25	0.34
	Straight	Regular		0.40		0.25
		Irregular				0.08
	Beak	Regular		0.20		0.08
		Irregular				
	Notched		0.07			
	Denticulate	Regular	0.07			
		Irregular				
	Drill			0.40	0.50	
Edge Damage	Unifacial Damage		0.65	0.60	0.50	0.50
	Bifacial Damage		0.14	0.20	0.25	0.16
	Grinding		0.50	0.60	0.50	0.33
	Battering		0.07			0.16
	Unifacial Flaking		0.79	0.80	0.75	0.75
	Bifacial Flaking			0.20	0.25	0.08
	Step Fracture					0.16
	Ground Face		0.36			0.16

The total number of FFT analyzed from Sample IIIB (Transitional) sites is 10 (Table 5.7). Most Transitional FFT are whole (70.0%) and 30.0% are margin fragments. FFT were made primarily from early and late cortical flakes (40.0% and 30.0%, respectively), with another 30.0% made from early interior flakes. Transitional FFT have average measurements of 5.18 cm long, 2.97 cm wide, and 1.55 cm thick. These measurements are similar to Sample IIIA FFT, as is the use of cortical flakes.

As with most FFT, Transitional specimens tend to have a single edge (80.0%) (see Table 5.7). Out of 12 edges, edge shapes are relatively diverse, including convex regular (25.0%), convex irregular (25.0%), straight regular (25.0%), and 8.3% each straight irregular, beaked, and drill tip (see Table 5.7). Most edges (58.0%) have regular outlines. Edge regularity is a measure of shaping effort and use intensity. In all cases, the few irregular edges are secondary to the main working edge on the FFT.

FFT use wear is quite diverse (see Table 5.7). Edges were primarily unifacially retouched (75.0%), with a small proportion of bifacially retouched edges (25.0%). Scraping characterizes half of all edges with unifacial edge damage while cutting is implied on 25.0% other edges that have bifacial edge damage. However, bifacial edge damage can occur from excessive scraping. Edge grinding was observed on 33.3% of all edges—one of these is polished—and 16.6% have ground dorsal faces. Pounding is indicated by the presence of step fracturing on some edges (16.6%). No direct evidence of hafting was identified, but it is likely that some of these tools were secured in a bone or wood haft to increase leverage and overall utility. Hafting would be consistent with the generally heavy amount of use implied by edge damage observed on Transitional FFT.

Overall, the analysis of FFT reveals a trend of decreased intensity of use over time. This trend fits with the sharp drop in the proportion of FFT after the bow arrives and again in Sample IIIA assemblages. The high proportion of FFT in Sample IIIB (Transitional) assemblages is an indication of greater technological investment. Consistent with this evidence, Sample IIIB (Transitional) FFT were used with more regularity and intensity, exhibiting regular edge shapes and a diverse range of edge damage attributes.

5.2.1.4 Retouched Flakes

Analyzed retouched flakes total 26, including eight specimens from Sample I, six from Sample II, 11 from Sample IIIA, and one Sample IIIB (Transitional) RET (Table 5.8). In Sample I, all eight retouched flakes are whole with average measurements of 5.35 x 3.92 x 1.78 cm, and ranges for each measurement of 4.7 cm, 2.8 cm, and 2.7 cm. These measurements show that RET are longer, on average, than FFT and SFT in all samples. RET are mostly primary (25.0%) and secondary (37.5%) decortication flakes, but early interior flakes are not uncommon (37.5%). All RET have a single edge. Edge shapes are mostly convex irregular (50.0%) or irregular denticulates (37.5%); straight irregular edges amount to 12.5%. In terms of edge damage on Sample I RET, 37.5% exhibit bifacial microchipping and 87.5% are unifacially flaked, exhibiting between 4-7 discontinuous flake detachments from the edge. Other observed edge damage attributes include grinding (12.5%), battering (12.5%), and step fracturing (12.5%) indicating use for pounding/pulverization. Three large RET, with average metrics of 7.37 x 4.97 x 2.8 cm, seem to have been used as incipient choppers. The rest were either discarded soon after manufacture without being used, were used on materials that were too soft to accrue wear, or were used with such a short period of time that wear did not accrue.

Sample II retouched flakes total six, five whole, one fragment. These were primarily made from early (33.3%) and late (50.0%) decortication flakes (see Table 5.8). Average metrics are 5.9 x 4.22 x 1.78 cm for length, width, and thickness, respectively. Though a small sample, these items are smaller by about one centimeter all around than retouched flakes in Sample I. The smaller size of Sample II RET probably has more to do with the availability of flakes scavenged for quick use as RET, rather than a selection bias. All Sample II RET have a single edge, and edge shapes include convex (50.0%), straight (16.7%), and denticulate (33.3%). Half of all edges are irregular in shape—including one convex edge and both denticulates. All edges are unifacially retouched, 83.3% exhibit unifacial microchipping, 16.7% are ground, and 33.3% exhibit step fractures (see Table 5.8). That nearly all RET after A.D. 500 exhibit unifacial microchipping, in addition to the other attributes, means that these tools were probably used for incipient scraping tasks.

Sample IIIA analyzed RET total 11 (see Table 5.8). Consistent with Samples I and II, RET in Sample IIIA are made primarily from hard metavolcanic stone; one is made from quartz. Most RET are whole (81.8%), the rest are margin fragments. Primary cortical flakes are the most common parent flake (81.8%), similar to those in Samples I and II. The higher incidence of primary cortical flakes in Sample IIIA, however, could reflect minimal preparation of flake blanks, simply splitting a cobble and driving off a single cortical flake from the exposed platform. Alternatively, the higher proportion of primary cortical flakes could represent scavenging for flakes to be retouched. However, Sample IIIA RET are larger, averaging 6.91 cm long, 4.31 cm wide, and 1.41 cm thick. These measurements are more than 2 cm longer and 1 cm wider than Sample II RET; thickness is roughly the same for both samples. The larger size of Sample IIIA RET suggests they were intentionally struck from cobbles rather than scavenged. The debitage assemblages contains a much wider array of flake types increasing the probability of using smaller flakes rather than spending more time being selective while scavenging.

Table 5.8. Retouched Flake Attributes by Sample

			Sample I	Sample II	Sample IIIA	Transitional Sample IIIB
Condition	Whole		1.00	.83	.82	1.00
	Fragment			.17	.18	
	Total	%	1.00	1.00	1.00	1.00
		N	8	6	11	1
Flake Type	Cortical		.75	.83	.91	.50
	Interior		.25	.17	.09	.50
#Edges	1		1.00	1.00	1.00	1.00
	2					
	3					
	Total # Edges		8	6	11	1
Edge Shape	Concave	Regular				
		Irregular				
	Convex	Regular		.17		
		Irregular	.50	.33	.45	1.00
	Straight	Regular				
		Irregular	1.2	.17	.27	
	Beak	Regular			.9	
		Irregular				
	Notched					
	Denticulate	Regular		.33		
		Irregular	.38		.18	
	Drill					
Edge Damage	Unifacial Damage			.83		1.00
	Bifacial Damage		.37			
	Grinding		.12	.17	.09	
	Battering		.12		.18	
	Unifacial Flaking		.88	.50	.91	
	Bifacial Flaking				.09	
	Step Fracture		.13	.33	.18	
	Ground Face					

All Sample IIIA retouched flakes have a single edge and are irregular in outline. Edge shapes include convex (45.4%), straight (27.3%), beaked (9.1%), and denticulate (18.2%). The most common form of edge modification was unifacial retouch (91.9%); one specimen was bifacially retouched. Edge damage was minimal but includes grinding (9.1%), battering (18.2%), and step fracturing (18.2%). These edge characteristics imply that at least some retouched flakes were used for heavy chopping and scraping, but only for brief periods of time since edge damage was not uniform or extensive enough to imply prolonged use. The absence of unifacial edge damage is a departure from Sample II, in which 83.3% exhibited unifacial microchipping. The lack of unifacial microchipping may indicate that Sample IIIA retouched flakes were used less intensively for scraping. Such decreased intensity of use among RET fits with Sample IIIA SFT that exhibit wear consistent with increased use intensity.

5.2.1.5 Simple Flake Tools

Simple flake tools are the second most common analyzed flakedstone tool category with 70 specimens (Table 5.9). The analyzed sample includes 21 from Sample I, 14 from Sample II, 22 from Sample IIIA, and 14 from Transitional (Sample IIIB) sites.

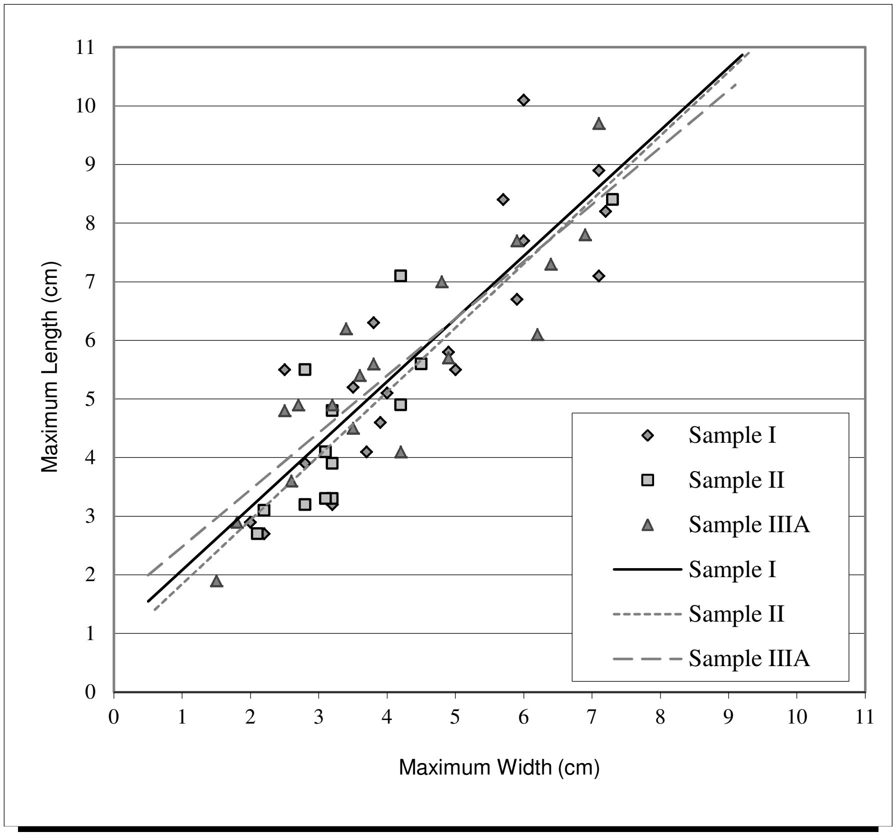
Most Sample I SFTs are whole (90.5%); two thirds (66.7%) are decortication flakes and the rest are early interior flakes (Table 5.9). Sample I SFT tend to have a single working edge (85.7%); two others have two edges, and one has three tool edges (see Table 5.9). Considering 25 total edges, edge shapes include concave (8.0%), convex (60.0%), straight (28.0%), and beaks (4.0%). However, 56.0% of all edges are irregular in shape (see Table 5.9). As with flake size, the irregularity of SFT edge shapes is a product of expedient use. The majority of edges (56.0%) exhibited minor intentional edge preparation on one side of the flake. Other common forms of edge damage include unifacial microchipping (44.0%), bifacial damage (28.0%), grinding (4.0%), battering (28.0%), bifacial edge preparation (4.0%), and step fracturing (8.0%). Though edge preparation is typically a characteristic of FFT and RET, its occurrence on several SFT is more related to minor shaping of part of the flake to remove a protrusion, etc., rather than to make the tool more reliable or to create a certain edge shape/angle. Overall, the wide range of edge modification types observed on Sample I SFT indicates that numerous tasks were completed with these tools, including cutting, scraping, sawing, and drilling.

Sample II SFT total 14 specimens; the majority of which are whole (78.6%) (see Table 5.9). Interior flakes are relatively common in Sample II SFTs, amounting to 43.0%. Additionally, secondary decortication flakes (i.e., those with less than 30.0% dorsal cortex) are more common (50.0%) than primary decortication flakes (7.0%). The shift in flake types for use as SFTs suggests several possibilities. Prior to the bow, cortical flakes were probably driven off of a raw cobble for immediate, local use. After the bow arrived, flakedstone reduction was geared toward specific flake production to make arrow points. During this process, flakes of various types and sizes were scavenged for use as SFT, and late cortical flakes and early interior flakes were more common than early cortical flakes, given the greater amount of flakedstone reduction occurring during arrow point manufacture.

Of the 20 edges on Sample II SFTs, convex edges were the most common (47.0%), followed by straight (27.0%), and concave (26.0%) shapes (see Table 5.9). Irregular edge shapes account for 58.0% of all edges—nearly the same as Sample I SFTs, indicating similarity in use intensity. However, edge damage attributes suggest that the functional orientation of Sample II SFT shifts to assume the chores performed with FFT in Sample I. Fully 74.0% of all edges exhibit unifacial edge damage, but only half as many edges exhibit edge preparation (see Table 5.9). There is also a roughly 10.0% increase in bifacial edge damage, possibly signaling more extensive use as cutting tools. The reduction in the incidence of battering is also a sign that stone tool function is shifting away from the heavy pulverization and chopping activities characteristic of Sample I assemblages. A reduction in edge angle from 53 degrees in Sample I to 34 degrees in Sample II is interesting, given that SFT seem to have picked up scraping duties from previous FFT. However, it is probably related to increased use of later stage cortical and interior flakes with more acute angles. In fact, Sample II SFT are smaller on average, by at least one centimeter than Sample I SFTs. Average metrics for Sample II SFT are 4.61 x 3.53 x 1.1 cm. In contrast, Sample I SFT metrics are 5.89 x 4.55 x 1.62 cm for length, width, and thickness. The more than half a centimeter reduction in flake thickness, related to flake type, is consistent with more acute edge angles and probably has more to do with a higher proportion of later stage flakes available for use as SFTs.

A regression using maximum width to predict maximum length on SFT from Samples I and II reveals a strong relationship in these dimensions from both samples. The adjusted R-square value of 0.85 is quite high, indicating a strong positive relationship between the maximum width and length of SFT. The regression sum of squares (SS) value of 86.1 means that roughly 86.1% of flake tool length is predicted by width. The strong relationship between length and width is also implied in the maximum width coefficient (i.e., slope) of 1.1—i.e., for every 1 cm increase in width, length should increase by 1.1 cm. The regression analysis essentially shows that a specific flake dimension over a range of sizes was consistently selected for use as a SFT in both samples. That is, the selection of flakes for use as expedient tools does not appear to have been random. Individual pieces of debitage were size-sorted, rather than individually measured, preventing a regression on the overall debitage sample. However, cursory observations revealed that flake shape was highly variable, suggesting that a regression on unused flakes would not show a significant relationship between flake length and width.

Turning to Sample IIIA, a total of 22 SFT was analyzed in detail (Table 5.9). Average metrics indicate that SFT in this sample are larger than those from Sample II. Sample IIIA SFTs average 5.56 cm long, 4.17 cm wide, and 1.32 cm thick—a full centimeter longer and nearly a centimeter wider than those of Sample II. Once again, a regression on Sample IIIA SFT also documented a strong relationship (adjusted R^2 = 0.78) with an intercept of 1.51 and a slope of 0.97. In the Sample IIIA analysis, the intercept is twice as high; this relates to larger flakes used as tools. The similarity in slope between Sample II and IIIA SFTs indicates that overall flake shape preference remained similar (Figure 5.4).



	Sample I	Sample II	Sample IIIA
Observations	19	13	18
Adjusted R Square	0.72	0.72	0.78
Standard Error	0.89	0.89	0.89
Intercept	0.49	0.75	1.51
Slope	0.70	1.09	0.97
Regression Sum of Squares	38.41	25.79	48.81
Residual Sum of Squares	13.52	8.78	12.79

Figure 5.4. Regression chart comparing maximum length and width for SFT in Samples I, II, and IIIA; the sample includes 50 whole specimens, including outliers.

Sample IIIA SFTs are mostly metavolcanic flakes (77.0%), with smaller amounts of quartzite and PDL chert. This raw material profile is similar to Sample I and II SFTs. Metavolcanic cobbles are some of the most prevalent in local geologic formations, and their hardness makes unmodified flake edges superior for cutting and scraping relative to other available stone. In Sample IIIA, 45.0% of SFTs are made from cortical flakes, the remainder are made from interior flakes. More specifically, primary cortical flakes (31.0%) are more common than secondary cortical flakes (14.0%). In Sample II, 57.0%

of SFTs are cortical flakes (21.3% primary cortical flakes, and 35.7% secondary cortical flakes). The greater range of flake types (i.e., cortical vs. non-cortical) in Sample IIIA is related to more intensive flakedstone reduction that produced more non-cortical flakes.

SFTs in Sample IIIA typically have one used edge (77.3%) with a lower incidence of multi-edge tools (22.7%) than in Sample II (see Table 5.9). Edge shapes also vary. Concave edges decrease in proportion from Sample II to Sample IIIA, from 26.0% to 22.1%, and straight edges decrease from 27.0% to 11.1%. In contrast, convex edges increase by 5.0% and denticulates, not present in Sample II SFT, make up 11.1% of Sample IIIA SFT. Edge shape regularity (a proxy for use intensity) increases from 42.0% of all edges in Sample II to 47.9% in Sample IIIA, indicating slightly more intensive use. The incidence of edge damage also indicates more intensive use per specimen. While unifacial edge damage is still the most common (57.1%), all other kinds of edge damage were observed, including edge grinding (52.0%) and battering (22.9%)—uncommon or absent in Sample II (see Table 5.9).

Overall, the increase in single-edge tools in Sample IIIA suggests that each tool was used for a narrow range of tasks, while the increase in the kinds of edge damage indicates use of unmodified flakes for a wider range of tasks in general. The implication of these patterns is that expedient flake tools are more economically important in Sample IIIA assemblages, especially in light of the decreased proportion of FFT and RET.

Simple flake tools analyzed from Sample IIIB (Transitional) sites total 14, 78.6% of which are whole (Table 5.9). Average metrics for Transitional SFT are 4.76 cm long, 3.81 cm wide, and 1.49 cm thick. The range of each measurement is quite large: 5.9 x 6.2 x 3.1 cm. There are some very small SFT and others that are larger than 8.0 cm in length.

A regression on Transitional SFT length and width returned an adjusted R-square value of 0.49. Compared to the 0.78 adjusted R-square value for Sample IIIA SFT, the lower value at Transitional sites is an indication of the higher degree of variability in size and shape than at non-Transitional sites. This may relate to the import of lithic raw material to the site for tool production, rather than producing or scavenging suitable flakes of suitable dimension from another location.

Raw material and flake type profiles are similar for SFT from Sample IIIA and Sample IIIB (see Table 5.9). Metavolcanic stone accounts for 77.0% of Sample IIIA SFTs and 86.0% of those from Sample IIIB (the rest are PDL chert). Most SFTs from both samples are early interior flakes, although interior flakes are 10.0% more common in Sample IIIB (see Table 5.9). As with size variation, the use of flakes with minimal cortex may be more a factor of raw material acquisition and reduction on site, having a limited pool of debitage to draw from.

SFT edge characteristics in Sample IIIB assemblages differ from those in contemporary Sample IIIA sites. While both assemblages are dominated by single-edge tools, edge shapes are different. Transitional assemblages have less concave and convex edges, and higher proportions of straight, denticulate, and notched edges (see Table 5.9). Edge shape irregularity is higher among Sample IIIB (Transitional) SFT at 58.9%. Along with more variable edge shapes, Transitional SFT edges exhibit less edge damage overall. The same kinds of edge attributes prevail, however, with grinding, battering, and unifacial microchipping being the most commonly observed. In all, increased variation in SFT metrics and edge characteristics indicate that SFTs from Transitional sites were used less intensively than among Sample IIIA SFTs. The decreased importance of these tools (along with RET) at Transitional sites is probably related to the increased use of FFT at these late sites.

Table 5.9. Simple Flake Tool Attributes by Sample

			Sample I	Sample II	Sample IIIA	Transitional Sample IIIB
Condition	Whole		.90	.79	.91	.79
	Fragment		.10	.21	.09	.21
	Total	%	1.00	1.00	1.00	1.00
		N	21	14	22	14
Flake Type	Cortical		.67	.57	.45	.36
	Interior		.33	.43	.55	.64
#Edges	1		.86	.71	.77	.79
	2		.09	.22	.23	.21
	3		.05	.06		
	Total # Edges		25	20	26	17
Edge Shape	Concave	Regular	.08	.05	.07	
		Irregular		.21	.15	.06
	Convex	Regular	.16	.26	.22	.06
		Irregular	.44	.21	.30	.35
	Straight	Regular	.16	.11	.07	.12
		Irregular	.12	.16	.04	.18
	Beak	Regular	.04		.04	
		Irregular				
	Notched					.06
	Denticulate	Regular			.07	.18
		Irregular			.04	
Edge Mod	Unifacial Damage		.44	.74	.57	.35
	Bifacial Damage		.28	.37	.15	
	Grinding		.04	.16	.52	.29
	Battering		.28		.23	.18
	Unifacial Flaking		.56	.26	.23	.18
	Bifacial Flaking		.04		.04	.06
	Step Fracture		.08	.05	.08	
	Ground Face				.08	

5.1.2.6 Debitage

Debitage from 29 sites, totaling 17,473 pieces, was analyzed to better understand flakedstone reduction trajectories (Table 5.10). Eleven sites containing 4,970 pieces of debitage comprise Sample I, and another eight sites containing 4,861 pieces of debitage make up Sample II. In Sample I, a total of 2,087 pieces of debitage at seven sites from San Elijo Lagoon at the southern end of the study area was analyzed by Iversen (2005), and another 359 pieces of debitage from W-95 at Batiquitos lagoon were analyzed by Smith and Moriarty (1985). Two sites in Sample II (SDI-14170 and SDI-14748) contained 813 pieces of debitage analyzed by York et al. (2006). All production waste from Sample IIIA and Sample IIIB (Transitional) was analyzed as part this research.

Table 5.10. Frequency of Analyzed Debitage by Site and Sample

Sample I		**Sample II**		**Sample IIIA**		**Sample IIIB Transitional**	
Site	**N**	**Site**	**N**	**Site**	**N**	**Site**	**N**
691	505	5138	519	5144	287	10712/713	1553
10728 Lower	483	5143	121	5146	255	10714	554
12814	1536	10006	622	8303	1516	14571	408
SEL-1	902	10723	1461	9824	1032	16780	1892
SEL-2	53	10726	539	10726 Upper	93	-	-
SEL-3	178	10728 Upper	786	10728 Upper Late	52	-	-
SEL-4	170	14170	347	-	-	-	-
SEL-5	279	14748	466	-	-	-	-
SEL-6	100	-	-	-	-		-
SEL-9	405	-	-	-	-	-	-
W-95	359	-	-	-	-	-	-
11 Sites	**N=4970**	**8 Sites**	**N=4861**	**6 Sites**	**N=3235**	**4 Sites**	**N=4407**

One of the most important results of the debitage analysis is that a singular form of flakedstone reduction was practiced throughout the prehistoric sequence: cobble reduction (see also Becker and Iversen 2006; Eighmey et al. n.d.). The cobble reduction technique involves detachment of flakes from a platform created by splitting cobbles open, often resulting in flakes that exhibit cortical platforms. There is no evidence of prepared-core reduction, which involves increased time spent preparing core platforms for predictable flake detachments. Prepared cores (e.g., bifacial cores) are often found in deserts to the north (see Giambastiani et al. 2007). In San Diego County, there is very little evidence of tools made from biface blanks. Rather, most tools, even arrow points, appear to have been made on flake blanks struck from a cobble core.

Comparing Samples I and II, several characteristics of the debitage assemblage indicate an increase in care in flakedstone reduction, including size profiles and the quantities of non-diagnostic shatter. A comparison of diagnostic flakes smaller than 2.0 cm with larger flakes reveals that smaller flakes increase in proportion from 65.6% in Sample I to 74.2% in Sample II (Table 5.11). This is partly due to an increase in early and late biface thinning and finishing flakes from 3.0% to 4.3%; nearly all of these kinds of flakes are smaller than 2.0 cm.

Table 5.11. Proportion of Diagnostic Debitage by Size and Sample (Does Not Include Shatter)

Debitage Size (cm)	Sample I	Sample II	Sample IIIA	Transitional Sample IIIB
<1	37.3	61.0	47.9	48.7
1.0-1.9	28.3	13.2	27.8	25.1
2.0-2.9	17.0	13.2	15.1	14.8
3.0-3.9	8.7	5.0	4.0	6.8
4.0-4.9	5.3	4.4	2.0	1.7
5.0-5.9	1.8	1.8	1.8	1.9
6.0-6.9	.9	.7	.9	.7
7.0-7.9	.3	.5	.1	.3
8.0-8.9	.2	.2	.2	< .1
9.0-9.9	.2	-	-	-
10.0-10.9	-	< .1	< .1	-
11.0-11.9	-	< .1	-	-
16.0-16.9	-	< .1	-	-
Total	1743	2713	1639	1324

The increase in biface thinning and finishing flakes resulted from the manufacture of small arrow points that generally produces smaller, later stage flakes than previous dart points. This same process is also expected to generate larger amounts of smaller, later stage debitage in general.

A change in reduction care is more obvious in the proportion of non-diagnostic shatter to flakes. This is characterized by the Lithic Waste Index (LWI). LWI values drop from 0.53 before A.D. 500 to 0.30 in Sample II. The more than 20.0% reduction in shatter does not signal a shift in reduction techniques; it is evidence that masses of raw material (i.e., cobbles) were being reduced further along the same cobble reduction trajectory than they were prior to arrival of the bow. Generally, the further along in the reduction process the smaller debitage becomes (Andrefsky 1989) and, with the use of pressure flaking techniques, there is a reduction in the proportion of non-diagnostic shatter. Additionally, breaking open a raw cobble produces more shatter than subsequent flake detachments.

Other important shifts in debitage types from Sample I to Sample II include a 20.0% decrease in cortical flakes (types 1 and 2), and a large increase in early and late interior flakes (Table 5.12). The drop in flakes with cortex is an indication that cobbles are being reduced further than they were previously, generating more interior debitage relative to pieces that contain traces of the original stone surface.

Table 5.12. Proportion of Debitage by Type and Sample

Debitage Type	**Sample I**	**Sample II**	**Sample IIIA**	**Transitional Sample IIIB**
Primary Decortication	3.7	3.0	1.9	2.4
Secondary Decortication	5.8	4.6	1.9	4.8
Early Interior	10.3	21.4	17.3	12.5
Late Interior	25.5	37.3	21.6	38.3
Linear Interior	.1	.3	.6	.4
Early Biface Thinning	.1	1.3	1.7	.5
Late Biface Thinning	.1	.2	.8	.3
Finishing or Pressure	1.2	1.5	4.9	3.4
Shatter (LWI value)	53.2	30.5	49.3	37.4
Total	4970	4861	3235	4407

Regional differences in flakedstone reduction are also evident. Most (77.0%) of the Sample II biface thinning and finishing flakes are located in the upland and inland areas at sites that generally post date A.D. 1200 (i.e., Case Springs). This suggests that the final stages of arrow point manufacture occurred in upland and inland settings, even if flake blanks were manufactured at the coast where abundant cobble raw material occurs. That these sites are later than the appearance of arrow points suggests that there was a lag effect before use of the bow and arrow came into full swing.

In summary, a comparison of debitage from Sample I and II sites shows that Sample II sites have larger amounts of small-sized and later stage debitage than Sample I sites. Further, Sample II sites have a smaller proportion of non-diagnostic shatter, leading to a lower LWI index. These shifts are related to the appearance of the bow and arrow at Sample II sites and more extensive reduction efforts.

The analysis of debitage from Sample IIIA sites revealed that trends characterizing Sample II debitage are not simply continued after A.D. 1400. The main similarity between Sample II and IIIA debitage is that diagnostic flakes are generally small (<2.0 cm), comprising 75.7% of the samples combined (see Table 5.11). However, the small average size of Sample IIIA debitage is due primarily to the larger proportion of finishing flakes (4.9%) and biface thinning flakes (2.5%), relative to a 50.0% decline in cortical flakes (see Table 5.12). Considering the much higher assemblage proportion of arrow points and preforms in Sample IIIA assemblages, the shifts in debitage type are not unexpected.

A key reversal in the Sample IIIA debitage is the increase in the LWI value to 0.49, nearly equal to that of Sample I debitage. A 20.0% increase in non-diagnostic shatter in Sample IIIA is interesting, considering the increase in biface thinning and finishing flakes (see Table 5.12). The higher Sample IIIA LWI value is probably reflecting less care taken during the early stages of flakedstone reduction. The fact that the average size of shatter from both time periods remains stable supports this inference. It is also true that arrow points are increasingly made from higher quality materials, negating the argument that the higher LWI for Sample IIIA reflects use of lower quality materials (i.e., quartz). In fact, PDL chert accounts for 10.0% of the shatter in Sample II and 31.0% in Sample IIIA, indicating greater use of higher quality materials. That is, the bulk of shatter originated from earlier stages of reduction in Sample II and IIIA, not the finishing stages of artifact production.

Perhaps the most striking trend in Sample IIIA assemblages is the regional difference in debitage. Inland sites have the most debitage, followed by upland sites, while coastal assemblages have very little debitage. While the site sample is limited, the pattern holds true across the northern San Diego region. Sample IIIA analyzed debitage from coastal sites amounts to less than 5.0% of the analyzed assemblage. In the overall site sample, Sample IIIA coastal assemblages contain only 6.0% of the debitage, in contrast to Sample II coastal sites that contain 52.0% of the debitage.

Fully 19.0% of debitage from Sample IIIA coastal sites is composed of cortical flakes, while only 3.0% and 4.0% of the debitage at inland and upland sites, respectively, is composed of cortical flakes. In Sample II, the proportion of cortical flakes at both coastal and inland sites is 9.0%, compared to 3.0% of upland sites. Taken together, the increased frequency of debitage and the two-thirds decrease in cortical flakes at Sample IIIA inland sites shows that flakedstone reduction was more intensive, but was focused on the later stages of tool production. In contrast, coastal sites saw limited amounts of flakedstone reduction primarily geared toward production of flake blanks to be transported elsewhere.

Comparing Sample IIIA and Sample IIIB (Transitional) debitage, size profiles are similar (see Table 5.11). Small (<2.0 cm) debitage comprises 73.8% of the assemblage from Sample IIIB, 75.7% of Sample IIIA.

Aside from trace amounts of Monterey chert, obsidian, and basalt, raw material profiles for Sample IIIB debitage consist of 38.0% metavolcanic, 40.0% PDL chert, and 21.0% quartz. Sample IIIA sites are similar but have a higher proportion of metavolcanic stone (52.0%), and less PDL chert (32.0%), and quartz (15.0%). Despite this minor variation, there is no significant patterning of debitage type by raw material when contrasting Sample IIIB and Sample IIIA assemblages.

Little can be said about regional differences in debitage types since all Sample IIIB sites are inland. However, Sample IIIB debitage types are similar to those from Sample IIIA inland assemblages. Sample IIIA inland and Sample IIIB (Transitional) sites have generally higher amounts of late interior flakes, biface thinning flakes, and shatter than Sample IIIA coastal sites.

An interesting difference in the Sample IIIA and IIIB debitage types is visible in the proportion of shatter to diagnostic flakes. In Sample IIIA, the LWI value is 0.49, compared to 0.37 for Sample IIIB debitage. The reduction in shatter shows increased care being exercised during flakedstone reduction.

Regarding diagnostic debitage, Sample IIIB sites exhibit some notable differences. Primary and secondary cortical flakes amount to 7.2% of all debitage from Sample IIIB. This is almost double the amount of cortical flakes present in diagnostic debitage from Sample IIIA (3.8%). The larger amount of cortical flakes in Sample IIIB assemblages supports the idea that raw material was imported in raw cobble/nodule.

Cobble-core reduction remained the dominant reduction strategy. That is, cobbles were being brought to Sample IIIB sites and were reduced to produce flakes suitable for the manufacture of other tools. Very little evidence of prepared core reduction was observed, except for the few nodule-based bifaces. Similarity in reduction strategies account for the equal proportion of biface thinning and finishing flakes in both Sample IIIA and IIIB debitage (see Table 5.12).

Overall, the debitage analysis demonstrated that flakedstone tool manufacture was based on simple cobble-core reduction in all samples, rather than time consuming prepared core reduction. However, despite the consistent reduction trajectory, debitage profiles reflect changes in manufacturing investment. With the appearance of the bow (Sample II), the LWI index drops by more than 20.0% to 0.30 and finishing flakes are much more common, owing to the manufacture of arrow points. Sample IIIA debitage reverses this trend with an increase in the LWI value to 0.49, while maintaining high levels of finishing flakes. Sample IIIA debitage has the lowest proportion of cortical flakes. Finally, Sample IIIB has the widest range of debitage types, probably because cobbles were imported to the sites for on-site manufacture of various stone tools. Supporting evidence is the lower LWI value of 0.37 at Transitional sites coupled with higher proportions of cortical flakes.

5.2.2 Groundstone

Groundstone tools are among the most common assemblage constituents throughout the prehistoric sequence in the San Diego region. The regular occurrence of groundstone tools before and after arrival of the bow is telling of the economic significance of vegetal processing. However, groundstone tools vary in terms of formality and use intensity after the bow and arrow arrives, and during intensification. The following description of analyzed groundstone tools includes a discussion of bedrock milling elements (i.e., slicks, basins, and mortars), which became increasingly important in the San Diego region later in time.

Analyzed groundstone implements include 468 handstones, 104 millingstones, and 123 bedrock milling elements (Table 5.13). Bedrock milling elements include 54 slicks, 17 basins, and 52 mortars (see Table 5.13). Except in specific cases, metrics are not reviewed because they were mainly found to reflect the range of sizes of unmodified raw material, in cobble or block form. Even highly shaped handstones were no larger or smaller, on average, than unshaped, incipient specimens. The same is true for millingstones, which tend to be thick, whether exhibiting flat or basined surfaces (see Hale 2005). In fact, some of the thickest millingstones have basin surfaces, and these specimens tend to exhibit the highest degrees of shaping, such as those from SDI-525 (see Hale 2001).

Regarding the lack of analyzed mortars (non-bedrock) and pestles, some pieces reported as mortars or pestles were relocated and determined to be basined millingstone fragments, or handstones, respectively. The occurrence of mortars and pestles in Sample I and II assemblages is generally problematic because specimens categorized as pestles and mortars do not appear to have been used for intensive vegetal processing. Regardless, mortars and pestles are not considered here as an unknown technology, but were occasional manufactured and used when the need arose, although such occurrences were rare given the rarity of these tools in early assemblages.

Table 5.13. Analyzed Groundstone by Sample

	Handstone	**Millingstone**	**Bedrock Milling**			**Total**
			Slick	Basin	Mortar	
Sample I	217	64	-	-	-	281
Sample II	188	29	5	8	17	247
Sample IIIA	50	7	28	4	7	96
Transitional Sample IIIB	13	4	21	5	28	71
Total	**468**	**104**	**54**	**17**	**52**	**695**

Two Sample I sites account for almost all of the reported mortars and pestles: SDI-4629/W-20 reported 21 pestles (Smith and Moriarty 1985) and SDI-12814 reportedly contained four mortar fragments and nine pestles (Gallegos et al. 1999). Gallegos et al. (1999) report nine pestles (five fragments, four complete) occurring within the primary cultural deposit between 20 and 50 cm below surface. Four exhibit shaping, the rest do not. None of these specimens could be relocated for analysis, thus making it hard to properly characterize the tools relative to the this analysis. Regardless, the ratio of mortars and pestles to millingstones and handstones at SDI-12814 is 1:12, an indication of the relatively low economic significance of mortars and pestles. Complicating matters further, no distinction could be made in the original analysis between bowls and true mortars (Gallegos et al. 1999:4-24), making it difficult to distinguish between vegetal processing—primarily associated with mortars—and other light duty pulverizing activities, likely to be associated with small bowls (i.e., pigments, poisons, etc.).

None of the pestles from SDI-4629/W-20 could be relocated for analysis. However, from artifact descriptions and published images, the pestles appear to be unmodified battered cobbles with some having incipient handstone wear facets (see Smith and Moriarty 1985:487-490). Battering and end polish are commonly observed on handstones, especially those from Millingstone contexts, and are evidence that these tools were multifunctional (see Hale 2001; Hale and Becker 2005). As such, the pestle category from SDI-4629 is misleading and does not signal traditional mortar-pestle technology. The same can be said for the five unmodified pestles reported from SDI-12814 (see Gallegos et al. 1999:4-24).

5.2.2.1 Handstones

Handstone formality and use intensity exhibit only minor fluctuations between Samples I, II, and IIIA. However, Sample IIIB (Transitional) handstones deviate from the pattern, exhibiting relatively high degrees of use wear. Attention is paid below to particular patterns among handstones in each sample that clarify formality and Groundstone Use Intensity (GUI) values, especially concerning regional variation in handstone form.

Sample II handstones differ from Sample I handstones primarily in use intensity/regularity. Notably, the Sample II specimens show a 10.0% increase in the amount of irregular handstone surface textures, double the proportion of surfaces lacking polish, and a 4.0% increase in surfaces lacking rejuvenation (i.e., pecking) (Table 5.14, Figure 5.5). The GUI value for Sample I handstones is 0.65, compared to 0.59 for Sample II handstones. However, these values differ by region after A.D. 500. The GUI value for coastal Sample II handstones is 0.53, while upland and inland Sample II handstones have GUI value of 0.76. The same is true for the GFI values. Overall, GFI values are similar for Samples I and II (0.30 vs. 0.32, respectively). However, regional differentiation in handstone shaping shows that upland Sample II handstones have a higher GFI value (0.42) than coastal handstones (0.22).

Table 5.14. Handstone Attributes by Sample

	Sample I	**Sample II**	**Sample IIIA**	**Transitional Sample IIIB**
Condition				
Whole	46.1	31.9	50.0	30.8
End	27.2	23.9	2.0	
Margin	22.6	41.0	32.0	61.6
Interior	4.1	3.2	16.0	7.6
Shaping Degree				
Unshaped	57.7	61.5	41.7	46.1
1	11.9	7.5	12.5	15.4
2	18.9	14.9	14.6	15.4
3	11.5	16.1	31.2	23.1
Indeterminate (n)	14	33	2	-
# of Surfaces				
1	30.1	30.3	26.0	23.0
2	65.3	68.6	74.0	77.0
3	4.6	1.1		
Total # Surfaces	377	321	87	23
Surface Shape				
Flat	26.3	28.3	20.7	39.1
Convex	73.7	71.7	79.3	60.9
Texture				
Smooth	81.4	71.4	79.3	82.6
Irregular	18.6	28.6	80.7	17.4
Polish				
Present	96.0	91.6	98.8	91.3
Absent	4.0	8.4	1.2	8.7
Striae				
Present	55.4	56.4	56.3	78.3
Absent	44.6	43.6	43.7	21.7
Pecking				
Present	53.3	49.2	55.1	69.6
Absent	46.7	50.8	44.9	30.4
Secondary Use	39.2	30.3	46.0	100.0
Total	**217**	**188**	**50**	**13**
GUI Value	65.1	59.8	67.1	84.4

The dichotomous pattern of greater use intensity of upland and inland handstones, compared to expedient handstones at coastal sites indicates that processing tools were shaped and used in accordance with mobility needs. Inland and upland sites were occupied for relatively shorter periods of time by smaller groups of people (see Reddy 2000). Upland and inland areas also have less abundant cobbles suitable for use as grinding implements than coastal areas, requiring increased planning for processing tasks. Comparatively, large coastal middens are located next to abundant cobbles that could be used as handstones; these sites were occupied longer by larger groups—i.e., multiple families—but processing was largely situational (see Hale and Becker 2006).

Thus, after the bow arrives, typified by Sample II, handstone use generally decreases in intensity, but there is more intensive processing at upland sites and expedient processing at coastal sites. This pattern is not continued after A.D. 1400 in Sample IIIA.

Sample IIIA (A.D. 1400-1700) handstones tend to exhibit higher degrees of shaping (46.0%)—up 15.0% from Sample II handstones (see Table 5.14, Figure 5.5). The greater number of shaped handstones is correlated with a more than 5.0% increase in specimens with two wear facets. Smooth and polished surfaces are 7.0-8.0% more abundant in Sample IIIA, as is the incidence of pecking—up by 6.0% (see Table 5.14). Additionally, nearly half (46.0%) of Sample IIIA handstones were used for secondary purposes, such as battering and grinding of the cobble ends. These attribute patterns are correlated with a GUI value for Sample IIIA handstones of 0.67, up from 0.59 for Sample II handstones (see Table 5.14). This shift in GUI values is indicative of elevated handstone use. This reflects an increase in handstones with shaping and greater use wear at coastal sites, which is a consequence of two factors. First, greater regularity in seasonal movements such that handstones transported for use in upland and inland locales were discarded in exhausted condition at coastal sites and exchanged for fresh cobbles. Second, handstones were simply used with greater regularity at coastal sites.

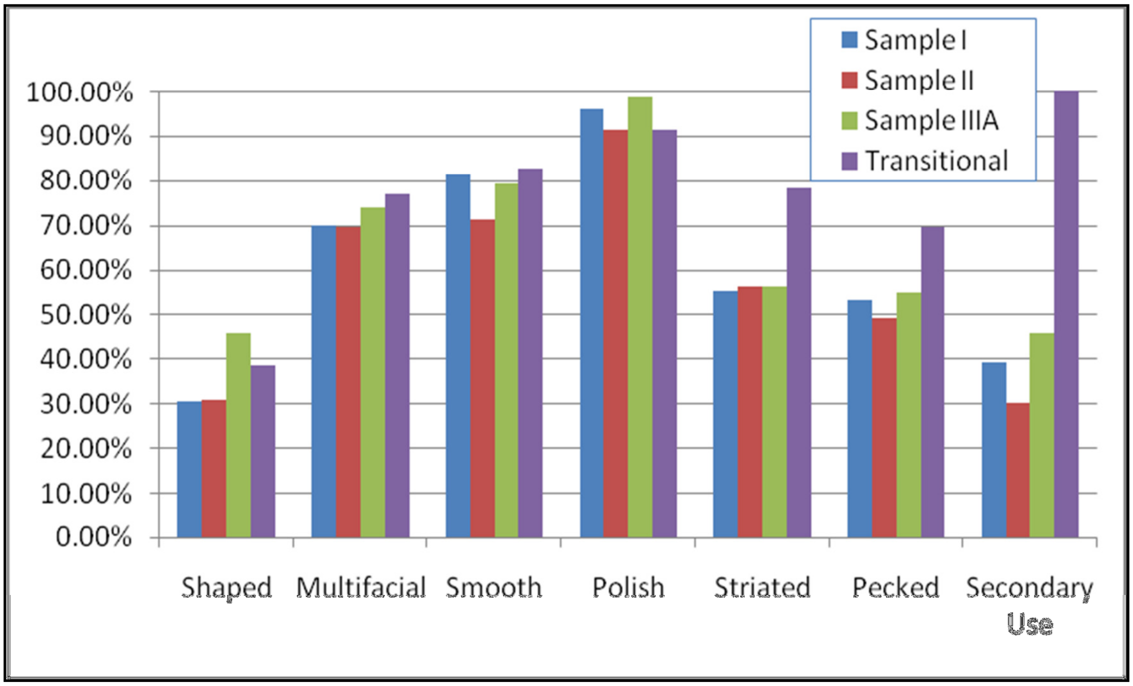


Figure 5.5. Handstone wear facet attributes by Sample.

The most intensively used handstones derive from Sample IIIB. Of the 13 Sample IIIB handstones, four are whole and the rest are large margin or end fragments. Shaping of handstone margins through pecking and grinding was observed on 39.0% of the specimens, slightly less than Sample IIIA handstones, but higher than the regional norm. Transitional handstones have the highest proportion of multi-faceted specimens (77.0%), and the lowest proportion of irregular surface textures (17.4%) (see Table 5.14). Sample IIIB handstones have by far the highest proportion of striated (78.3%) and pecked (69.6%) wear facets, and all were used for secondary purposes. Combined, Transitional handstones surfaces have a GUI value of 0.84—up from a GUI value of 0.67 for Sample IIIA handstones.

All Sample IIIB handstones were battered on at least one end; all whole specimens exhibited battering on both opposing ends. Polish was observed on seven handstone ends. End polish might have been more common but was obliterated by heavy pounding. Additionally, two miscellaneous groundstone pieces were categorized as handstone-pestles and had high degrees of polish on the ends (see Hale and Becker 2006), but these were not included in this analysis. Handstones were used not only for horizontal grinding, but also as pestles. This partly explains the lack of formal pestles in the analyzed inventory, and fits well with the large numbers of bedrock mortar surfaces.

5.2.2.2 Millingstones

Millingstones are less informative than handstones in terms of shaping because few millingstones were well shaped in the San Diego region. Nevertheless, moderate and highly shaped millingstones account for 39.0% of Sample I millingstones, dropping to 22.0% in Sample II (Table 5.15).This is coupled with a drop in the amount of bifacial specimens, from 25.0% in Sample I to 14.0% in Sample II. In both samples, basined surfaces are the most common. Despite the drop in formalization, Sample II wear facets seem to have been used more intensively, if for shorter periods of time. There is an increase in all wear attributes, including a 9.0% rise in smooth textures, a 15.0% increase in the occurrence of polish, and a 33.0% increase in striations; pecking remains somewhat even, increasing only 3.0% (see Table 5.15). These use wear attributes equate to a shift in the GUI value from 0.63 in Sample I to 0.73 in Sample II; a 10.0% increase in overall millingstone use intensity, despite less formalization.

Table 5.15. Millingstone Attributes by Sample

	Sample I	Sample II	Sample IIIA	Transitional
	Pre A.D. 500	A.D. 500-1400	A.D. 1400-1700	A.D. 1400-1700
Condition				
Whole	7.8	-	28.5	25.0
End	9.3	3.4	-	-
Margin	53.2	41.3	57.2	75.0
Interior	29.7	55.3	14.3	-
Shaping Degree				
0	40.7	77.8	85.7	25.0
1	20.3		14.3	25.0
2	27.1	11.1	-	50.0
3	11.9	11.1	-	-
Indeterminate	5	20	-	-
# of Surfaces				
1	73.4	86.2	85.7	75.0
2	26.6	13.8	14.3	25.0
Total # Surfaces	**79**	**33**	**8**	**5**
Surface Shape				
Flat	38.0	42.4	37.5	60.0
Basined	62.0	57.6	62.5	40.0
Texture				
Smooth	86.1	96.9	100.0	80.0
Irregular	13.9	3.1	-	20.0
Polish				
Present	72.1	96.9	100.0	80.0
Absent	27.9	3.1	-	20.0
Striae				
Present	48.1	84.8	75.0	80.0
Absent	51.9	15.2	25.0	20.0
Pecking				
Present	79.7	81.8	75.0	80.0
Absent	20.3	18.2	25.0	20.0
Secondary Use				
Surface Battering	62.5	-	14.3	50.0
Anviling	4.7	3.4	14.3	25.0%
Burning	12.5	65.5	100.0	-
Total	**64**	**29**	**7**	**4**

The number of Sample IIIA millingstones is small (n=7). Two of the Sample IIIA specimens are whole, four are large margin fragments, and one is an interior fragment. Shaping is essentially absent and there was only one specimen with opposing milling surfaces (one basined, the other flat). Basined surfaces are the most common (n = 5 out of 8), as in Sample II. Use wear attributes essentially show that processing intensity on millingstones remained stable, but reuse probably declined. Smooth and polished surfaces are somewhat elevated in proportion (6.0% and 3.0%, respectively) relative to Sample II surfaces. However, striations decline in proportion by 10.0% and the incidence of pecking is 7.0% less common than among Sample II millingstones (see Table 5.15).

Sample IIIB (Transitional) millingstones are limited to four specimens; three are margin fragments and one is whole . The whole specimen is large (30.0 x 29.0 cm), but relatively thin (7.5 cm). It is moderately shaped by pecking and grinding, mostly to remove a few protrusions, and it has two opposing surfaces. The main surface is a basin 3.5 cm deep that has been intensively used. The secondary surface is an flat surface exhibiting polish, striations and pecking, indicating fairly intensive use. The other millingstone fragments are small margin fragments. One is lightly shaped and exhibits an intensively used basin surface that was more than 4.5 cm deep when whole. Another margin fragment is moderately shaped and exhibits an intensively used flat surface, with polish, striations, and pecking. The remaining piece is an interior fragment with a single ephemeral flat surface. Aside from the single ephemeral surface, Sample IIIB millingstones are similar in surface configuration (i.e., mostly basins) to Sample II millingstones, but Sample IIIB millingstones show greater intensity of use (80.0% are regular in shape, polished, striated and pecked) (see Table 5.15).

5.2.2.3 Bedrock Milling Features

Bedrock milling features are an important element of assemblages that postdate A.D. 500 in the San Diego region. A total of 123 bedrock milling surfaces was analyzed, including 30 from Sample II, 39 from Sample IIIA, and 54 from Transitional sites (Table 5.16).

Four upland sites in Sample II (SDI-5139, -5141, -5142, and –5143) are associated with milling features. These sites are characterized by mostly single component midden deposits surrounding granitic outcrops that contain milling surfaces, such as slicks, basins and small circular mortars. The total number of surfaces is 30: 17 mortars, 5 slicks, and 8 basins. Mortars are essentially round and shallow, averaging 21.0 x 19.0 x 9.0 cm. Thirteen mortars are shallow, averaging 6.0 cm in depth and four others are moderately deep, averaging 21.0 cm in depth. The highly regular, circular outline implies that these surfaces were intentionally manufactured to achieve such a shape. The presence of several abandoned mortars at inland sites to the south corroborates this inference (see Hale 2006). Mortars were well used, with nearly all having polished and pecked surfaces indicative of prolonged use. The presence of pecking along the interior mortar sides and base implies that these surfaces were used as much for grinding as they were for pulverization. Basined surfaces are longer than mortars and are essentially the stationary counterpart to basined milling slabs. Basins average 25 x 18 x 8 cm, having an oval outline. All of these surfaces were well used exhibiting polish, striations, and pecking. Milling slicks are more ephemeral, with vague surface boundaries and irregular use wear characteristics. All slicks lacked striations and pecking, indicating relatively ephemeral use. Overall, the use of bedrock milling stations implies greater planning in seasonal occupation and resource exploitation. A variety of resources were probably processed using mortars, basins and slicks. The presence of pecking on the interior of mortars surfaces implies that they were used for grinding seeds in addition to other pulpy resources.

Table 5.16. Bedrock Milling Surface Attributes by Sample

	Sample II			Sample IIIA			Sample IIIB Transitional		
	Slick	**Basin**	**Mortar***	**Slick**	**Basin**	**Mortar**	**Slick**	**Basin**	**Mortar**
Surfaces N	5	8	17	28	4	7	21	5	28
%	16.7	26.7	56.6	71.8	10.3	17.9	38.9	9.3	51.8
Regular Form	60.0	100.0	64.7	17.9	100.0	100.0	71.0	100.0	100.0
Smooth Texture	40.0	100.0	94.1	39.3	50.0	100.0	81.0	100.0	100.0
Polished	80.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Striated	-	100.0	76.5	35.7	100.0	85.7	48.0	100.0	14.0
Pecked	-	100.0	76.5	39.3	100.0	85.7	67.0	100.0	57.0

Note: *, these are saucer mortars, more similar to basins than traditional mortars

A total of 39 milling features were analyzed from two Sample IIIA sites (SDI-5144 and SDI-9824): 7 mortars, 4 basins, and 28 slicks. Immediately apparent is the large number of milling slicks in this sample. Of the analyzed surfaces, mortars vary from shallow to deep. Five mortars are relatively small, having average metrics of 13.0 x 13.0 x 7.0 cm; these are typically referred to as saucer mortars. Each exhibits a regular outline with extensive wear, including polish, striations, and pecking on three specimens. Basin surfaces are typical for the area; measuring approximately 24.0 x 17.0 x 4.0 cm and exhibiting extensive wear (i.e., smooth, polished, striated, and pecked surfaces). In contrast, of the 28 Sample IIIA milling slicks, only 17.9% have regular shapes, 39.2% are smooth, 35.7% striated, and 29.3% pecked (see Table 5.16). The rest are irregular in shape and use, showing small amounts of polish on elevated facets. The large amount of irregular slicks implies some degree of unplanned, situational processing to suit immediate needs, whereas the well used mortars and basins imply planned reoccupation and reuse for relatively intensive grinding.

Sample IIIA mortars were used for grinding, evidenced by polish and pecking to maintain a rough surface, as well as vertical pulverization of pulpy materials—implied by the mortar shape. It is probably true that mortars were used to process acorns, as well as many other seeds, tubers, and small animals. However, the presence of millingstone-like grinding wear on mortar surfaces in conjunction with a high number of basins and slicks indicates that acorns were part of a generalized processing regime rather than being an economic specialization at Sample IIIA sites. When acorns become the primary food source during ethnohistoric times, milling features are dominated by numerous deep mortars, such as the late component of SDI-11068 (Gallegos and Schroth 1992) and at SDI-10697 (Reddy et al. 1997).

Bedrock milling surfaces from Sample IIIB (Transitional) sites total 54: 28 mortars, 5 basins, and 21 slicks. Comparing the proportion of milling surfaces between Sample IIIA and IIIB reveals significant changes in milling surface shape and function. Sample IIIB is dominated by mortars (51.0%), with 39.0% slicks, and the rest basins (see Table 5.16). In contrast, Sample IIIA has 34.0% mortars, 35.0% basins, and 31.0% slicks. The higher proportion of traditional mortars in Sample IIIB indicates greater investment in milling technology, mortars requiring at least some manufacturing time, whereas flat slicks or basins can be generated through regular use. Once manufactured, mortars are superior for processing large nuts and other pulpy items (as well as animal products). Evidence that mortars were manufactured comes from one mortar from SDI-14571 was abandoned prior to finishing the surface, leaving a small, rough cone in the center that had yet to be removed with a stone hammer and stone chisel (see Hale and Becker 2006:402).

Bedrock milling surfaces in Sample IIIB (Transitional) were used with more regularity and intensity than those from Sample IIIA. Sample IIIB mortars were all regular in form, smooth, and polished (see Table 5.16). Striations and pecking are rarely observed on mortars because these attributes generally reflect intensive grinding and subsequent rejuvenation of surfaces smoothed by use (i.e., rendered less efficient). However, 14.0% of Sample IIIB mortars were striated and 57.0% were pecked to some degree. These attributes may indicate that a variety of resources were processed in mortars requiring more grinding with the lateral sides of a handstone/pestle inside the mortar. The same pattern of use was evident on Sample IIIA mortars. Sample IIIB mortar shapes and depths mirror those from Sample IIIA, i.e., roughly the same proportions of round, shallow mortars and deep, oval mortars. The functional difference between these mortar shapes is not clear but Hale (2005) speculates that round, shallow mortars were probably used for intensive seed processing as much as for other resources, such as acorns. Deeper mortars are probably more related to processing large amounts of pulpy materials, including acorns; True (1993) surmised as much.

Sample IIIB (Transitional) basins were all intensively used, as those in Sample IIIA. These surfaces typically exhibit regular surface shapes that have been smoothed, generating polish, striations, and pecking through use and maintenance (see Table 5.16). Basin surfaces were probably used for seeds and fibrous materials (i.e., roots and tubers). The low frequency of Sample IIIB basins (n = 5) probably relates to a decreased emphasis on processing fibrous materials, as well as increased use of costly to make mortars for processing traditional foods, including seeds.

Sample IIIB milling slicks were more intensively used than Sample IIIA slicks. Sample IIIB slicks have a higher proportion of regular surface shapes (71.0%) and smooth surface textures (81.0%) than Sample IIIA slicks (36.0% each) (see Table 5.16). Moreover, Sample IIIB slicks all show polish, 48.0% are striated, and 67.0% are pecked. This is in contrast to 36.0% each polished, striated, and pecked for slicks in Sample IIIA. The more intensive use of Sample IIIB milling slicks supports the idea that processing was much more intensive.

5.3 SUBSISTENCE

A substantial amount of subsistence data were readily available from published manuscripts in the San Diego region. These data are reviewed to provide supporting evidence of trends identified at the assemblage level and from the flakedstone and groundstone analysis. Vertebrate faunal data were compiled from 22 assemblages, Invertebrate faunal data were compiled from 18 assemblages, and ethnobotanical data from 13 assemblages. In the following sections, vertebrate fauna are discussed first, followed by invertebrate fauna and ethnobotanical remains. Regarding vertebrates, data were tallied by Number of Individual Specimens (NISP) because this was the most common reporting method in manuscripts. Invertebrate data were tallied by weight in grams—the most common reporting method for shellfish.

5.3.1 Vertebrates

Differences in vertebrate fauna between each sample indicate shifts in subsistence. The Sample I vertebrate assemblage is composed of 16,576 individual elements (Table 5.18). Most of these (54.2%) are small mammal remains, dominated by various species of rodents and hares (e.g., Wake 2000) (Figure 5.6). The next most common vertebrate class is fish (31.5%). The majority of identifiable fish remains consist of bottom dwellers commonly found in estuaries/lagoons with a smaller amount of fish found in the surf zone and kelp beds.

All fish remains in Sample I are from sites that are situated directly on the margin of a lagoon or estuary, 66.0% deriving from just two estuarine sites (SDI-10728 and W-131). Other vertebrate remains include approximately 5.0% each of large and medium-sized mammals, and a little more than 2.0% of birds (mostly duck). Unidentifiable mammal remains account for just 2.0% of the assemblage.

The Sample II vertebrate assemblage consists of 11,995 vertebrate elements from 10 sites in inland, upland, coastal, and lagoonal settings. In comparison with Sample I, the Sample II vertebrate profile shifts, showing almost a four-fold increase in large mammal (i.e., deer) remains from 4.2% to 15.3%, and an approximate 5.0% increase in the proportion of small mammals (see Table 5.18, Figure 5.6). Additionally, unidentifiable mammal remains increase from trace amounts to 22.0% of the total assemblage in Sample II (see Figure 5.6). The high frequency of unidentifiable mammal remains in Sample II is not likely due to differences in analytical protocol since regional studies by Wake (1996, 2000) show consistent increases in this category. The increase in small mammal bone fragments may be due to pulverization of bone to extract more nutrients. Other differences in Sample II vertebrates include the near disappearance of bird and a dramatic drop in fish (see Table 5.18, Figure 5.6). Despite the drop in fish bone, the proportion of bottom dwellers versus open water/kelp dwelling fish is comparable for Sample I and Sample II, at approximately 50.0% each.

Table 5.18. Proportion of Number of Individual Specimens for Vertebrates by Sample

	Sea Mammal	Large Mammal	Medium Mammal	Small Mammal	Mammal	Bird	Fish	Reptile	Total N
Sample I	0.0	4.2	6.0	54.2	1.7	2.3	31.5	0.1	16576
Sample II	0.3	15.8	1.4	59.0	22.0	0.1	1.5	0.3	11995
Sample IIIA		4.5	1.2	65.3	5.9	2.6	20.4	0.0	11040
Sample IIIB		14.0	3.0	54.7	27.3	0.5	0.0	0.5	766

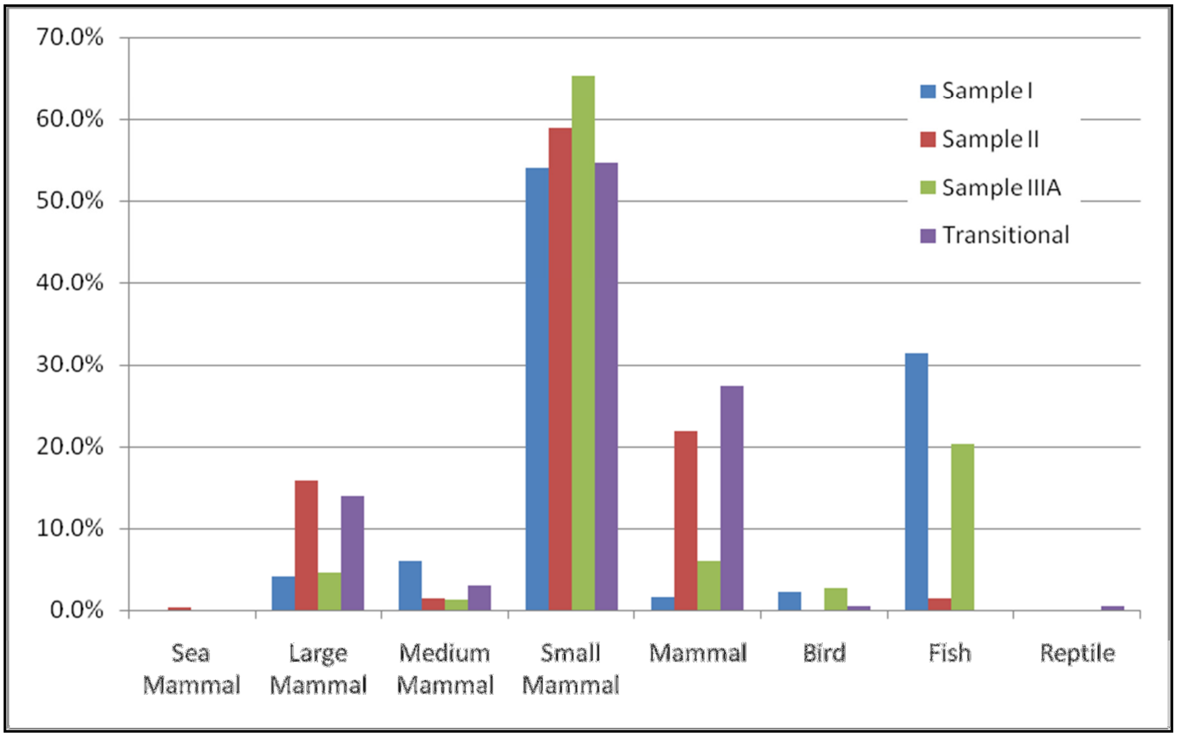


Figure 5.6. Relative proportion of vertebrate elements by sample. Adapted from: Becker and Iversen 2007; Byrd 1996, 1997; Gallegos and Carrico 1984; Gallegos et al. 1999; Gallegos et al. 1984; Hale and Becker 2006; Reddy 1997, 2000; Smith 1986; Smith and Moriarty 1985; Stropes and Gallegos 2005; York et al. 1999; Wake 1997, 1999.

Some regional patterning occurs in Sample II. Coastal sites are more dominated by small mammals (rodents and hares) with no more than 30.0% large and medium-sized mammals. In contrast, 33.0% of inland assemblages and 68.0% of upland assemblages are of large mammal remains. Unidentifiable mammal elements also pattern by region: 15.0% of all bone from coastal sites is unidentified, compared to 34.0% of from inland assemblages. Lagoonal sites are more similar to coastal sites in Sample II with a dominance of small mammal remains (91.0%) and a near disappearance of fish remains, down from 64.0% in Sample I.

After A.D. 1400, the profile of vertebrate fauna is not a continuation of the trend identified in Sample II. In Sample IIIA (A.D. 1400-1700), large mammals drop in frequency by more than two thirds, from 15.4% in Sample II to 4.5% in Sample IIIA (see Table 5.18, Figure 5.6). Similarly, unidentified mammal elements drop four-fold, from 22.0% in Sample II to 5.9% in Sample IIIA. The decrease in both large mammals and unidentified mammal bone implies some relationship between the two categories. However, small mammals increase in frequency in Sample IIIA to 65.3%, and birds—essentially absent in Sample II—increase to 3.5%. Fish also make a strong comeback, increasing more than twelve fold, amounting to 20.0% of the Sample IIIA assemblage (see Table 5.18, Figure 5.6). As fish remains increase, species diversity decreases (see Wake 1999). Most fish remains (82.0%) consist of fish that occupy the surf zone with smaller amounts of kelp dwelling species (i.e., sardines, herring, croaker, sheephead, etc.); only 18.0% are bottom dwelling species commonly found in lagoons/estuaries (i.e., bats, rays, guitarfish, etc.).

Differences between Sample II and IIIA vertebrate fauna suggests an economic shift to focus on prey that were easier to capture and were more abundant than large mammals. The small mammal category consists almost entirely of rodents and hares. The greater use of birds (mostly duck) and fish indicates that more time was spent acquiring these items while residing at seasonal coastal camps. A maritime focus is not implied in this assemblage; fish remain unimportant compared to small terrestrial mammals. The lack of hooks, gorges, net weights, and other tackle in assemblages from all samples is indirect evidence in support of a terrestrial focus.

Sample IIIB vertebrate fauna show another reversal. The Sample IIIB assemblage is similar to Sample II in terms of having higher proportions of large mammal remains, but Sample IIIB fauna are generally less diverse. The faunal assemblage from Sample IIIB is relatively small, consisting of 766 individual elements (Table 5.18). However, much less volume was excavated at Sample IIIB sites than at Sample IIIA sites.

Sample IIIB sites have a relatively high proportion of large mammal elements (14.0%), similar to Sample II (16.0%). In contrast, Sample IIIA has much less large mammal elements (4.0%). Unidentified mammal remains are also high in Sample II and Transitional assemblages (27.0% and 22.0%, respectively), while they are minimal in Sample IIIA (6.0%) (see Figure 5.6). This supports the idea that much of the unidentifiable mammal remains are fragments leftover from processing large mammal bone in an effort to maximize nutritional yield. It also suggests that large mammal exploitation during the last 1500 years was not contingent on environmental conditions but was an adaptive phenomenon. There is no environmental reason why the proportion of large mammals in Sample IIIA is not on a par with those from Sample IIIB.

Small mammal remains are still the most common assemblage constituent in Sample IIIB (55.0%), although they account for a smaller proportion of the assemblage due to the higher amount of large mammals. Interestingly, all other vertebrate remains are much less common than in Sample IIIA (see Table 5.18, Figure 5.6). While the amount of bird and reptile bone at Sample IIIB sites is similar to Sample II, fish are absent in Sample IIIB.

5.3.2 Invertebrates

Invertebrate fauna exhibit decreasing amounts of lagoonal species over time, matched by increases in sandy beach species. This is partly due to the decreased productivity of lagoons and estuaries after approximately 1500 B.C., and to a shift in emphasis on opportunistically gathered *Donax sp.* (i.e., small—1 to 3 cm—bean clam) that were common on sandy beaches by at least A.D. 0 (Warren 1968; Laylander and Saunders 1993).

Not including unidentified and miscellaneous shell, the total amount of shell in weight (g) from Sample I is 111,051g deriving from seven sites: four coastal, one lagoonal, and two inland sites (Table 5.19). The Sample II assemblage consists of 40,638g of shell, not including unidentified specimens, and these derive from one coastal site and three inland sites. The Sample I assemblage is dominated by *Chione* and *Argopecten*, with trace amounts of other shellfish such as *Ostrea*, *Donax*, and *Mytilus*. In Sample II, *Chione* is still the most common type of shellfish at more than 70.0%, but *Argopecten* is replaced by *Donax*, accounting for more than 25.0% (Figure 5.7).

Invertebrates from Sample IIIA exhibit a few key reversals in the kinds of prey consumed. First, *Chione* drops to 21.0% of Sample IIIA assemblage—down from 73.0% in Sample II. Next, *Donax* increases to more than 76.0% in Sample IIIA (see Figure 5.7). In terms of frequency, *Chione* decreases by almost half and *Donax* increases more than 6.5 times in Sample IIIA. The total amount of shell from post A.D. 1400 sites is more than twice that of Sample II, despite a narrower time span for Sample IIIA (A.D. 1400-1700).

Table 5.19. Proportion of Weight (g) of Key Invertebrates by Sample

	Chione	Pecten/ Argopecten	Ostrea	Donax	Mytilus	Subtotal	Misc./ Unidentified	Grand Total

Sample I	64.0	32.4	1.2	0.2	2.2	111051	35.5	172338
Sample II	72.9	1.1	0.4	25.5	<0.1	40638	0.8	40984
Sample IIIA	21.3	2.1	0.2	76.4	<0.1	88596	5.1	93123
Sample IIIB	-	6.7	-	93.3	-	30	16.7	35

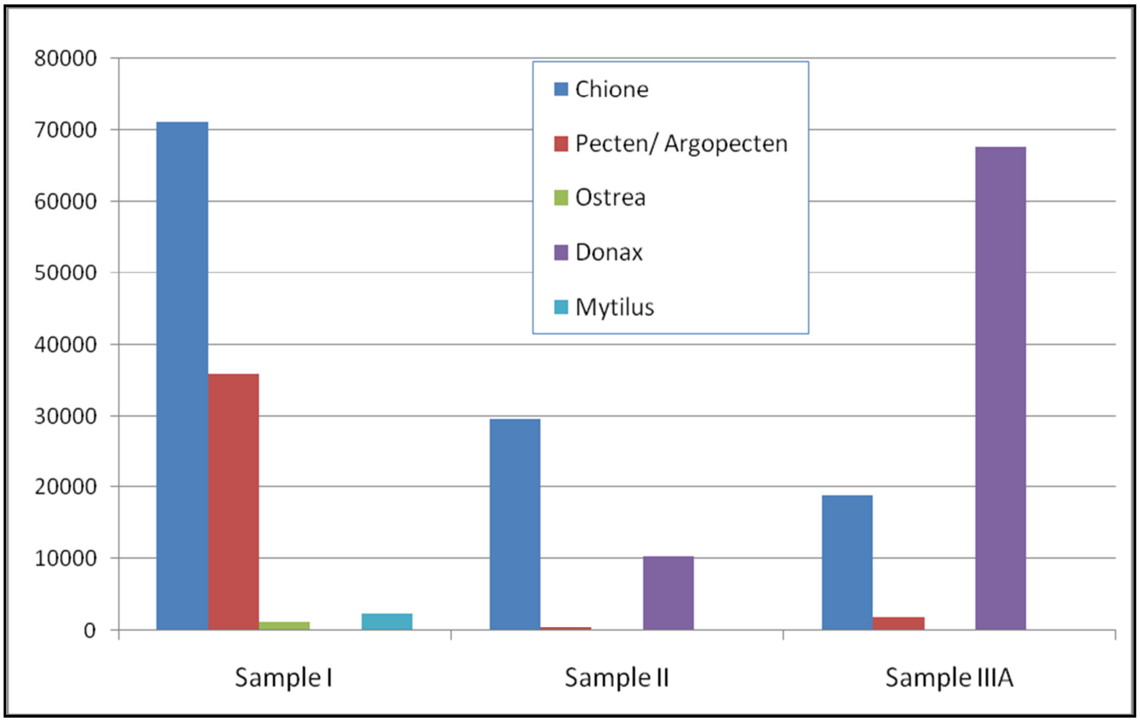


Figure 5.7. Relative proportion in weight (g) of invertebrates by sample, not including the trace amount of shell from Transitional sites. Adapted from: Becker and Iversen 2007; Byrd 1996, 1997; Gallegos and Carrico 1984; Gallegos et al. 1999; Gallegos et al. 1984; Hale and Becker 2006; Reddy 1997, 2000; Smith 1986; Smith and Moriarty 1985; Stropes and Gallegos 2005; York et al. 1999; Wake 1997, 1999.

A minimal amount of shell was recovered from Sample IIIB sites, totaling 35 g (see Table 5.19). Five grams of shell consisted of a single piece of abalone and other unidentifiable fragments. Most other identified shell consisted of *Donax* (28 g, 93.0%), with a few small fragments of *Argopecten* making up the rest of the assemblage. The lack of shell in Sample IIIB is a clue to the diminished importance of this resource compared to vertebrates and plant foods. This is especially true considering one would think *Donax* would be opportunistically exploited when abundant, requiring little time or energy to acquire and process.

5.3.3 Ethnobotanicals

Ethnobotanical studies are limited to the northern part of the study area, particularly on Camp Pendleton. Analysis of sediment for plant remains—seeds, nuts, etc., in particular—has not been a common component of archaeological research in southern California. Reddy (1997a, b, 2000, 2006; Reddy et al. 2005) has conducted comprehensive ethnobotanical studies from archaeological sites on Camp Pendleton, and at a few other locations to the south. However, Reddy's work has not been matched at other locations in the San Diego region, and in southern California in general. Ethnobotanical studies have high value for interpretation of socioeconomic trends, particularly when collections from sites in different regions can be compared. Despite Reddy's extensive work, certain time periods are poorly understood with respect to plant remains, particularly before A.D. 500 and during ethnohistoric times. Part of this relates to preservation, many sites predating A.D. 500 (Sample I) having been destroyed by development or excavated prior to the widespread practice of recovering plant remains through flotation.

Setting aside obvious problems of sample size and regional coverage, plant remains from 13 archaeological sites in the northern San Diego region have been compiled, including one Sample I site, six Sample II sites, six Sample IIIA sites, and one Sample IIIB (Transitional) site.

Seed densities in Sample II are much higher than in Sample I (Table 5.20; Figure 5.8). However, the single Sample I site is located on the coast, and its seed density is higher than the Sample II coastal assemblages. If other samples from inland sites were available, it is likely that they would exhibit a higher seed density. It is unclear why there is such a difference in seed density by region (see Figure 5.8). It may be that coastal sites have poor preservation (see Reddy 1997a). The large numbers of well used groundstone tools at Sample I coastal and lagoonal sites are evidence of intensive processing, thus it is probably not true that the difference in density is entirely due to differences in seed use.

Table 5.20. Frequency of Seeds, Nuts, and Other Plant Remains by Sample

	Sample I	**Sample II**			**Sample IIIA**			**Transitional**
Common Names	Coastal	Coastal	Inland	Upland	Coastal	Upland	Inland	Inland
Tarweed		18	13	45	2	1	15	41
Elderberry	4	8	3	26	2	2	37	6
Goosefoot	46	25	11	38	3	4	147	80
Legumes		150	29	23	7	13	113	171
Acorn	1	1		18		3	2	**0.44g***
Grasses	18	298	634	383	12	74	747	287
Other/Unidentified	307	119	121	274	27	44	537	1828
Liters Analyzed	192.5	739	76	209.95	225	76.5	37.5	50
Density/Liter	1.9	0.75	10.7	37	0.2	1.1	21.5	48.6

Adapted from Reddy 1997a, 1997b, 2000, 2006, Reddy et al. 2005.

Understanding changes in the kinds of plants being exploited before and after A.D. 500 is complicated by the large amount of unidentified seeds/fragments in Sample I (Table 5.20). Based on identified seeds, Chenopods are the most common item in Sample I and grasses second—though less than half as common as Chenopods. In Sample II, grass seeds comprise almost half of all plant remains with Chenopods in a close second, and legumes make a strong entrance at 24.0% of the assemblage (see Table 5.20). Small amounts of other well-known plants also appear, such as tarweed and elderberry. Inland and upland sites show a different profile, having assemblages dominated by grasses with small amounts of everything else other than unidentified seeds. The higher representation of plants other than grasses and Chenopods at inland and upland sites suggests that a broad spectrum of plants was exploited from spring months through the fall.

Ethnobotanical data was compiled from six Sample IIIA sites: two each from the coast, inland, and upland. All of these assemblages were analyzed by Reddy (1997a, 1997b, 2000, 2003). Sample IIIA ethnobotanical remains are generally less dense than earlier assemblages and pattern differently by region (Table 5.20, Figure 5.8).

Sample IIIA inland sites have the highest seed densities, upland and coastal sites much lower densities. The volume of Sample IIIA analyzed sediment is less than half of the volume analyzed for Sample II and this may account for some of the variability in seed density (see Table 5.20). However, it does not explain the shift in high seed densities from upland to inland sites. Inland seed density more than doubles while upland seed density diminishes to trace amounts. Sample IIIA upland sites are characterized by small middens, bedrock processing facilities, and relatively diverse assemblages—consistent with seasonal residential habitation. This probably resulted in uneven preservation between sites in similar depositional contexts, whether at upland, inland, or coastal locations. Nevertheless, that seed densities double at inland sites implies that inland areas were subject to more intensive processing and occupation.

Seed profiles at inland sites are slightly more diverse in Sample IIIA, having larger amounts of chenopods and other plant remains (i.e., goosefoot, legumes, and sage), although grasses are still the most common. Unidentified seeds and seed fragments are twice as common in Sample IIIA (see Table 5.20). Coastal sites also have much larger amounts of unidentified seeds and reduced amounts of chenopods. Despite the reduction in seed density at upland sites, the seed profile is similar, being dominated by grasses. Notably, acorns are lacking from Sample IIIA, as they are in Sample II.

Ethnobotanical data is available from one Sample IIIB (Transitional) site—SDI-16780 (Reddy et al. 2006). These results are compared to assemblages from several other sites from each time period (see Table 5.20). The one site in Sample IIIB has the highest density, at 48.6 seeds/liter. This is more than double the density from any sample, except upland sites in Sample II which have an average density of 37.0 seeds/liter—25.0% less than Sample IIIB (Figure 6.9). In Sample IIIA, inland sites have the highest seed density by far (see Figure 5.8). The extremely low seed densities from coastal sites during all time periods is probably biased by preservation problems, given large amounts of milling tools at coastal sites. However, the high seed density at inland sites is also a factor of intensified plant exploitation that is tied to greater use of inland environments after A.D. 1400.

Seed profiles for Sample IIIB have an exceptionally large amount of other/unidentified seeds (n = 1828/2413, 76.0%). Some of the unidentified or miscellaneous seeds may have entered the record indirectly as plants that were used for fuel or other non-subsistence purposes. Considering identified seeds, grasses and legumes together make up 49.0% and 29.0% of the assemblage, respectively, with small amounts of tarweed and Elderberry (see Table 5.20). This profile is similar to that of Sample I coastal sites. Inland sites from Sample IIIA, however, show a focus on grasses with less emphasis in Legumes and chenopods than Sample IIIB sites. Grasses and legumes were probably the most reliable and carbohydrate-rich plant foods. Also present in Sample IIIB are charred acorn remains. These were recovered from column samples as very small fragments with a total weight of 0.44g (see Reddy et al. 2006). It is difficult to compare this amount with acorn remains from other sites, particularly Sample II upland sites, but their presence in Sample IIIB indicates use of this resource.

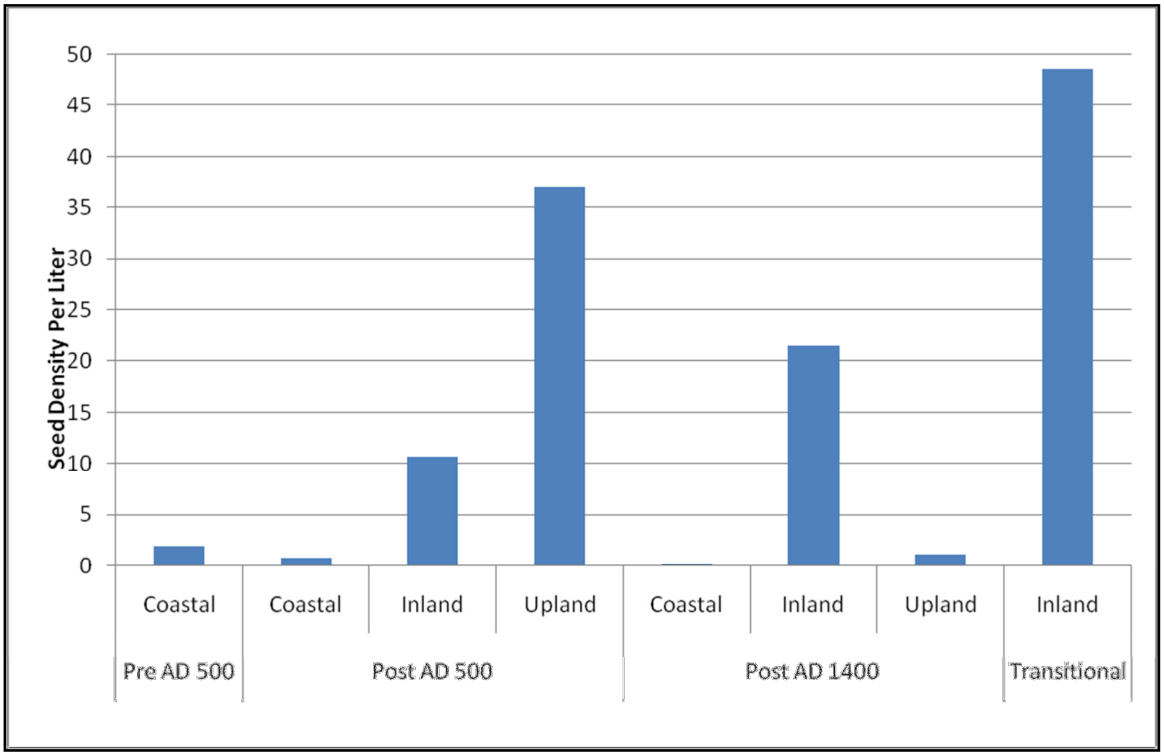


Figure 5.8. Seed density (per liter) by region and time period (adapted from Reddy 1997a, 1997b, 2000, 2006; Reddy et al. 2005).

5.4 SUMMARY

A comparison of assemblage composition between the different samples, including the results from the flakedstone and groundstone analyses, indicated that assemblage formality in the San Diego region is generally low throughout the prehistoric sequence. Aside from arrow points, formal flakedstone tools dramatically decline after the bow is adopted (Sample II) and remain uncommon in Sample IIIA, in contrast to Sample IIIB (Transitional), which has high flakedstone formality. Overall, debitage profiles indicate greater care taken in reduction in Sample II (less non-diagnostic shatter) followed by decreased care in reduction in Sample IIIA (greater non-diagnostic shatter).

Sample IIIB debitage is richer and non-diagnostic shatter is generally less common than in Sample IIIA. While groundstone formality is similar in Samples I, II, and IIIA, GUI values indicate a drop in processing intensity in Sample II, followed by a modest increase in Sample IIIA. Similar to flakedstone, groundstone formality and use intensity are highest among Sample IIIB assemblages. These patterns are interpreted with respect to predictions of the Tmin-Emax and IFD models in Chapter 6.

6. INTERPRETATION OF THE SAN DIEGO REGION DATASET

In this chapter, predictions of the Tmin-Emax and Ideal Free Distribution models are evaluated against data generated for the San Diego region, paying particular attention to changes in assemblage formality indices. Supporting evidence from flakedstone and groundstone analyses, and subsistence remains, is integrated to provide clarity where appropriate. Predictions of the Tmin-Emax model are evaluated first, regarding introduction of the bow and arrow and intensification, followed by predictions of the Ideal Free Distribution model for the transition from Tmin to Emax. Overall, data from the San Diego region are consistent with expectations of how a Tmin economy should respond to the bow and arrow, and how this same kind of adaptive strategy should intensify subsistence. Additionally, Transitional sites in the San Diego region fit expectations of founding events predicted by the Ideal Free Distribution model for the transition from Tmin to Emax modes of production.

6.1 PREDICTIONS OF THE TMIN-EMAX MODEL FOR THE INTRODUCTION OF THE BOW AND ARROW

Predictions derived from the Tmin-Emax model for the introduction of the bow and arrow are repeated in Table 6.1. The model predicts that a Tmin economy should use the bow's increased efficiency to save time on subsistence, while an Emax economy should invest more time in subsistence. The archaeological signatures of each prediction are very different. In a Tmin economy, the flakedstone formality index (FFI) and groundstone formality index (GFI) should both drop, indicating decreased investment of time in non-arrow point tool manufacture. With increased time spent making arrow points, the lithic waste index (LWI) should drop. Debitage assemblages should have a higher proportion of finishing flakes relative to non-diagnostic shatter—the latter being produced primarily in the earlier stages of reduction.

Conversely, in an Emax economy after arrival of the bow, the FFI and the GFI are expected to increase signifying increased time spent making other tools used during subsistence. Finishing flakes should increase, relative to shatter, with more time spent refining tools resulting in a drop in the LWI. Essentially, part of the time saved by using the bow should be invested in making other tools more efficient to maximize energetic yields.

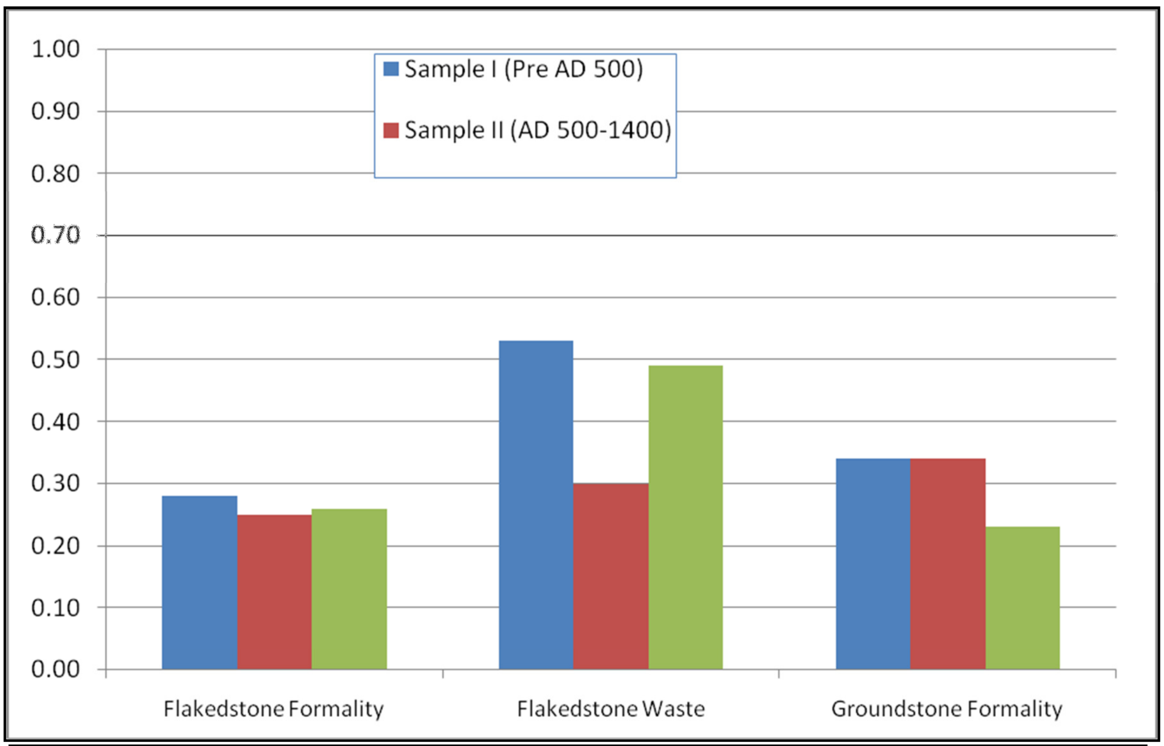
Table 6.1. Archaeological Predictions of the Tmin-Emax Model Following Introduction of the Bow and Arrow

	Tmin	**Emax**
Model Prediction	Spend less time in subsistence	Use time saved by using bow to get more energy
Archaeological Prediction		
Lithic Formality Index	⇩	⇧
Lithic Waste Index	⇩	⇩
Groundstone Formality Index	⇩	⇧

6.1.1 Assemblage Formality Indices

For a time minimizing economy, the Tmin-Emax model predicted that there should be a drop in tool formality after the bow and arrow is adopted. This is clearest in the FFI, with a slight shift from a value of 0.30 characterizing Sample I assemblages to 0.27 for Sample II assemblages that postdate A.D. 500 (Figure 6.1). The approximate 3.0% drop in assemblage formality is not large, or significant, but fits with model predictions for a Tmin economy. The shift in FFI is due to a sharp drop in the proportion of FFT in Sample II, and the scarcity of dart points.

Next, the prediction that the LWI should decrease after introduction of the bow is also confirmed (see Figure 6.1). The LWI drops by 23.0% from 0.53 in Sample I to a value of 0.30 in Sample II. The decreased LWI value is related to an increase in the amount of late-stage finishing flakes produced during arrow point manufacture, dropping the proportion of non-diagnostic shatter that is typically produced during the earlier stages of reduction.



Index	Flakedstone Formality	Flakedstone Waste	Groundstone Formality
Sample I (Pre AD 500)	0.28	0.53	0.34
Sample II (AD 500-1400)	0.25	0.30	0.34
Sample IIIA (AD 1400-1700)	0.26	0.49	0.23

Figure 6.1. Assemblage formality index values for flakedstone, debitage, and groundstone for Samples I, II, and IIIA in the San Diego region.

Finally, the Tmin-Emax model predicted a drop in the GFI for a Tmin economy. The GFI value in Sample I is 0.34; this value is slightly less for Sample II (0.32). Though a slight decrease of two percent, the pattern is clarified when regional variation is considered. Groundstone formality is highest in upland regions (GFI = 0.42) that witness substantial residential occupation after the bow arrives. Upland areas lack ample sources for groundstone raw material, and most handstones in upland areas were imported from the coast, intended for reuse. Thus, upland milling tools are more formalized as a result of extensive reuse and intentional shaping to facilitate transport (see Hale 2006). Conversely, coastal habitation sites have large amounts of expedient groundstone, with a GFI of 0.22. Coastal locales have easy access to cobbles eroding from drainages and beaches that can be used as handstones. The contrast is greater when considering that less than 10.0% of all groundstone tools from all of Sample II derive from upland sites.

Overall, shifts in the different formality indices after the bow appears are consistent with model predictions for a Tmin economy since the overall response to the arrival of the bow and arrow is decreased investment in other subsistence tools. Though changes in each index are not robust, assemblages from the San Diego region were already relatively informal prior to arrival of the bow.

6.2 PREDICTIONS OF THE TMIN-EMAX MODEL FOR SUBSISTENCE INTENSIFICATION

Evidence suggests that hunter-gatherers in the San Diego region practiced a Tmin economy when the bow and arrow was adopted after A.D. 500. Building on this, the Tmin-Emax model predicts that time minimizers and energy maximizers should intensify subsistence in different ways. Guided by a strong, stable preference for free time, a Tmin response to diminishing returns is to employ time-saving tactics wherever possible. With assemblage formality already low, time saving tactics during intensification can take on many forms. However, it is most likely that FFI values should decrease given ample raw material, and LWI values should increase, signifying less care taken in finishing flakedstone tools (Table 6.2). Conversely, diminishing returns in subsistence should lead to an increased emphasis on traditional plant foods (i.e., small seeds) and small animals to bolster caloric yields, causing more intensive and regular use of groundstone tools. This should cause GFI values to increase.

Table 6.2. Predictions of the Tmin-Emax Model Regarding Intensification

	Tmin	**Emax**
Model Prediction	Spend more time in subsistence	Spend more time in subsistence
Archaeological Prediction		
Flakedstone Formality Index	⇩	⇧
Lithic Waste Index	⇧	⇩
Groundstone Formality Index	⇧	⇧

Note: the model prediction for both Tmin and Emax will spend more time in subsistence, despite a strong preference for non-subsistence time in Tmin.

Essentially, the Tmin-Emax model predicts that traditional subsistence tools continue to be used, but more intensively so. There should not be a wholesale shift in assemblage composition toward more expensive tools, such as FFT and mortars. Tools with a high manufacturing cost should be avoided, choosing instead to maximize the efficiency of traditional, relatively low-cost tools.

6.2.1 Assemblage Formality Indices

Differences in assemblage formality between Samples II and IIIA confirm expectations of an intensified Tmin economy. Already low formality is maintained, with the FFI value remaining constant at 0.27 (see Figure 6.1). Low flakedstone formality in

Sample IIIA is due to the fact that nearly all flakedstone tools are arrow points or arrow point preforms, the remainder being a handful of FFT and bifaces.

An increase in the LWI value from 0.30 in Sample II to 0.49 in Sample IIIA was also anticipated for an intensified Tmin economy. That half of all debitage is non-diagnostic shatter is related to less care taken in the initial stages of flakedstone reduction, producing large amounts of shatter while breaking cobbles open. Given the large amount of arrow points in Sample IIIA, an increase in shatter is likely due to more frequent assaying of cobbles to produce one or two flakes suitable for arrow point production. In this sense, more frequent quarrying of cobbles for a decreased number of tools made from each cobble should produce greater proportions of shatter relative to finishing flakes.

Turning to groundstone, there is a slight increase in the GFI value from 0.32 in Sample II, to 0.33 in Sample IIIA. Unlike the transition from Sample I to Sample II in which large amounts of expedient groundstone tools were found at coastal locales, these same locations witness greater regularity and intensity of groundstone use in Sample IIIA, leading to a slight increase in the overall GFI value. This shift was anticipated by the Tmin model, predicting that diminishing returns in subsistence would lead to greater emphasis on small animals and plant foods processed with traditional technology—millingstones and handstones.

Changes in assemblage formality between Sample II and IIIA generally confirm expectations of the Tmin-Emax model for a time minimizing economy undergoing subsistence intensification. Low flakedstone and groundstone formality is maintained, despite the fact that arrow points are present in massive quantities. While differences in

FFI and GFI values are minimal between Samples II and IIIA, the lack of an increase in time spent finishing flakedstone and groundstone tools is telling. These tools are expected to exhibit high degrees of formality in an intensified Emax economy.

6.2.2 Supporting Evidence for the Tmin-Emax Model

Substantial data were generated from analyses of flakedstone and groundstone tools, and debitage, in an effort to both test the validity of formality indices and provide clarity where changes in index values were not robust. General themes drawn out of each dataset (flakedstone and groundstone) are reviewed in the following sections. These themes provide additional support for formality indices in the evaluation of the Tmin-Emax and IFD models. A brief interpretation of subsistence trends is also provided.

6.2.2.1 Flakedstone

The theme derived from the analysis of flakedstone tools and debitage is one of decreasing formality over time for Samples I through IIIA. The analysis of projectile points confirmed assemblage patterning of the appearance of small arrow points. However, all arrow points were made from small flake blanks that were primarily struck from cobble cores, rather than prepared core platforms. That is, most arrow points were made from flakes generated from cobble core reduction, rather than being struck from a bifacial core. Thus, the accommodation of the bow and arrow was made with existing reduction techniques rather than investing more time in the preparation of flake blanks.

Another insight from the analysis of arrow points is that nearly all from Sample II and IIIA were variants of the Cottonwood type. Within the Cottonwood type, variability in arrow point form is higher later in time (i.e., in Sample IIIA), evidenced by greater variation in basal metrics and a higher proportions of expedient points. The increase in arrow point variability later in time resulted from a combination of factors, including an increase in the proportion of arrow points hastily made for immediate needs, and possibly an increase in stylistic expression.

The analysis of non-projectile bifaces indicated that nearly all bifaces in Samples II and IIIA were arrow point preforms or rejects, as opposed to cores, knives, or other bifacial tools. This result is expected, given that bifaces are rare in the San Diego region in general, sharing equally low assemblage proportions in Samples II and IIIA.

The decrease in the FFI over time foreshadows the decline in formed flake tools. Analyzed FFT not only become rare in Sample II, but they are also less intensively used. Certain traits remain the same throughout the sequence, such as the kinds of edge shape and a wide range in metrics, given more time was spent making these tools for specific uses. However, the decrease in use intensity is telling of their decreased economic importance relative to RET and SFT. In particular, RET jump in proportion in Sample II.

The analysis of Sample II RET showed that they were minimally used, but that they likely took over scraping tasks once performed by FFT. The near disappearance of RET in Sample IIIA, along with a resurgence of SFT, is evidence of an even further decline in technological investment. Such a decline is predicted by the Tmin-Emax model for an intensified Tmin economy, but the FFI remained the same at 0.27. In that both RET and SFT are categorized as expedient, the reversal in the proportion of these tool categories clarifies the pattern. Interestingly, the dimensions of SFT remained very similar throughout the sequence for Samples I, II, and IIIA. A regression on length and width proved a strong relationship between the two metrics in each sample, implying strong selectivity in flake outline, despite changes in the proportion of flake types and sizes indicated by the debitage analysis. The significance of this relationship for model predictions is that the overall reduction in tool formality was mitigated by increased selectivity in flake form to ensure minimum levels of efficiency.

The debitage analysis revealed that unprepared cobble-core reduction was the dominant reduction technique for the entire prehistoric sequence. Evidence for prepared core platforms (i.e., bifacial cores, microblade cores, prismatic cores, etc.) was lacking or nonexistent. Cobble-core reduction is a very expedient strategy that involves splitting a cobble, creating an immediate platform from which flakes can be detached. This strategy was detected in a number of ways, the most obvious being platform configuration. Flakes commonly exhibited unprepared, single-faceted, cortical platforms. Additionally, biface thinning flakes were exceptionally rare—the majority of these being smaller than 2.0 cm in size indicating that they were detached from a tool preform rather than a prepared core. After the bow was introduced, tool production efforts largely shifted toward the manufacture of arrow points, increasing the proportion of finishing flakes relative to shatter, resulting in a drop in the LWI value, as predicted. A subsequent increase in the LWI value in Sample IIIA is consistent with an intensifying Tmin strategy in that less time is spent reducing each individual cobble-core.

6.2.2.2 Groundstone

The groundstone analysis produced GFI values for each sample that were roughly consistent with the model predictions, as previously discussed. More important is the lack of a significant increase in GFI values in Samples II and IIIA. Such an increase would be expected from an Emax economy.

Regional differentiation in processing intensity and manufacturing effort in Sample II implies that one of the Tmin responses to the introduction of the bow and arrow was to employ a geographically stratified settlement strategy, with coastal locales used for less intensive, but frequent processing and upland sites used for seasonally intensive processing. This regional distinction is blurred in Sample IIIA as coastal processing is intensified.

One of the most important trends identified in the analysis was the increased use of bedrock milling facilities in Samples II and IIIA. Serial use of bedrock facilities implies greater planning in landscape use. Interestingly, Sample II bedrock surfaces were used with more regularity and/or intensity than later Sample IIIA surfaces. The increased proportion of incipient bedrock slicks in Sample IIIA is consistent with hasty, but intensive short term processing. This may be an indication that territories were becoming more circumscribed, leading to a higher frequency of occupation at any given location. In any case, the Sample IIIA bedrock milling pattern fits with a decrease in manufacturing effort predicted for an intensifying Tmin economy (i.e., a decreased number of manufactured surfaces).

Sheer frequencies of bedrock mortars by sample are a clear indication of manufacturing effort. In both Samples II and IIIA, mortar surfaces are minimal, representing just 3.0% and 3.7% of all netherstone surfaces, respectively. The small proportion of mortars compared to flat and basined surfaces indicates that traditional technologies were used after the bow arrives (Sample II) and during intensification

(Sample IIIA), without significant increases in manufacturing investment that are implied in later, Transitional assemblages.

6.2.2.3 Subsistence Remains

Fortunately, a substantial amount of subsistence data were available from a limited number of authors, facilitating comparison by sample. After the bow arrives, Sample II sites show a sharp increase in the proportion of large mammal remains, and a decrease in fauna captured in estuarine settings (i.e., birds and fish). This is anticipated, given that the bow makes individual hunters more successful than did the atl atl.

Interestingly, Sample IIIA sites have much less large mammal remains, and more diverse assemblages with an increase in bird and fish remains, similar to Sample I fauna. The decreased proportion (and frequency of NISP) of large mammals in Sample IIIA is expected for an intensifying Tmin strategy that should redirect subsistence efforts to the most productive foods, such as plants and easily acquired small animals, birds, and schooling fishes (though the latter are never in high abundance). The reduction in large mammals is not likely due to environmental conditions, given that contemporary Transitional sites also have relatively high proportions of large mammal remains and lower faunal diversity (see below). For this reason, shifts in the faunal profiles for each sample are considered behavioral responses.

Invertebrate fauna shift in focus after the bow arrives from being dominated by lagoonal species in Sample I to open beach/brackish species in Sample II. The prevalence of *Chione* in Sample II is not surprising because these animals can also be found along sandy beaches, particularly among patches of eelgrass that are frequently exposed during seasonal low tides (Hilton 1988; Seashore Life of Southern California). Interestingly, *Donax* do not appear in the archaeological record until several hundred years after A.D. 100 when they possibly became more prevalent along the littoral (Laylander and Saunders 1993). *Donax* from archaeological sites typically postdate A.D. 700, with the majority of dated *Donax* shells postdating A.D. 1300 (see Hale and Becker 2006; Reddy 1996, 2000). This implies that the shift in shellfish species profiles from before and after A.D. 500 is a behavioral phenomenon.

The shift in species acquired and lower amount of shellfish recovered from Sample II sites is probably related to their decreased importance overall between A.D. 500 and 1400. This pattern is reversed in Sample IIIA that has large amounts of bean clam shells with a minority of *Chione* and other sandy beach shellfish.

The exploitation of bean clams fits with an intensified Tmin economy that is minimizing time spent on subsistence by targeting a species that blooms in the billions and can be easily processed. The irregularity of bean clam blooms means that these animals were opportunistically gathered in mass when in bloom. This is in contrast to Byrd et al. (1998) who suggests that *Donax* exploitation is evidence that hunter-gatherers in the San Diego region were undergoing intensification on a trajectory similar to all other hunter-gatherer groups, moving toward high cost processing and increased sedentism. Rather, *Donax* exploitation is characteristic of a different kind of intensification, one that involves minimizing handling time to satisfy a preference for non-subsistence time rather than more energy.

The limited amount of ethnobotanical remains available for comparison indicates that traditional plant foods were exploited in every time period and component. The most significant finding is that the diversity of species exploited decreases over time by sample, with Sample IIIA sites showing high densities of *chenopods* and a select number of grasses; trace amounts of other seeds are present. This pattern is not very strong, but clear enough to suggest that processing shifted in Sample IIIA to focus on plants with the highest return on carbohydrates. Data regarding tubers and roots are virtually non-existent in the sample. However, the steady decline of scraper planes and other bulky processing tools over time may be an indication that such resources were not as intensively used later in time.

The lack of acorn remains in all samples is questionable. Taphonomic processes work against the preservation of acorn hulls, especially since acorn processing involves discarding hulls early on, reducing the chance that they will be burned. However, Wohlgemuth (1999) found a substantial amount of acorn remains at an ethnohistoric village site in the northern San Diego County (i.e., SDI-812/H) that generally postdates A.D. 1600 (see Rosenthal et al. 1999). Wohlgemuth's results suggest that acorns became a significant economic staple during ethnohistoric times. The lack of acorn remains compiled for this research is certainly consistent with processing technology that implies a focus on traditional small, hard seeds. However, it is likely that additional sampling in the San Diego region is likely to yield at least noticeable amounts of acorn remains since this resource was probably used when necessary for millennia, but only intensified during ethnohistoric times.

6.3 PREDICTIONS OF THE IDEAL FREE DISTRIBUTION MODEL

A modified version of the Ideal Free Distribution (IFD) model, presented in Chapter 3, compared time minimizing and energy maximizing strategies as modes of production to make predictions about the Tmin response to deteriorating conditions. The IFD model predicted a series of attempts to start an Emax economy under poor Tmin conditions. Labeled Transitional sites, attempts to start an Emax economy should look different than traditional habitations; Transitional sites should be rare, consisting of residential hubs having diverse, formal assemblages. Additionally, the Tmin-Emax model predicted that an Emax assemblage should look much different that a Tmin assemblage; the former having much higher index values for flakedstone and groundstone formality (Table 6.3). Considering that data generated for San Diego region are consistent with expectations of a Tmin economy, four such Transitional (i.e., Sample IIIB) sites were identified in the San Diego region that date between A.D. 1400 and A.D. 1700—a time when the Tmin economy was undergoing subsistence intensification (i.e., Sample IIIA).

Table 6.3. Predictions of the IFD Model for the Transition Between Tmin and Emax Economies

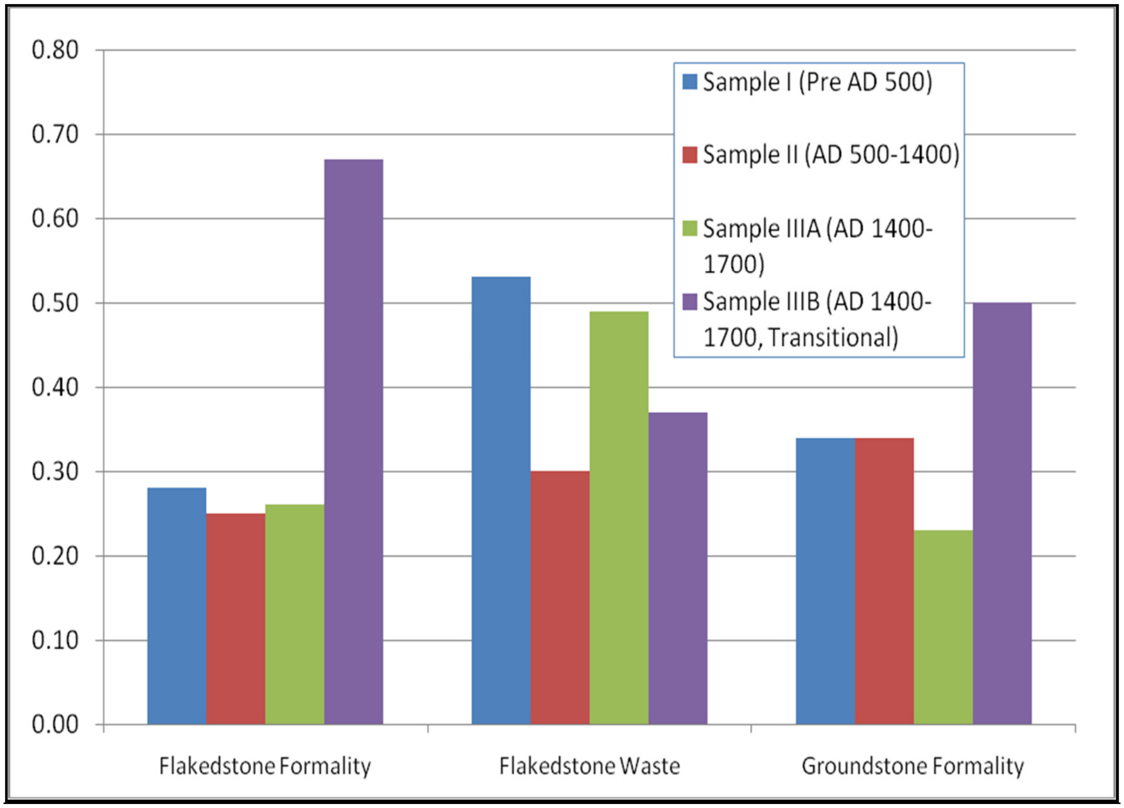
	Intensified Tmin	**Transitional Emax**
Model Prediction	Spend more time in subsistence	Spend more time in subsistence
Archaeological Prediction		
Flakedstone Formality Index	⇩	⇧⇧
Lithic Waste Index	⇧	⇩
Groundstone Formality Index	⇧	⇧⇧

6.3.1 Assemblage Formality Indices

The most striking attribute of Transitional sites is the high FFI value of 0.67—more than twice the value of any other time period, including contemporary Sample IIIA sites, in the San Diego region (see Figure 6.2). The larger FFI value for Transitional sites is due to a sharp increase in FFT and bifacial tools (i.e., knives and other cutting tools). Supporting increased production of formal flakedstone tools is the drop in the LWI value to 0.37. Since more effort is being placed on finishing flakedstone tools, small diagnostic flakes increase in proportion to shatter.

Groundstone formality also increases sharply. GFI values at Transitional sites (0.49) are much higher than contemporary non-Transitional assemblages or those from earlier periods (see Figure 6.2). Transitional sites have much higher GFI values partly because of the large number of relatively deep bedrock mortar surfaces. Mortars are expensive to manufacture and are a direct indication of increased investment in processing efficiency. However, it is also true that handstones exhibit higher degrees of shaping than those at non-Transitional sites.

Formality index values for Transitional sites, compared to Sample IIIA, are consistent with predictions of the Tmin-Emax and IFD models. These values indicate that Transitional assemblages reflect much higher degrees of investment in the manufacture of subsistence tools.



Index	Flakedstone Formality	Flakedstone Waste	Groundstone Formality
Sample I (Pre AD 500)	0.28	0.53	0.34
Sample II (AD 500-1400)	0.25	0.30	0.34
Sample IIIA (AD 1400-1700)	0.26	0.49	0.23
Sample IIIB (AD 1400-1700, Transitional)	0.67	0.37	0.50

Figure 6.2. Assemblage formality index values for flakedstone, debitage, and groundstone in the San Diego region, including all Samples.

6.3.2 Supporting Evidence for the Appearance of Transitional Sites

In support of the formality index values, the following sections explore the details of flakedstone and groundstone analyses, along with subsistence remains. Analytical results support the implications drawn from the formality indices. Taken together, all evidence indicates that Transitional sites represent a much different, early Emax economy in the San Diego region.

6.3.2.1 Flakedstone

The Transitional flakedstone toolkit is much different than any other sample. The most obvious difference is the presence of relatively high proportions of FFT and bifaces, as implied in the formality index values. FFT essentially replace RET and are equal in proportion to expedient SFT. FFT at Transitional sites were used more intensively, having regular edge shapes and diverse kinds of edge damage. The decreased emphasis on expedient tool use is supported by the fact that SFT exhibit less intensive wear than those in Sample II or IIIA. Spending more time manufacturing FFT was a strategy used to maximize tool efficiency. Adding to the formality of Transitional flakedstone is the increased proportion of non-projectile bifaces. These items were intended for use as knives or other kinds of tools, rather than projectiles. Finally, debitage profiles at Transitional sites indicate that cobbles were being imported and reduced on site to a greater degree. This is in contrast to Sample IIIA debitage profiles that suggest a higher frequency of incipient assayed cobbles. This shift toward more extensive on-site reduction implies that immediately local tasks (i.e., intensive processing) were as or more important than those conducted in offsite contexts.

6.3.2.2 Groundstone

Transitional groundstone is best explained by high GFI values, as discussed above. However, it is worth repeating that bedrock mortars account for 26.0% of the overall Transitional assemblage, compared to just 3.7% in Sample IIIA and 3.0% in Sample II. The high proportion of mortar surfaces is a direct indication that large amounts of time were spent in the manufacture of subsistence tools. Unlike other kinds of groundstone (i.e., handstones, pestles, and portable millingstones), the manufacture of a mortar surface requires a significant time investment, implying that such tools are intended for prolonged, intensive use.

6.3.2.3 Subsistence Remains

The vertebrate profile from Transitional shows a focus on large and small mammals, with less evidence for the exploitation of secondary, low yield resources. Compared to Sample IIIA and earlier samples, this trend can be considered energy maximizing behavior since small mammals are in abundance and produce large amounts of energy when captured in mass quantities, and large mammals are individually rich in energy and nutrients. The Transitional faunal profile stands out as distinct, compared to Sample IIIA sites that exhibit an opposite pattern, focusing instead on small terrestrial animals, birds, and surf fish.

A general lack of shell at Transitional sites reflects the reduced economic importance of shellfish compared to terrestrial animals and plants. Considering that contemporary Sample IIIA sites are defined by large *Donax* middens, the lack of shell at Transitional sites is telling of a shift in the local subsistence focus. Thus, Transitional fauna are less diverse than contemporary or earlier samples, implying a narrowing of the diet to focus on the most energetically productive resources (see also Hildebrandt et al. 1999).

6.4 SUMMARY

Predictions of the Tmin-Emax model evaluated against archaeological data indicate that the San Diego region was characterized by a time minimizing economy from before A.D. 500 until ethnohistoric times. After the bow arrives at approximately A.D. 500, time-saving tactics were employed to offset the cost of investing in this new technology. Similarly, traditional tools continued to be used with low formality during a period of intensification. Important here is that diminishing returns on subsistence elicited a time-minimizing response that maintained low levels of technological investment. The shift to an Emax economy, characterized by the ethnohistoric record, is foreshadowed by the appearance of Transitional sites during the A.D. 1400-1700 period of intensification. Transitional sites fit expectations of the IFD model that an Emax economy should be preceded by a series of colonizing events characterized by sites with highly formal toolkits. The pattern identified in the San Diego region strongly contrasts that of the Santa Barbara region—the latter being characterized by high assemblage formality prior to the arrival of the bow and arrow, increasing even more later in time. The following two chapters (Chapter 7 and 8) present archaeological data from the Santa Barbara region to evaluate expectations of the Tmin-Emax model for an energy maximizing economy.

7. THE SANTA BARBARA REGION DATASET

The Santa Barbara dataset consists of 25 archaeological sites altogether spanning the last 9,000 years of prehistory (Table 7.1; Figures 7.1 and 7.2). All of these sites are located on the mainland of the Santa Barbara Channel along the coastal margin, estuaries, and further inland along major drainages. Each site is considered a residential hub, whether seasonal or permanently occupied. Most, if not all sites consist of an amalgamation of occupations that occurred for different purposes and durations, but teasing such episodes apart is difficult or impossible, given depositional mixing. At some sites more than others (i.e., SBA-46, -71, -73), mixing of very different chronological components inhibits clarification of different economic trends (see Erlandson and Rick 2002; Erlandson et al. 2008; Gamble 1990, 1991). This is especially true when trying to determine the terminus of Millingstone Horizon deposits (Erlandson 1991, 1997). However, within each broad time period the problem of mixed occupations benefits this research in the sense that a wider range of activities are represented in the assemblages (i.e., task-specific exploitation and residential habitation), giving a more complete picture of tool production and use.

To simplify research goals and logistics, sites on the Channel Islands were not included because doing so would inherently assume that populations inhabiting the islands were undergoing the same socioeconomic trends at the same time as groups on the mainland. While this may be true for the last 1,500 years or so, it is less clear during earlier periods. Kennett (2005) describes archaeological patterns on the Channel Islands that imply strong socioeconomic links with mainland populations, especially after A.D. 1350 (e.g., possible trade of island resources for mainland acorns), making it clear that developments on the mainland affected, and were affected by, island occupations. However, focusing on just the mainland sites simplifies this perspective.

Several sites from the mainland Santa Barbara region that have been important in the development of regional chronologies are excluded (e.g., SBA-81, -119) because they consist of incomplete assemblages. Of the substantial excavations conducted by Rogers (1929) at SBA-81, and work conducted by Bowers (1888) and Harrison (1964) at SBA-119, only limited type collections remain inhibiting the current analysis that relies on the frequencies and proportions of different artifacts and their attributes. At other sites, such as SBA-1, only select investigations were drawn on for assemblage data due in part to data redundancy in comparison with other studies, and because assemblages from other investigations were difficult to access. Despite the limitations on assemblage selection, the current sample is considered representative of regional socioeconomic trends.

Most cultural chronologies proposed for the Santa Barbara region identify a transition at around A.D. 0 to the Late Prehistoric (Canalino, Late Canalino, Chumash Tradition), and another transition after A.D. 1500 to the Historic Chumash (see Harrison 1964; King 1990; Orr 1943; Rogers 1929; Wallace 1955; Warren 1968). King (1990) suggests a three period system with a transition from the Early to Middle period at 1500 B.C., and a transition to the Late Period at around A.D. 1000. Arnold (1992) proposed a Middle-Late Transition phase between A.D. 1150 and 1350, which Kennett (2005) supports, citing intensified fishing.

For the purposes of this research, arrow points first appear in assemblages between A.D. 400 and 600 (possibly earlier at SBA-117)—presumably accompanied by the plank canoe (Gamble 2002). Next, the refined circular hook (i.e., not the j-shaped hook) becomes much more frequent after A.D. 1350 and is considered a symbol of intensified subsistence (Kennett 2005:195). Using these indicators, assemblages are arranged chronologically to make comparisons before and after the introduction of the bow and arrow, and during intensification after approximately A.D. 1350 (see Arnold 1992; Glassow et al. 2007; Kennett 2005). Despite these clear chronological indicators, many mainland sites from the Santa Barbara region are not precisely dated and contain multiple occupations from different periods or overlap chronological categories.

Similar to the San Diego region dataset, assemblages from the Santa Barbara region are grouped according to a simple chronological scheme based on the various indicators mentioned above—i.e., appearance of the bow and arrow and circular fishhook. However, prior to introduction of the bow and arrow, several changes in assemblage composition indicate that a basic socioeconomic shift occurred prior to 1000 B.C. and intensified thereafter. These pre-bow assemblage shifts are also considered. Concerning chronological overlap, assignment of each assemblage to a time period is based on the main occupation of the site (e.g., SBA-117 ranges in age from A.D. 340 to A.D. 1300, but it is assigned to the A.D. 500-1350 category—Sample B). Specifically, the sample categories defined for the Santa Barbara region are:

- *Sample A, Pre A.D. 500*: This category includes sites that predate the arrival of the bow and arrow, arbitrarily set at A.D. 500; *n* = *16 sites*.
    - *Sample AI, pre 1000 B.C. Millingstone*: Millingstone sites are differentiated from other pre A.D. 500 sites by low assemblage formality dominated by generalized tools, consistent with the traditional Millingstone Horizon concept; *n = 7 sites*.

    - *Sample A2, Pre 1000 B.C., Non-Millingstone*: Sample A2 sites are differentiated from Sample A1 sites by larger frequencies of finished flakedstone tools and a higher proportion of mortars and pestles; n = 7 sites.

- Sample A3, 1000 B.C.-A.D. 500: These sites generally postdate the appearance of the single-piece fishhook that probably occurred at around 1000 B.C. (i.e., not the refined circular hook) (Rick et al. 2002); n = 2 sites.

- Sample B, A.D. 500-1350: This sample includes sites that postdate the arrival of the bow and arrow and that generally predate a period of intensification after A.D. 1350; n = 7 sites.

- Sample C, post A.D. 1350: Sites in this sample reflect intensified subsistence after A.D. 1350, primarily indicated by the appearance of the refined circular fishhook; n = 3 sites.

Sample A1, Pre 1000 B.C., Millingstone: Sample AI is comprised of seven sites that fit the profile of a traditional Millingstone Horizon site—these having low frequencies of formal flakedstone tools and being dominated by large numbers of millingstones and handstones (see Table 7.1). However, Millingstone sites in the Santa Barbara region tend to have higher assemblage formality than Millingstone sites elsewhere in California, particularly concerning groundstone (Hale 2001). Combined with occupational overlap and depositional mixing, this unique characteristic of Santa Barbara Millingstone sites makes it particularly difficult to define the Millingstone pattern apart from other early sites (see Erlandson 1988, Erlandson and Rick 2002). It is also true that Millingstone sites in this sample have similar flakedstone formality to non-Millingstone sites that predate 1000 B.C. (i.e., Sample A2). These are just a few reasons justifying the combination of Millingstone assemblage data with those from Samples A2 and A3 when measuring assemblage changes after the introduction of the bow and arrow.

Sample A2, Pre 1000 B.C., non-Millingstone: Non-Millingstone sites that predate 1000 B.C. are easier to define, particularly based on the addition of tools that are rare or absent in Millingstone assemblages, such as mortars and pestles and higher frequencies of formal flakedstone tools. Assemblage data for seven sites comprise Sample A2 (see Table 7.1). These sites are all located on coastal bluffs or the margins of lagoons (see Figure 7.1). Depositional mixing is a problem for almost all Sample A2 sites (e.g., SBA-75, Erlandson et al. 2008), however, the main occupations generally predate 1000 B.C.. The purpose of defining Sample A2 apart from Sample A1 is to briefly analyze changes in assemblage composition to better understand fundamental adaptive shifts—i.e., the shift from Tmin to Emax adaptive strategies. SBA-53 is one of the most important sites in Sample A2, having very high frequencies of cobble mortars combined with radiocarbon dates in excess of 2500 B.C. (Harrison and Harrison 1964).

Sample A3, 1000 B.C.-A.D. 500: Sites that date between 1000 B.C. and A.D. 500 are rare in the Santa Barbara region—across much of southern California, for that matter. As discussed above, several well-known and important sites in the Santa Barbara region fall into this time period (e.g., SBA-81) but existing collections are too limited such that basic frequency data for assemblage constituents are unavailable. Two coastal sites from Tecolote Canyon comprise Sample A3—SBA-71 and SBA-2149—and both are somewhat muddled with earlier and later occupations (see Erlandson et al. 2008) (see Table 7.1). Regardless of mixing problems, simply having radiocarbon dates that fall into the 1000 B.C.-A.D. 500 category, along with sizeable assemblages, is enough to warrant their inclusion in the analysis. If or when additional assemblages are identified that date to this interval, assemblage formality index values will change to some degree due to sample bias. The importance of defining assemblage composition for Sample A3 is to better understand adaptive shifts that occurred when the single-piece fishhook appeared after 1000 B.C..

Sample A, Pre A.D. 500: Sample A includes all assemblages from Samples A1, A2, and A3 (n=16) for the purposes of comparing regional assemblage formality values before and after the arrival of the bow and arrow (see Table 7.1). Combining sites from each of these samples lowers the overall formality index values, enhancing the contrast between Sample A (pre bow) and Sample B (post bow). However, this heightened contrast is not too erroneous, given that average formality index values for the overall Sample A, versus Sample A3, are not much lower (see below). It is also important to combine all pre A.D. 500 sites in Sample A to capture more of the regional variation in assemblage formality that derives from differential landscape use (i.e., short term camps versus major settlements). Most sites compiled for this analysis are themselves amalgamations of short and longer-term occupations.

Sample B, A.D. 500-1350: Sample B is composed of seven sites that generally postdate the arrival of the bow and arrow and were occupied primarily before a pronounced period of intensification at around A.D. 1350 (see Table 7.1). Six of these sites are situated on coastal bluffs or along lagoons, while one is located approximately 13 km inland (SBA-2202). As with all other samples, radiocarbon dates and other chronological indicators (i.e., beads, obsidian hydration, etc.) from Sample B sites indicate multiple occupations that differ in age (both earlier and later), but the primary occupations occurred within the A.D. 500- 1350 interval.

Sample C Post A.D. 1350: Three sites comprise Sample C—primary occupations at these sites generally postdating A.D. 1350 and the appearance of the refined circular fishhook (see Table 7.1). Despite the small number of sites in Sample C, assemblages from each site are robust, signifying intensive occupation. The circular hook signifies intensified fishing and is generally consistent with an increase in fish remains (see Kennett 2005). There are many more complexities in assemblage composition that are evident in Sample C, including intensified bead manufacture, plank canoe manufacture/ maintenance (implied by drills), etc. While these trends are important, this analysis will focus on differences in assemblage formality between Samples B and C to better understand how the local economy intensified subsistence.

Table 7.1. Archaeological Sites by Sample for the Santa Barbara Region.

Sample A1 Site	SBA-1807	SBA-891/ 2105*	SBA-1747
Age	7272-4937 B.C.	Diagnostic Artifacts Pre 1000 B.C.	6450-5750 B.C.
Setting	Coastal	Lake Cachuma	Coastal
Flakedstone			
Arrow Point			
Dart Point		1	
Point Preform/ Frag.	1	5	
Biface	8	7	1
Formed Flake Tool	23	2	9
Retouched Flake	17	34	7
Simple Flake Tool	10		5
Core	25	84	
Core/ Cobble Tool		12	
Hammer	190	2	13
Miscellaneous			
Debitage	1276	10566	1800
Groundstone			
Mortar		6	
Pestle		4	
Millingstone	30	35	5
Handstone	110	56	18
Handstone Pestle			
Miscellaneous	2		1
Indeterminate		49	
Bone/Shell Tools			
Miscellaneous			
Gorge			
Hook			
Composite Hook			

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample A1 Site	SBA-2499	SBA-1856*	SBA-16
Age	6025-5685 B.C.; 500 A.D.	Obsidian Hydration 3000-2000 B.C.	Obsidian Hydration 3000-200 B.C.
Setting	Tecolote	Coastal	Coastal
Flakedstone			
Arrow Point			
Dart Point			6
Point Preform/ Frag.	1	2	1
Biface	8	5	9
Formed Flake Tool	19	4	
Retouched Flake		3	
Simple Flake Tool	14	13	22
Core	35	17	11
Core/ Cobble Tool		2	1
Hammer	1		29
Miscellaneous			
Debitage	2494	447	8235
Groundstone			
Mortar	1		
Pestle			3
Millingstone	9	21	71
Handstone	11	70	313
Handstone Pestle			
Miscellaneous	3		2
Indeterminate	2		36
Bone/Shell Tools			
Miscellaneous			14
Gorge			
Hook			
Composite Hook			

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

		Sample A 2 SBA-97 SE	SBA-75
Age	**Total Sample A1**	5750-4600 B.C.	4115-3635 B.C.
Setting		Coastal	Coastal
Flakedstone			
Arrow Point			
Dart Point	**7**	4	5
Point Preform/ Frag.	**10**	13	
Biface	**38**	7	10
Formed Flake Tool	**57**	3	13
Retouched Flake	**61**		
Simple Flake Tool	**64**	7	
Core	**172**	10	7
Core/ Cobble Tool	**15**	1	
Hammer	**235**	3	1
Miscellaneous			
Debitage	**24818**	2083	859
Groundstone			
Mortar	**7**		3
Pestle	**7**		1
Millingstone	**171**	1	12
Handstone	**578**	2	11
Handstone Pestle			
Miscellaneous	**8**	1	
Indeterminate	**87**		
Bone/Shell Tools			
Miscellaneous	**14**	25	
Gorge		1	
Hook			
Composite Hook		1	

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample A2 Site	SBA-53	SBA-54, Middle Holocene Component	SBA-1326*
Age	5040-4540 B.C.	3900-3400 B.C.	none; part of SBA-75
Setting	Lagoonal	Lagoonal	Coastal
Flakedstone			
Arrow Point			
Dart Point	89	48	1
Point Preform/ Frag.			
Biface	144	47	1
Formed Flake Tool	307	39	
Retouched Flake	54		7
Simple Flake Tool	586	67	
Core	18	10	2
Core/ Cobble Tool	187	2	
Hammer	88	10	1
Miscellaneous			
Debitage		18397	76
Groundstone			
Mortar	70	4	3
Pestle	60	2	2
Millingstone	68	5	16
Handstone	131	22	27
Handstone Pestle	13		
Miscellaneous	51	19	
Indeterminate	66		
Bone/Shell Tools			
Miscellaneous	60	31	
Gorge	1		
Hook			
Composite Hook			

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample A2 Site	SBA-84	SBA-1808	
Age	3040 B.C.; 2550 B.C.; 760 B.C.	1530-1080 B.C.	**Total Sample A2**
Setting	Coastal	Coastal	
Flakedstone			
Arrow Point	11		11
Dart Point	16		163
Point Preform/ Frag.		1	14
Biface	57		266
Formed Flake Tool	50	6	418
Retouched Flake		2	63
Simple Flake Tool	73	6	739
Core	36	3	86
Core/ Cobble Tool	7		197
Hammer	9	1	113
Miscellaneous			
Debitage	2013	19005	42433
Groundstone			
Mortar	3		83
Pestle	4		69
Millingstone	24		126
Handstone	80	2	275
Handstone Pestle			13
Miscellaneous	10		81
Indeterminate			66
Bone/Shell Tools			
Miscellaneous	18		134
Gorge			2
Hook	4		4
Composite Hook			1

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample A3 Site	SBA-2149	SBA-71		
Age	890-50 B.C. / A.D. 1490-1641	230 B.C.-A.D. 680	**Total Sample A3**	**Sample A Grand Total**
Setting	Coastal	Coastal		
Flakedstone				
Arrow Point	1	1	2	**13**
Dart Point				**170**
Point Preform/ Frag.	2		2	**24**
Biface	8	7	15	**319**
Formed Flake Tool	9	17	26	**501**
Retouched Flake	28		28	**152**
Simple Flake Tool	5	2	7	**810**
Core	5	2	7	**265**
Core/ Cobble Tool		18	18	**230**
Hammer	6	5	11	**359**
Miscellaneous				
Debitage	1448	1391	2839	**70090**
Groundstone				
Mortar		12	12	**102**
Pestle	2	8	10	**86**
Millingstone	5	5	10	**307**
Handstone	1	15	16	**869**
Handstone Pestle				**13**
Miscellaneous	1	1	2	**91**
Indeterminate	3	3	6	**159**
Bone/Shell Tools				
Miscellaneous	16		16	**164**
Gorge	10		10	**12**
Hook		10	10	**14**
Composite Hook				**1**

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample B Site	SBA-72	SBA-46	SBA-117
Age	A.D. 1-1451	A.D. 460-1310/ 600-1470 B.C.	A.D. 340-1300
Setting	Tecolote	Lagoonal	Coastal
Flakedstone			
Arrow Point	33	25	107
Dart Point	4		16
Point Preform/ Frag.	13		39
Biface	24	18	70
Formed Flake Tool	48	91	99
Retouched Flake	5	7	32
Simple Flake Tool	65	34	44
Core	10	5	110
Core/ Cobble Tool	22	2	13
Hammer	6	11	5
Debitage	21267	6237	2094
Groundstone			
Mortar	17	3	7
Pestle	7	4	8
Millingstone	2	4	
Handstone	4	18	1
Handstone Pestle			
Miscellaneous	8	13	5
Indeterminate	18	8	
Bone/Shell Tool			
Miscellaneous	53	30	81
Gorge		3	
Hook	84	4	7
Miscellaneous	45 (asphaltum)	8	302
Ornaments			
Shell		44	6
Stone			29

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample B Site	SBA-73 N/S	SBA-1* Sample	SBA-2202*
Age	A.D. 790-1280 / 40 B.C.-A.D. 131	Post A.D. 500	A.D. 500-1400; Obs. Hydration and beads
Setting	Tecolote	Coastal	13 km
Flakedstone			
Arrow Point	17	14	1
Dart Point		4	3
Point Preform/ Frag.	105		
Biface	103	17	39
Formed Flake Tool	97	33	7
Retouched Flake			3
Simple Flake Tool	194	12	30
Core		8	17
Core/ Cobble Tool	27	6	1
Hammer	20		3
Debitage	3962	3404	10350
Groundstone			
Mortar	35		4
Pestle	30	3	3
Millingstone	8		2
Handstone	6		4
Handstone Pestle			
Miscellaneous	7		8
Indeterminate	70		
Bone/Shell Tool			
Miscellaneous	89	10	
Gorge	2	1	
Hook	35	22	
Miscellaneous	71 (asphaltum)		
Ornaments			
Shell		807	
Stone			

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

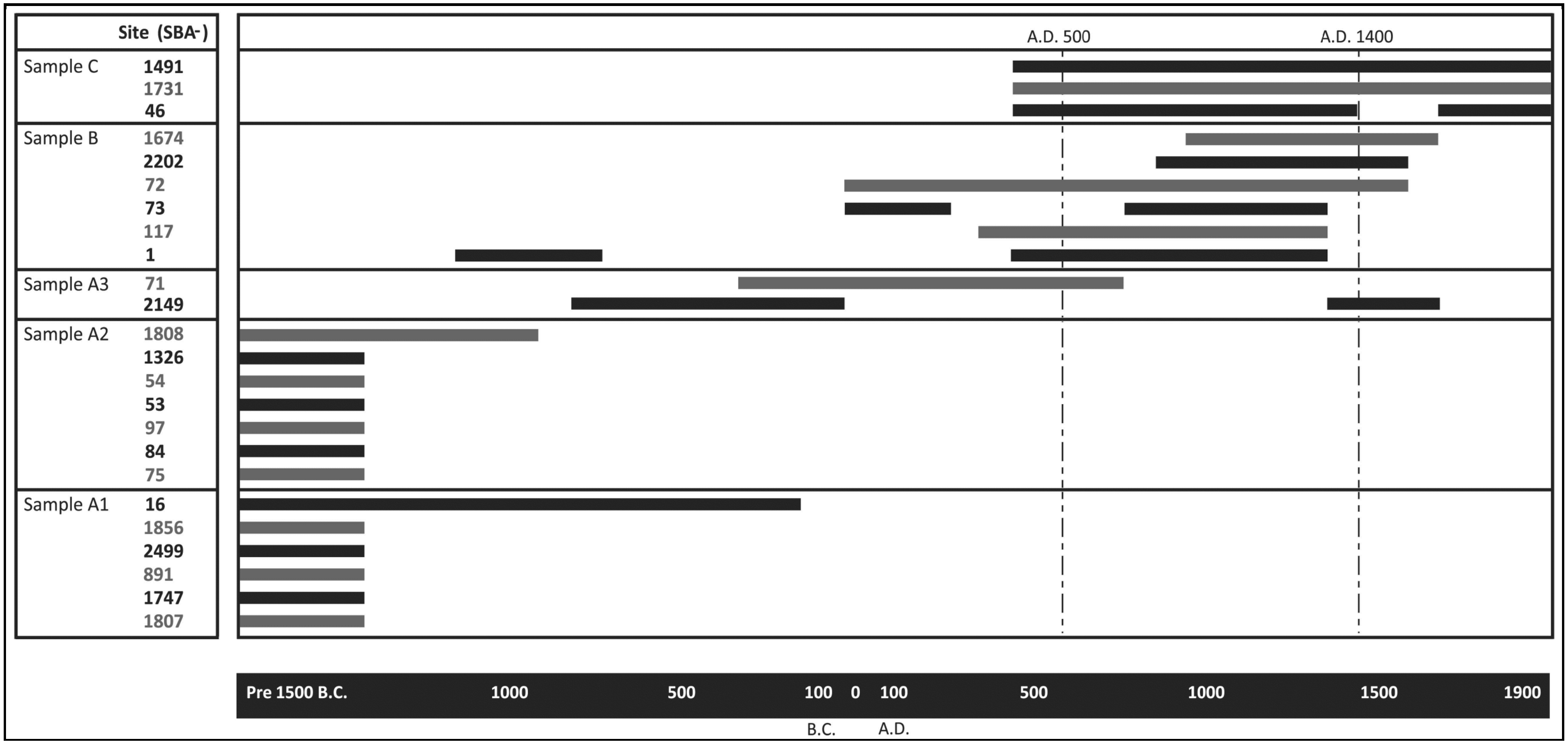
Sample B Site	SBA-1674	
Age	A.D. 940-1590	**Total Sample B**
Setting	Tecolote	
Flakedstone		
Arrow Point	3	**200**
Dart Point		**27**
Point Preform/ Frag.		**157**
Biface	9	**280**
Formed Flake Tool	6	**381**
Retouched Flake		**47**
Simple Flake Tool	9	**388**
Core	1	**151**
Core/ Cobble Tool	1	**72**
Hammer	1	**46**
Debitage	2352	**49666**
Groundstone		
Mortar		**66**
Pestle	1	**56**
Millingstone		**16**
Handstone	4	**37**
Handstone Pestle		
Miscellaneous	1	**42**
Indeterminate	4	**100**
Bone/Shell Tool		
Miscellaneous		**263**
Gorge		**6**
Hook		**152**
Miscellaneous		**426**
Ornaments		
Shell		**857**
Stone		**29**

Table 7.1, Continued. Archaeological Sites by Sample for the Santa Barbara Region.

Sample C Site	SBA-1731	SBA-1491	SBA-46	
Age	A.D. 470-1831	A.D. 400-1951	Post A.D. 1700	
	A.D. 1150-1550; main	A.D. 1350-1810 main		
Setting	Coastal	Coastal	Coastal	**Total Sample C**
Flakedstone				
Arrow Point	26	81	14	**121**
Dart Point	2	5	16	**23**
Point Preform/ Frag.	33	57		**90**
Biface	32	136	24	**192**
Formed Flake Tool	21	311	66	**398**
Retouched Flake	7		30	**37**
Simple Flake Tool	13	115	12	**140**
Core	13	24	3	**40**
Core/ Cobble Tool			2	**2**
Hammer		45	2	**47**
Miscellaneous				
Debitage	7000	13074	1259	**21333**
Groundstone				
Mortar	1	20	4	**25**
Pestle	6	6		**12**
Millingstone	2	3	2	**7**
Handstone	9	4	3	**16**
Handstone Pestle				
Miscellaneous			13	**13**
Indeterminate				
Bone/ Shell Tool				
Miscellaneous	27	77 (frags)	9	**113**
Gorge	4			**4**
Hook	32	12	16 (4 bone)	**60**
Ornaments				
Shell		262	3855	**4117**

Note: *, Main occupation chronology estimated based on diagnostic artifacts or obsidian hydration.

Figure 7.1. Map showing the locations of archaeological sites included in this study, distinguished by color for each sample.


Site (SBA-)
Sample C
1491
1731
46
Sample B
1674
2202
72
73
117
1
Sample A3
71
2149
Sample A2
1808
1326
54
53
97
84
75
Sample A1
16
1856
2499
891
1747
1807
A.D. 500
A.D. 1400
Pre 1500 B.C.
1000
500
100
0
100
500
1000
1500
1900
B.C.
A.D.

[illegible]

7.1 ASSEMBLAGE COMPOSITION

7.1.1 Artifact Proportions

7.1.1.1 Samples A1 and A2

Samples A1 and A2 exhibit strong differences in artifact frequencies (see Table 7.2). Not surprisingly, Sample A1 (Millingstone) assemblages are dominated by millingstones, handstones, hammers, and cores, with small amounts of formal flakedstone tools (i.e., points, bifaces, FFT), and bone/shell tools. In contrast, Sample A2 assemblages have much higher proportions of points, bifaces, and FFT (34.0% combined), and a five-fold increase in expedient SFT (from 5.0% to 29.0%) (see Table 7.2). In addition, Sample A2 has higher proportions of mortars and pestles, together comprising 6.0%. Finally, bone and shell tools amount to less than one percent of Sample A1 assemblages while they comprise 5.0% of Sample A2. These differences in assemblage composition hint at much different adaptive strategies for Sample A1 (Millingstone) and Sample A2 (non-Millingstone) sites that predate 1000 B.C..

The comparison of Sample A1 and A2 assemblages is biased by one site—SBA-53—with an unusually large assemblage (see Table 7.1). SBA-53 (Sample A2) is a site located on Goleta Slough excavated by Harrison and Harrison (1964), who used the assemblage to define the Santa Barbara Hunting Culture. No other assemblage is as large as the one from this site and Glassow (1997) suggests that this accounts for the unusual variety of artifacts, particularly mortars and pestles. Glassow (1997) suggest that the site was a magnet location within local settlement and subsistence patterns, rather than representing an influx of people from the Campbell Tradition, claimed by Warren (1968). The site is best known for the large numbers of dart points (n = 89) and cobble mortars (n

= 70), but bifaces (including formal knives; n = 144), FFT (n = 307), and SFT (n = 586) are also present in unusually high frequencies. By itself, SBA-53 has an FFI value of 0.40.

If SBA-53 (Sample A2) is excluded from the comparison of Samples A1 and A2, several interesting shifts in assemblage proportion emerge. Given the large number of SFT from SBA-53, the exclusion of such items drops their overall proportion from 29.0% to 17.1%. Similarly, the exclusion of 70 mortars and 60 pestles drops their total assemblage proportion for Sample A2 from 6.0% to 2.4%. Bone and shell tools increase from 5.0% to 8.9% overall, and points and bifaces increase in proportion from a total of 17.0% to 23.2% (see Table 7.2). With these changes, the FFI value for Sample A2 without SBA-53 increases 20.0% to 0.66. Thus, excluding SBA-53 from the overall comparison of Samples A1 and A2 shows that other Sample A2 assemblages are much more formal than Sample A1 (Millingstone) assemblages.

Whether or not Glassow (1997) is correct in assuming that SBA-53 is the result of local socioeconomic developments, the assemblage is sufficiently unique to warrant further consideration. Specifically, this site contains the largest number of mortars of any site on the Santa Barbara mainland, with the next largest sample—half as much (n = 35)—deriving from SBA-73. Moreover, most of the mortars from SBA-53 are whole, carrying more significance than all other mortar assemblages that are dominated by fragmentary specimens. While nearly all mortars from SBA-53 are unshaped cobbles, all mortar surfaces were manufactured—a feat requiring more time and energy than shaping the exterior of a millingstone. While it is true that SBA-53 was subject to more extensive controlled excavation than any other site on the mainland Santa Barbara coast, other sites have been leveled by construction, with archaeological monitors present to collect exposed artifacts and not other site has yielded as large an inventory of mortars.

Investing in mortar surfaces—rather than using traditional millingstones—indicates that processing/ pulverization was a major economic pursuit. Glassow (1997) suggests that these mortars were probably used to process bulrush and other estuarine plants rather than acorns, because of the estuarine situation of the site and lack of oak groves. On the contrary, Bettinger et al. (1997) argue that it is economically viable to transport large quantities of acorns over long distances, meaning that acorns could have been imported to SBA-53. The debate over what kinds of resources the mortars were intended for matters less than their large numbers overall. It is not likely that they were manufactured to be generalized processing implements because millingstones and handstones at SBA-53 are present in large quantities as well (n = 68 and 131, respectively). Millingstones and handstones were more likely to be used for generalized processing. Cursory observations on the latter indicate that they were intensively used.

In addition to mortars and pestles, SBA-53 contains the largest assemblage of dart points of any mainland site in this sample (n = 89). Together with 144 bifaces (including finished knives) and 307 formed flake tools, the flakedstone toolkit also indicates that large quantities of time were spent making finely finished hunting-related tools. Expedient tools (i.e., SFT, core/cobble tools, hammers) are also common, indicating some situational use of flakedstone tools.

7.1.1.2 Samples A2 and A3

A comparison of Samples A2 and A3 indicates that assemblage formality is higher in Sample A3. Overall, in Sample A3 there are larger proportions of formal flakedstone tools (i.e., bifaces and FFT), millingstones (6.0%) are less abundant than shaped mortars (8.0%), and the single-piece (j-shaped) fishhook appears (all shell hooks prior to 1000 B.C. are probably intrusive; see Rick et al. 2002) (see Table 7.2). Formal items, including bifaces, formed flake tools, mortars, and bone and shell tools, comprise 35.0% of Sample A2, increasing to 53.0% for Sample A3 (see Table 7.2). This increase occurs despite the fact that Sample A3 assemblages generally lack projectile points and preforms.

Table 7.2. Relative Proportion of Assemblage Constituents by Sample for the Santa Barbara Region

	Sample A1 Millingstone	**Sample A2 Pre 1000 BC**	**Sample A3 1000 BC - AD 500**	**Sample A (All)**	**Sample B**	**Sample C**
Points	.01	.07	.01	.05	.13	.13
Point Frag./Preform	.01	.01	.00	.01	.09	.08
Bifaces	.03	.10	.10	.08	.16	.17
Formed Flake Tool	.05	.16	.17	.13	.21	.36
Retouched flakes	.05	.02	.18	.04	.03	.03
Simple Flake Tool	.05	.29	.05	.21	.22	.13
Core/Cobble Tools	.01	.08	.12	.06	.04	.00
Hammers	.19	.04	.07	.09	.03	.04
Mortars	.01	.03	.08	.03	.04	.02
Pestles	.01	.03	.06	.02	.03	.01
Millingstones	.14	.05	.06	.08	.01	.01
Handstones	.46	.11	.10	.22	.02	.01
Total Stone Tools	1250	2537	155	3942	1773	1110
Simpson Diversity Index	4.39	6.96	9.27	8.10	7.53	5.29
Evenness	.34	.54	.71	.62	.58	.41
Bone Tool	.01	.05	.14	.04	.12	.09
Hooks	.00	.00	.05	.00	.07	.05
Grand Total	1264	2678	191	4133	2194	1287

Note: *, percent of grand total. The Shannon Diversity Index is based on: [SUM : $(n_i(n_i\text{-}1))$]/N(N-1), where n_i = # artifacts in a category and N = total # of stone artifacts.

Changes in assemblage proportion are partly due to the unusually high number of dart points and expedient flakedstone tools in Sample A2. In Sample A3, points and expedient flake tools drop dramatically (see Table 7.2). Mortars and pestles double in relative proportion in Sample A3; millingstones and handstones remain somewhat stable.

7.1.1.2 Samples A and B

For this comparison, Sample A includes all assemblages from Samples A1, A2, and A3. Several important shifts in assemblage composition occur after the bow and arrow is introduced. First, projectile points more than double in frequency from 5.0% in Sample A to 13.0% in Sample B, accompanied by a more modest, yet still large increase in bifaces from 8.0% in Sample A to 16.0% in Sample B (see Table 7.2). Formed flake tools nearly double in proportion from 13.0% in Sample A to 21.0% in Sample B, while their expedient counterparts—RET and SFT—remain stable, together comprising an average of 25.0%. Crude core/cobble tools and hammers decrease in combined proportion by more than half, from 15.0% in Sample A to 7.0% in Sample B. The drop in the overall proportion of groundstone tools is due to the sharp increase in arrow points combined with a decrease in the absolute frequency of handstones and millingstones. However, an important shift in groundstone proportions is clear. In Sample A, the ratio of mortars to millingstones is 1:3, and in Sample B this ratio shifts to 4.1:1. This signals an important shift in the economic significance of intensive processing. Finally, there is a large increase in bone tools and shell fishhooks from a combined proportion of 4.0% for Sample A to 19.0% for Sample B (see Table 7.2). The assemblage shifts evident in Sample B are evidence that investment in subsistence technology increases after the bow is adopted (see Section 7.1.2 below).

7.1.1.3 Samples B and C

A comparison of Samples B and C is intended to gauge further shifts in tool manufacture in response to subsistence intensification. While projectile points remain stable between Samples B and C at approximately 21.0%, the proportion of bifaces increases slightly while FFT are much more prevalent, increasing from 21.0% in Sample B to 36.0% in Sample C (see Table 7.2). On the other hand, expedient SFT drop from 22.0% in Sample B to 13.0% in Sample C. The slight decline in proportion of mortars and pestles is due in part to the large proportion of FFT. Regardless, highly-shaped and decorated mortars and pestles are a hallmark of assemblages that postdate A.D. 1350, such as flower pot mortars (Figure 7.3).

Figure 7.3. A Flowerpot Mortar (Unprovenienced specimen).

The appearance of the circular fishhook after A.D. 1350 is evidence of increasing technological specialization. The circular hook—often with a grooved shank—is considered more refined in form and was probably more efficient in terms of reducing loss once a fish was hooked (see Salls 1988; Glassow et al. 2008; see Kennett 2005 for fishhook images). Kennett (2005) suggests that variability in earlier hook forms could relate to the targeting of a wider variety of fish, indirectly implying that the circular grooved shank hook is intended for a narrower range of fish. However, diverse fish remains from sites with circular hooks does not support this inference.

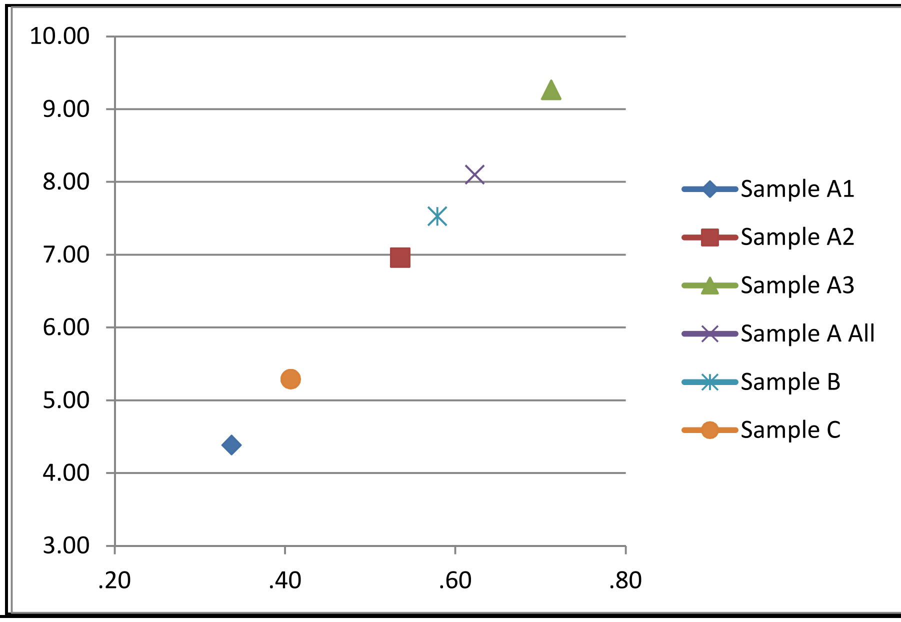
Another unique characteristic of Sample C sites is the commonality of microdrills used to manufacture beads. These formal tools are small bladelets that have been retouched on the distal end to form a narrow drill bit typically less than 1.0 mm in diameter. Arnold (1992) discusses the microblade industry on the Channel Islands and it is likely that the presence of these items signifies bead manufacture at mainland sites. Regardless, it is further direct evidence of technological specialization.

To summarize, several phases of increasing assemblage formality are evident in simple comparisons of assemblage proportion. The most significant of these include the appearance of mortars in significant quantities in Sample A2, large numbers of bifaces and FFT in Sample B, and increased technological specialization in Sample C. These trends are supported by assemblage formality indices for each sample, presented in the next section.

7.1.1.4 Simpson Diversity Index Values

The Simpson diversity index (D) used to measure assemblage diversity for San Diego region assemblages ($D = 1/[\sum(n_i/N)^2]$) was also used for each sample in the Santa

Barbara region, as was the measure of evenness (D/Total number of artifact classes in each sample) (see Chapter 5). These values are provided in Figure 7.4. Note that the straight line results from all samples having the same number of artifact classes represented (i.e., richness).



	Sample A1	Sample A2	Sample A3	Sample A All	Sample B	Sample C
Simpson	4.39	6.96	9.27	8.10	7.53	5.29
Evenness	.34	.54	.71	.62	.58	.41

Figure 7.4. Simpson diversity index and evenness values by Sample for the Santa Barbara region.

Considering just Samples A1 through A3, assemblage diversity and evenness increase in step, with Sample A3 having the highest diversity and evenness. Collapsing all of Sample A and comparing it to Samples B and C, the reverse trend appears. Sample A has the highest Simpson values and evenness; Sample B is slightly less diverse than Sample A, but Sample C is dramatically less diverse (see Figure 7.Y). While seemingly counter-intuitive, the trend of decreasing assemblage diversity and evenness is due to a shift toward more specialized technologies at the sacrifice of generalized processing and cutting tools. This is supported by substantial increases in the FFI and GFI values, indicating that as technological specialization increases, the diversity of artifact classes decreases—i.e., expedient tools become less common, replaced by formal tools.

7.1.2 Assemblage Formality Indices

The increasing trend of tool manufacturing effort, indicated by the comparisons of assemblage composition, is supported by changes in formality index values. Within Sample A, the lowest Flakedstone Formality Index (FFI) value characterizes Sample A1 (Millingstone) at 0.43 (Table 7.3). Comparatively, Sample A2 has an FFI value of 0.46. The higher FFI value for Sample A2 is due to an increase in bifaces and FFT, relative to RET and SFT. These same constituents increase in assemblage proportion in Sample A3, generating the highest average FFI value for all of Sample A at 0.54 (see Table 7.3).

The steady increase in the FFI value within Sample A is followed by a similar increase in flakedstone waste. Again, Sample A1 has the lowest LWI value at 0.23. This LWI value more than doubles to 0.49 for Sample A2, increasing slightly thereafter to 0.53 for Sample A3 (see Table 7.3). The increase in waste is due to a dramatic increase in the production of formal flakedstone tools; formal and expedient flakedstone tools are relatively uncommon in Sample A1, thus producing less production waste overall.

Groundstone Formality Index (GFI) values are only available for Sample A1 and A2 (see Table 7.3). However, a significant increase from a GFI value in Sample A1 of 0.54 to 0.67 for Sample A2 is evidence that investment in the manufacture of groundstone tools is greater in Sample A2. This is consistent with the higher FFI value for Sample A2. The higher GFI value for Sample A2 is due to the commonality of cobble mortars, requiring much greater manufacturing effort than shaping a millingstone.

Considering all of Sample A (i.e., Samples A1, A2, and A3 combined), assemblage formality increases over time. However, manufacturing effort after the bow arrives at around A.D. 500 is even greater. This is shown by comparing combined formality index values for Sample A against Sample B.

The average FFI value for Sample A is 0.46 (see Table 7.3). In contrast, Sample B has a much higher FFI value of 0.60. This increase is due to the increase in bifaces and FFT from a combined proportion of 20.0% in Sample A to 35.0% in Sample B. A drop in the LWI value from 0.50 for Sample A to 0.46 for Sample B indicates that greater care is taken in finishing flakedstone tools (i.e., larger amounts of finishing flakes relative to non-diagnostic shatter).

Regarding groundstone, the GFI value for Sample A is 0.58, increasing to 0.82 for Sample B (see Table 7.3). This is due to the higher proportion of shaped mortars and pestles in Sample B and a decline in the abundance of handstones. However, millingstones and handstones remain common, implying continued use of the more generalized processing equipment.

Assemblage formality increases sharply among post A.D. 1350 assemblages. The FFI value for Sample C is 0.77—up 17.0% from the 0.60 FFI value for Sample B (see Table 7.3). The much higher FFI value is due to further increases in bifacial tools and FFT, including both large and small drills. Fishhooks were probably made with larger, less-refined drills while beads were manufactured using small, microblade drills (see Bamforth 1991)—both circular fishhooks and shell beads are abundant in Sample C.

A decline in the LWI value from 0.46 in Sample B to 0.37 in Sample C is evidence that investment in tool finishing was a priority. This drop in non-diagnostic shatter occurs despite increased use of lower quality Monterey chert that would produce more shatter than higher quality Franciscan chert, especially since the latter had to be imported (see Section 7.1.2.6. Debitage).

There was limited access to Sample C collections, resulting in a relatively small number of groundstone tools that could be examined for shaping. Nevertheless, the GFI value is for Sample C is 0.77. A larger sample may increase this GFI value, as is implied by several pieces of "flowerpot" mortars (see Figure 7.3) and decorated pestles (Figure 7.5). These decorated items are the result of investing ideology in the manufacture of subsistence tools—an indirect symbol of the economic significance of these. Regardless, mortars and pestles are more common than millingstones and handstones in Sample C. The ratio of mortars to millingstones in Sample C is 3.6:1, similar to the 4:1 ratio for Sample B. A larger sample size may clarify the pattern further.

Figure 7.5. A decorated pestle from Sample B (SBA-117: catno. 107-81).

Table 7.3. Assemblage Formality Indices by Sample in the Santa Barbara Region

Formality Index	Flakedstone	Debitage	Groundstone
Sample A1 Millingstone	0.43	0.23	0.54
Sample A2 Pre 1000 B.C.	0.46	0.49	0.67
Sample A3 1000 B.C.-A.D. 500	0.54	0.53	NA
Sample A All Pre A.D. 500	0.46	0.50	0.58
Sample B A.D. 500-1350	0.60	0.46	0.82
Sample C Post A.D. 1350	0.77	0.37	0.77

Assemblage patterning and formality indices present a clear picture of increasing technological investment over time, particularly after the bow arrives at around A.D. 500 (i.e., Sample B), and then again during a pronounced period of intensification (i.e., Sample C). The following analytical sections provide more insight into shifts in manufacturing investment and tool use, ultimately supporting inferences gleaned from comparisons of assemblage content and formality indices.

7.2 FLAKEDSTONE AND GROUNDSTONE ANALYTICAL DATA

7.2.1 Flakedstone

A total of 839 flakedstone tools from eight sites in the Santa Barbara region were analyzed, including 285 projectile points, 155 bifaces, 204 FFT, 52 RET, and 143 SFT (Table 7.4). Sample A includes 200 analyzed tools, Sample B contains 519 analyzed tools, and 130 tools were analyzed from Sample C. A total of 156 flakedstone tools from SBA-54 were analyzed by Levulett et al. (2000), and rechecked for consistency during this research. The overall analysis experience was different for the Santa Barbara region compared to San Diego. Assemblages from the San Diego region generally were reported as having large numbers of certain kinds of tools (i.e., utilized flakes, scrapers, etc.) but when some assemblages were examined, many of the purported tools did not meet the criteria used in this analysis to identify tools (see Chapter 5). Recognizing the expediency of San Diego toolkits, researchers may have worked with loosened tool classification criteria. On the contrary, very few items classified as tools in Santa Barbara region assemblages failed to meet the criteria for tool identification used in this research. This is probably because Santa Barbara assemblages generally have much higher assemblage formality and, as will be discussed in the following sections, show signs of intensive use. Formal tools are easier to identify than expedient tools—especially those used without modification that may show very little use wear (i.e., SFTs).

Table 7.4. Flakedstone Analyzed from the Santa Barbara Region

	SITE	Projectile Point	Biface	Formed Flake Tool	Retouched Flake	Simple Flake Tool	Grand Total
Sample A	54*	25	34	37	-	60	156
	71	-	2	-	-	-	2
	1808	1	-	6	2	6	15
Millingstone	1856	2	5	4	3	13	27
Subtotal		28	41	47	5	79	200
Sample B	72	22	24	35	5	7	93
	73N	7	3	2	3	-	15
	117	166	70	99	32	44	411
Subtotal		195	97	136	40	51	519
Sample C	1731	62	17	21	7	13	120
Grand Total		285	155	204	52	143	839

Note: *, Tabulated from Levulett et al. 2000 and reassessed.

The following sections review analytical data generated for each artifact class by sample. Data from all subsets of Sample A (i.e., Sample A1, A2, and A3) are combined with the goal of clarifying change in tool manufacture and use before and after the bow arrives at around A.D. 500.

7.2.1.1 Projectile Points

The analysis of projectile points, like the San Diego region, was conducted primarily to separate out projectile points from other kinds of bifaces. In doing so, data on projectile points were generated for basic metrics and other attributes. Point typologies are poorly developed in the Santa Barbara region. Farquhar (2003) provided some clarity for the temporal and morphological variability associated with side notched points, but these dart points span much of the Holocene. Side notch dart points likely persist after the adoption of the bow and arrow, given their presence in significant numbers in assemblages that postdate A.D. 500 (i.e., Sample B). The large numbers of these points in Sample B assemblages, and other contemporary sites, are not likely to have been generated from scavenging for use as tools (darts do not typically show secondary modification) or keepsakes.

Arrow points are somewhat better defined than darts. Three basic forms are endemic to the Santa Barbara region: a contracting stem form with flared shoulders near the base, a convex-based form (sometimes with mild shoulders), and a much smaller concave-base form (Figure 7.6). Glassow (1996) suggests that the contracting stem point is the earliest arrow point for the Santa Barbara region. These are somewhat thick, stubby points, but thin versions are not uncommon. Glassow (1996) is likely correct in his assumption since these points are most common in assemblages that postdate A.D. 500.

Figure 7.6. Projectile point forms from the Santa Barbara Region. A, SBA-117, 183-850; B, SBA-72, 448-447; C, SBA-117, 107-71; D, SBA-117, 183-247; E, SBA-117, 183-1; F, SBA-117, 107-48; G, SBA-117, 107-47 (note impact fractured tip on G, and asphaltum on base of G and F).

Both convex and concave-base arrow points are referred to as Canalino types, with the concave-base point sometimes called Cottonwood Triangular. However, the concave-base Canalino point is much narrower and thinner, on average, than Cottonwood points. The average width for all analyzed concave-base Canalino points is 1.12 cm, and the average thickness is 0.37 cm (n=20; Samples B and C). In contrast, analyzed Cottonwood Triangular arrow points from the San Diego region average 1.42 cm wide and 0.49 cm thick (n=30), more than 0.03 cm wider and 0.01 cm thicker than the concave-base Canalino points. Considering outline, Cottonwood Triangular points tend to flare at the base while concave-base Canalino points tend to have parallel margins, tapering to a peak nearer to the distal end. Although Cottonwood points vary widely in outline across California, Canalino points are not as variable, supporting the argument that these points are not Cottonwood types but reflect a local development in arrow point form.

The convex-base Canalino arrow point is commonly categorized as an unfinished preform. Evidence to the contrary—i.e., that these are finished points—is that impact scars are common on convex-base Canalino points. Little clarity can be provided by the current analysis for determining whether convex-base or concave-base Canalino points are the earlier form since both were found in equitable proportions in the same assemblages, inhibiting separation by chronologically distinct components.

The analysis of dart points indicates that they become less formal later in time. Sample A analyzed darts and fragments thereof total 28, while Sample B contains 64, and Sample C contains eight (Table 7.5). In general, darts are similar in shape for all samples. The most obvious differences are evident in metrics, parent blank (i.e., form), and stage (see Table 7.5).

Sample A darts appear to have been made from a nodule, given traces of the parent raw material mass. On the other hand, Sample B and C darts were made exclusively from flake blanks; outlines of percussion bulbs and remnant flake surfaces identifiable. This difference in original form suggests that later darts were narrower and thinner—the idea being that darts made from nodules or biface blanks would retain more thickness and girth than would a flake. In fact, metrics on dart points indicate that later (i.e., Sample B) dart points are smaller. In Sample A, average whole metrics for dart points are 3.89 cm long, 2.69 cm wide, and 1.08 cm thick. In Sample B, darts measure 4.11 cm long, 2.45 cm wide, and 0.89 cm thick, while the few darts in Sample C measure 2.1 cm wide and 0.71 cm thick. Though not drastic, Sample B darts are an average of 2.0

mm narrower and thinner than those in Sample A, and darts from Sample C are even smaller. If not a sample bias, the smaller size of Sample B and C dart points may be related to increased use of flake blanks for dart manufacture.

Table 7.5. Projectile Point Attributes by Sample

		Sample A	Sample B		Sample C	
		Dart	**Dart**	**Arrow**	**Dart**	**Arrow**
Class	Arrow	.00	.00	.36	.00	.41
	Arrow Fragment	.00	.00	.56	.00	.50
	Dart	.36	.31	.00	.25	.09
	Dart Fragment	.64	.64	.00	.13	.00
	Blank	.00	.05	.08	.63	.00
	Total	28	64	131	8	54
Spine Plane Angle		41	51	43	63	39
Condition	Whole	.11	.13	.20	.25	.20
	Distal	.25	.41	.35	.25	.39
	Proximal	.21	.20	.18	.13	.24
	End	.18	.02	.01	.00	.06
	Medial	.21	.17	.22	.00	.06
	Margin	.04	.08	.04	.38	.06
Shape	Pointed	.39	.53	.66	.50	.52
	Rounded	.00	.00	.00	.00	.00
	Concave	.00	.02	.01	.00	.00
	Straight	.00	.06	.01	.00	.02
	Indeterminate	.61	.39	.33	.50	.46
Type	Arrow Size	.00	.02	.93	.13	.44
	Dart Size	.82	.97	.00	.25	.02
	Preform	.00	.00	.00	.13	.02
	Indeterminate	.18	.02	.07	.50	.52
Form	Nodule	.29	.00	.00	.00	.00
	Flake	.07	.22	.75	.50	.52
	Biface	.04	.00	.00	.00	.00
	Indeterminate	.61	.78	.25	.50	.48
Stage	1	.00	.00	.00	.00	.00
	2	.00	.02	.01	.00	.04
	3	.04	.03	.02	.00	.04
	4	.03	.22	.06	.75	.11
	5	.93	.73	.91	.25	.81
	Indeterminate	.00	.00	.00	.00	.00
Edge Damage	Bifacial Chips	.00	.00	.00	.00	.00
	Edge Ground	.00	.00	.00	.00	.00
	Battered/Dull	.00	.00	.00	.00	.00
	Step Fracture	.00	.00	.00	.00	.00
	Impact Fracture	.20	.13	.33	.13	.26
	Reject	.00	.00	.00	.00	.00

*, Retabulated from Levulett et al. 2000

Interestingly, efforts spent finishing dart points are reduced later in time. Sample A dart points are almost exclusively classified as Stage 5. In contrast, Sample B has a higher proportion of Stage 4 dart points (22.0%)—73.0% are Stage 5. Sample C takes this trend further in that 75.0% of all darts are classified as Stage 4—25.0% are Stage 5 (see Table 7.5). The increase in earlier stage dart points is not entirely due to the use of flake blanks since both Sample B and Sample C darts were made exclusively from flake blanks, but three-quarters of Sample C darts are Stage 4. Thus, the reduction in finely finished dart points suggests that less time and care was invested in producing dart points later in time. This is not surprising, given the mass production of arrow points after A.D. 500.

Raw material profiles for dart points provide little clarity for the decrease in dart point finishing. Sample A has the highest diversity of raw materials used to manufacture darts, although Franciscan and Monterey chert are the most common materials. Considering just these two chert types, Franciscan chert accounts for 23.0% of darts in Sample A and Monterey chert accounts for 77.0%. Similarly, in Sample B, Franciscan chert accounts for 29.0% and Monterey chert accounts for 71.0%. No darts made from Franciscan chert were identified in Sample C. The dominance of Monterey chert is also evident in arrow points—though less pronounced (discussed below), and is probably related to the fact that Franciscan chert primarily outcrops north of the Santa Barbara plain. Thus, Monterey chert is the most common material throughout the sequence and is not likely to account for the drop in dart finishing. Additionally, some Monterey chert used to make arrow points comes from Santa Cruz Island and is high quality (though this type of chert is much less common).

Turning to arrow points, raw material profiles also show a dominance of Monterey chert over Franciscan chert and other materials. Ignoring other raw materials present in trace quantities, Monterey chert accounts for 54.0% of all arrow points, fragments and preforms in Sample B, while Franciscan chert comprises 46.0%. In sample C, Monterey chert accounts for much more of the arrow point assemblage at 69.0%—just 31.0% are made from Franciscan chert. It can be argued that decreased use of Franciscan chert for arrow point manufacture is a factor of decreased access to this extralocal material later in time. However, arrow points can be fashioned from much smaller masses of raw material (i.e., small flakes), making it more likely that a suitable flake of Monterey chert without imperfections can be produced to make an arrow point.

Little variability in arrow point attributes was identified during the analysis (see Table 7.5). Arrow point size is similar for Sample B and Sample C. Average whole metrics for all Sample B arrow points are 2.75 cm long, 1.30 cm wide, and 0.50 cm thick. Sample C average whole metrics for arrow points are 3.03 cm long, 1.38 cm wide, and 0.45 cm thick. In general, arrow points are finely made, evidenced by detailed edgework and fine pressure flaking to produce thin, narrow blades. However, a slight drop in arrow point finishing is evident in the 10.0% drop in Stage 5 arrow points from Sample B to Sample C. Within Sample C, 19.0% of arrow points are Stage 4 or lower, compared to just 9.0% of earlier stage arrow points for Sample B. Earlier stage arrow points (not arrow point blanks) are not any thicker or wider than completely finished points. For arrows, earlier stages were identified by larger exposures of the parent flake ventral and/or dorsal flake surfaces. Some of these more expedient arrow points have a pronounced curvature remaining from the original parent bifacial thinning flake on which it was made, and minimally retouched margins.

Overall, the analysis of darts and arrow points indicates that once arrow point production began after A.D. 500 (i.e., Sample B and C), less time was spent finishing dart points (though no darts were expedient). A slight increase in expedient arrow points is evident in Sample C, but these specimens are rare compared to the overall sample of finely finished arrow points. Nevertheless, the manufacture of expedient arrow points from small flakes may indicate decreased access to raw materials overall (Monterey and Franciscan chert), or decreased investment in these tools as the circular hook comes in.

7.2.1.2 Bifaces

Bifacial tools are common throughout the prehistoric sequence, being present in significant proportions early in Sample A. The commonality of bifacial tools is an indication of their relative economic importance in day to day tasks. This inference is supported by the analysis of bifaces from Samples A, B, and C. Minor variation in parent form, shape, and type supports the basic categorization of bifaces as blanks, tools, or generic items (Table 7.6).

Raw material profiles for bifaces are similar to projectile points in that Monterey chert is the most common material type. Disregarding trace amounts of other raw materials, Monterey chert accounts for 68.0% of all bifaces in Sample A, while 32.0% are Franciscan chert. Sample B bifaces show an increase in the use of Monterey chert (79.0%), compared to 21.0% Franciscan chert. Sample C is similar to Sample B with 75.0% of bifaces being made from Monterey chert and 25.0% made from Franciscan chert. The use of lower quality Monterey chert in Samples B and C did not affect the manufacture of bifaces because the proportion of identified tools increases from 2.0% in Sample A to 10.0% in Sample B, and 35.0% in Sample C. Generic bifaces—i.e., tools that are not specific, such as scrapers or knives—are common in each sample (see Table 7.6).

Average whole metrics were obtained for width and thickness; length measurements were largely incomplete and provide little clarity in terms of morphological variation. For Sample A, average measurements on bifaces are 2.18 cm wide and 0.84 cm thick. For Sample B, bifaces averaged 2.58 cm wide and 1.01 cm thick. Sample C bifaces averaged 2.73 cm wide and 0.76 cm thick. Additionally, spine plane angles for Samples A, B, and C, average 44 degrees, 58 degrees, and 52 degrees, respectively. Width, thickness, and spine plane angle measurements indicate that Sample B bifaces are thicker and wider than in Sample A, while Sample C bifaces are slightly smaller than in Sample B.

Increased specialization in bifacial tool production is evident in the greater proportion of straight edge bifaces in Sample B and round edge bifaces in Sample C (see Table 7.6). Many of the straight edge bifaces in Sample B are knives with portions of hafting elements intact. In samples B and C, several bifacial end scrapers and knives were identified that retained the hafting element, some with asphaltum still stuck to the hafted base (Figure 7.7). Some of these hafted bifaces are disks (n=8) with extensive bifacial retouch around the perimeter, although some bifaces lacked retouch that spanned the original parent flake. All of the hafted bifaces exhibited extensively ground and dulled edges on the hafted element. Most used edges on bifacial tools were discarded at or near exhaustion and lacked extensive evidence of use wear because they had been resharpened. However, bifacial microchipping and ground edges were the most common forms of edge damage observed on the used edges of bifaces in each sample (see Table 7.6).

Table 7.6. Biface Attributes by Sample

		Sample A	Sample B	Sample C
Category	Tool Blank	.51	.00	.00
	Tool	.02	.10	.35
	Generic	.44	.42	.65
	Indeterminate	.02	.47	.00
	Total (n)	41	97	17
Spine Plane Angle		44	58	52
Condition	Whole	.10	.25	.06
	Distal	.07	.25	.18
	Proximal	.05	.00	.12
	End	.17	.13	.47
	Medial	.12	.24	.06
	Margin	.49	.13	.12
Shape	Pointed	.07	.13	.12
	Rounded	.07	.01	.24
	Concave	.00	.01	.00
	Straight	.05	.26	.00
	Indeterminate	.80	.59	.65
Type	Arrow Size	.00	.01	.00
	Dart Size	.12	.12	.12
	Preform	.51	.01	.00
	Not Applicable	.37	.86	.88
Form	Nodule	.32	.00	.00
	Flake	.22	.36	.71
	Biface	.02	.00	.00
	Indeterminate	.44	.64	.29
Stage	1	.17	.03	.18
	2	.17	.15	.18
	3	.22	.20	.35
	4	.20	.15	.06
	5	.15	.46	.24
	Indeterminate	.10	.00	.00
Edge Damage	Bifacial Chips	.27	.63	.25
	Edge Ground	.17	.05	.12
	Battered/Dull	.05	.00	.00
	Step Fracture	.00	.00	.00
	Impact Fracture	.00	.00	.00
	Reject	.00	.00	.00

*, Retabulated from Levulett et al. 2000

Comparing biface categories for Sample A with Samples B and C shows that Sample A is composed primarily of tool blanks (51.0%) and generic bifacial tools (44.0%), while Samples B and C show elevated proportions of specific tools (10.0% and 35.0%, respectively) (see Table 7.6). These specific tools are the hafted disks and straight edge knives previously mentioned, along with several other similar bifaces lacking hafted elements. Overall, the larger proportions of identified tools in Samples B and C is evidence of increased investment in the specialization of bifacial tools.

Figure 7.7. Hafted bifaces: A, a hafted, bifacially flaked disk with asphaltum (SBA-117, catno. 183-4570); B, a hafted bifacially flaked disk with stem and asphaltum (SBA-117, catno. 183-442); C, a hafted bifacial blade with asphaltum (SBA71, catno. 447-57).

7.2.1.3 Formed Flake Tools

A comparison of FFT from Samples A, B, and C indicates increasing formality and specialization later in time (i.e., in Samples B and C). The main differences in FFTs relate to shifts in the kinds of manufactured edges. Sample B contains a large number of drills, presumably related to the manufacture of fishhooks and plank canoes (large drills), and beads (microdrills) (Figure 7.8). Cortical flakes were more commonly used to manufacture FFT in Sample B (24.0%), up from 10.0% in Sample A (see Table. 7.7).

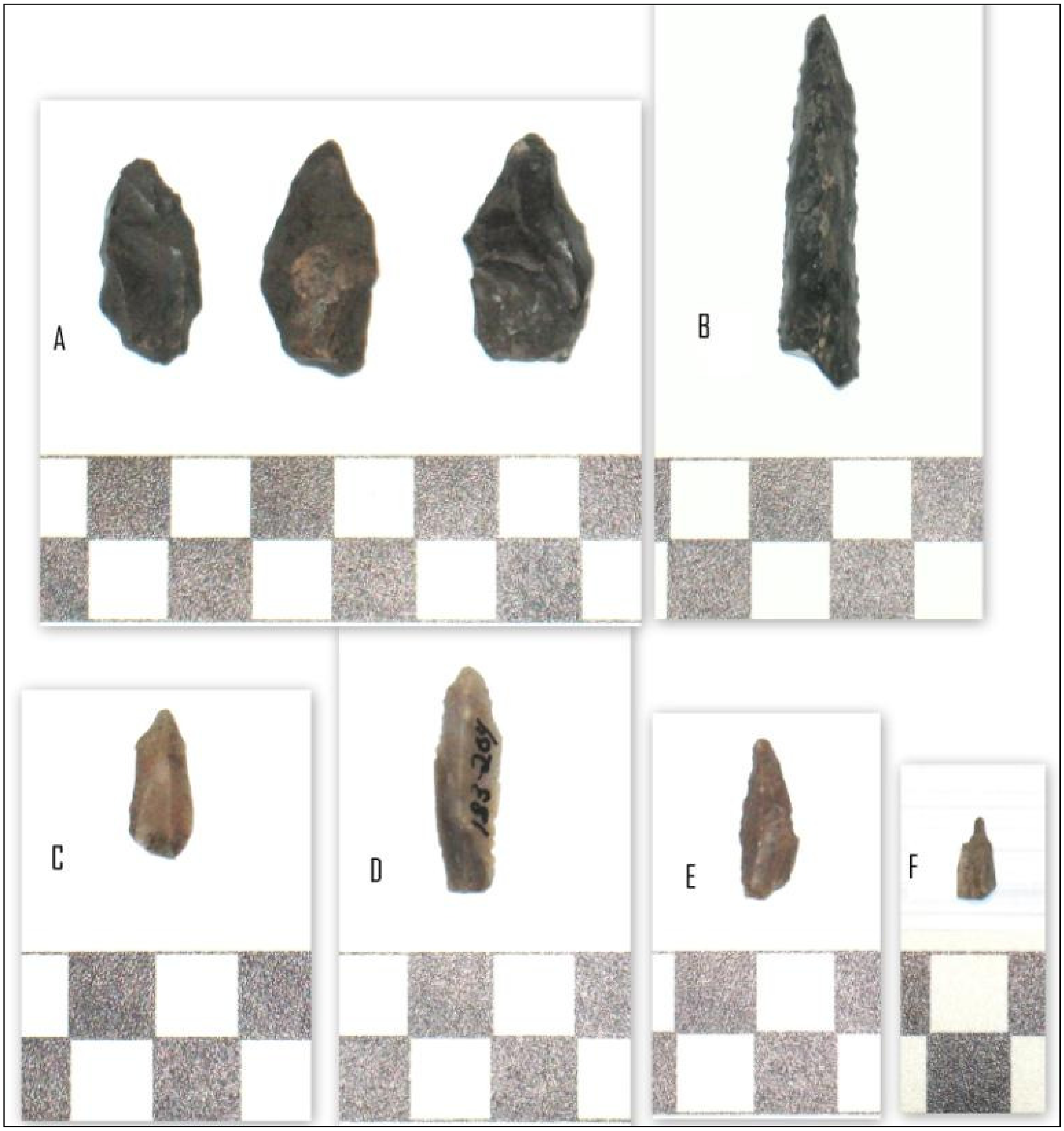


Figure 7.8. Three kinds of drills from the Santa Barbara region: a, large, crude drills (SBA-117, catno. 183-1498); b, large, fine drills (SBA-117, catno. 183-85); c-f, microdrills (SBA-117, catno. 183-1486, 183-579, 183-340, and SBA-72, 448-445). Scale = cm.

Many of the large drills in Sample B were made from flakes or chunks containing significant amounts of dorsal cortex. Non-drills continued to be constructed of interior flakes, with only 14.0% of these made from cortical debitage. The large number of drills in Sample B is partly responsible for the decreased number of tool edges identified on FFT. Sample B FFT tend to have a single edge (86.0%), compared to 66.0% of Sample A FFT that have more than one edge (see Table 7.7). Within Sample B, 86.0% of all drills have a single drill end. This is an indication that drills were specialized tools, intended for a single purpose. This is especially true for microdrills—all had a single drill bit edge, save one that was used as a SFT on one lateral edge.

Considering edge shape, Sample B drills are defined by converging margins shaped through unifacial or bifacial thinning. Edge damage on large drills (crude and fine) is common, with nearly all of these exhibiting bifacial flaking and microchipping. Seven large drills were used intensively enough without being resharpened that grinding was observed on the edge. Sample B microdrill bits tended to exhibit bifacial microchipping (85.0%); unifacial and bifacial flaking was also common (25.0% and 20.0%, respectively).

Sample B contains nine drill fragments that are considered to have been used to bore holes in plank canoes. These items are finely made trifacial implements made from high quality chert. Eight of these drills are from SBA-117 and one is from SBA-72. It is probable that other, less formal large drills were also used to bore holes in wood planks for canoe construction. However, without a microscopic examination, these are just inferences. Nevertheless, the production of fine trifacial drills is evidence of technological specialization.

Non-drill edge shapes show similar levels of diversity between Samples A and B. Convex edge shapes dominate, with lesser amounts of concave, straight, and beaked (see Table. 7.7). Unfortunately, little can be said about differences in edge shape regularity—a measure of refinement and use intensity—because no information was available on the multiple ancillary edges from SBA-54. Nevertheless, Sample B FFT edges are highly regular (91.0%, n=63 out of 69), despite shape. Only 5.0% Sample B convex edges were irregular in shape (see Table 7.7).

Edge damage on non-drill FFT suggests slightly different patterns of use. Sample A FFT edges commonly exhibit unifacial flaking (36.0%), battering (34.0%), and unifacial retouch (40.0%). Sample B edge damage attributes are more diverse, with 24.0% exhibiting unifacial microchipping, 61.0% have bifacial microchipping, 19.0% are ground, 39.0% have unifacial retouch, and 45.0% are bifacially retouched. Surprisingly, none of the Sample B FFT have battered edges, possibly indicating less intensive—or more specific, lighter duty scraping and cutting. Edge angles for Sample A FFT average 68.0 degrees, while Sample B FFT edge angles average 63.0 degrees. The relatively steep edge angle for both Samples A and B is a common attribute of FFT because these edges are intentionally manufactured and often maintained through retouch. It is also a functional attribute—steeper edges are assumed to be associated with scraping tasks, rather than back and forth cutting.

A regression on length and width for non-drill Sample B FFT produced an adjusted R^2 value of 0.37 (n=38), less than half of the variation explained by a similar regression on SFT (see SFT description, below). The greater variability in FFT dimensions may be due to increased specialization. However, it could also be that FFT metric variability is due to extensive resharpening over time as tools suffer attrition.

Raw material used in the manufacture of FFT was similar for Samples A and B. In both samples, Monterey chert was the preferred raw material for large drills: Monterey chert accounts for 75.0% of Sample A large drills and 71.0% of Sample B large drills. In contrast, non-drill FFT (i.e., scrapers, knives, etc.) were primarily made from Franciscan chert in Sample A (68.0%) and in Sample B (41.0%). That 32.0% of Sample B non-drill FFT were made from Monterey chert may be related to decreased access to Franciscan chert—an inference also made from changes in raw material used to make bifacial tools and projectile points. Regarding microdrills, 44.0% were made from chert that comes from Santa Cruz island and 50.0% were made from Monterey chert; 6.0% were Franciscan chert. The high proportion of Santa Cruz Island chert fits with the pattern of bead manufacture and microblade production on the island, and intra-channel economic relationships (see Arnold 1992). However, that the majority of microdrills were made from Monterey chert also implies that beads were being manufactured at mainland Santa Barbara Channel sites.

Regarding Sample C, raw materials used to manufacture FFT were dominated by Franciscan and Monterey chert. However, Monterey and Franciscan chert both account for 50.0% of all large drills. Additionally, there is a reversal in the proportion these chert types for non-drill FFT in Sample C: only 27.0% of non-drill FFT are made from Franciscan chert while 73.0% are made from Monterey chert. Again, this same pattern was identified for bifaces and projectile points and probably indicates decreased access to higher quality Franciscan chert.

Table 7.7. Formed Flake Tool Attributes by Sample

			Sample A*	Sample B	Sample C
Total			47	136	21
Condition	Whole		.30	.80	.67
	Fragment		.70	.20	.33
Flake Type	Cortical		.15	.24	.24
	Interior		.85	.76	.76
#Edges	1		.49	.86	.86
	2		.26	.13	.14
	3		.19	.01	.00
	4		.02	.00	.00
	6		.04	.00	.00
	Total # Edges		90	157	24
Edge Shape	Concave	Regular	.15	.03	.04
		Irregular	.00	.00	.00
	Convex	Regular	.30	.26	.30
		Irregular	.02	.05	.08
	Straight	Regular	.15	.05	.16
		Irregular	.04	.00	.14
	Beak	Regular	.15	.00	.00
		Irregular	.00	.00	.00
	Notched		.00	.01	.00
	Denticulate	Regular	.00	.07	.08
		Irregular	.11	.00	.00
	Drill		.09	.53	.20
Edge Damage	Unifacial Chips		.40	.24	.33
	Bifacial Chips		.04	.61	.38
	Grinding		.13	.19	.12
	Battering		.34	.00	.00
	Unifacial Flaking		.36	.39	.24
	Bifacial Flaking		.02	.45	.21
	Step Fracture		.00	.00	.00
	Ground Face		.02	.00	.01

Note: *, Includes SBA-54 retabulated from Levulett et al. 2000 (no information on edge regularity, or of the multiple ancillary edges).

Sample C FFT are similar to those from Sample B, but large drills are less common and no microdrills were identified in Sample C (see Table 7.7). Sample C large drills are very similar to those from sample B, having multiple bifacially shaped margins to produce a trifacial drill bit. Non-drill FFTs in Sample C are like those in Sample B, tending to have a single working edge (86.0%). However, Sample C FFT show slightly more diversity in edge shape. Convex and straight edges are still the most common, but denticulate and concave edges account for 12.0% (see Table 7.7). Sample C FFT edges are more acute, with an average edge angle for non-drill FFT of 49.0 degrees. An average thickness for Sample C FFT of 0.96 cm is 0.15 cm smaller than the 1.11 cm average thickness for Sample B non-drill FFT. However, edge damage attributes are similar for Samples B and C, implying similar use contexts (see Table 7.7).

The analysis of FFT from all samples supports the idea that these tools were economically important and used intensively. The appearance of large drills and in Samples B and C (and microdrills in Sample B) is evidence of technological specialization in the production of fishhooks, plank canoes, and beads (microdrills). Other kinds of FFT in each sample were used intensively for a variety of scraping and cutting tasks.

7.2.1.4 Retouched Flakes

Retouched flakes are the least common lithic tool in the Santa Barbara region, accounting for less than 4.0% of the total stone tool assemblage in each sample. The analyzed sample of RET totals 52, with five from Sample A, 40 from Sample B, and seven from Sample C (Table 7.8). In terms of overall assemblage composition, Sample A RET are the most numerous, but these derive primarily from just four sites: SBA-1807 (n=17), SBA-2105 (n=34), SBA-53 (n=54), and SBA-2149 (n=28). Similarly, most Sample B RET derive from one site (SBA-117, n=32), and Sample C RET derive mostly from SBA-46 (n=30). The biased occurrence of RET in this analysis was limited by the frequency of RET present in sampled assemblages.

An analysis on retouched flakes in Sample A says little about these specimens prior to A.D. 500; only five RET were analyzed: two from SBA-1808 and three from

SBA-1856. This sample is small compared to 40 specimens from Sample B (see Table 7.8). Analyzed RET from Sample C were also limited (n=7). Within Sample A, 40.0% of the RET were made from cortical flakes and the rest were made from interior flakes (see Table 7.8). Two Sample A RET (40.0%) had two edges for a total of seven analyzed edges. Most edges (86.0%) were straight with one that was convex. Edge modification on Sample A RETs includes 44.0% that were unifacially flaked, 28.0% bifacially flaked, and 14.0% each that showed unifacial and bifacial microchipping (see Table 7.8).

Given the small number of RET analyzed from Sample A, little can be made of a comparison with Sample B RET. Nevertheless, there are some interesting differences. More than three-quarters of Sample B RET were made from interior flakes, lacking cortex. Additionally, almost all Sample B RET had a single edge (87.0%), for a total of 45 analyzed edges (see Table 7.8). In contrast with Sample A, RET edge shapes from Sample B are biased toward convex outlines (87.0%), with smaller proportions of concave, straight, and denticulate edges; one edge is an incipient drill. Edge damage on Sample B RET is similar to Sample A, having unifacial and bifacially flaked edges, with a small number showing unifacial and bifacial microchipping (see Table 7.8).

For Sample B RET, whole specimens account for 82.0% of the sample. On average, RET measure 4.1 cm long, 1.3 cm wide, and 1.4 cm thick. A regression on length and width was conducted on 18 specimens with complete metrics to test consistency in basic shape. An adjusted R^2 value of 0.81 is high (slope = 1.09, intercept = 0.81), and indicates that specific flake dimensions were selected for incipient production of RET. Small sample sizes and incomplete measurements on Sample A and Sample C

RET precludes an inter-sample comparison. Regardless, the same pattern is found among Sample B SFT (see Section 7.2.1.5).

Sample C RET are similar to those from Sample B, being fashioned primarily from interior flakes with most having a single modified edge (see Table 7.8). Edge shapes for Sample C RET are also similar to those from Sample B, although Sample C RET have higher proportions of concave, convex, and straight edges without any denticulates. Edge modification attributes indicate that Sample C RET may have been used more intensively than Sample B RET. Unifacial microchipping was found on two-thirds of Sample C RET; bifacial microchipping and edge grinding was also identified (see Table 7.8).

Raw material profiles vary widely by sample, although Franciscan and Monterey chert account for nearly all RET. In Sample A, 60.0% of RET are Franciscan chert and 40.0% are Monterey chert. In contrast, 16.0% of Sample B RET are Franciscan and the rest are Monterey chert. Sample C is more balanced with 43.0% of RET made from Franciscan chert and 57.0% made from Monterey chert. The predominance of Monterey chert in Sample B is partly explained by the fact that 80.0% of the RET from this sample derive from SBA-117, which is located in an area where Monterey chert is available in cobble form.

In sum, RET from each sample are similar in that they are minimally modified flakes used as cutting or scraping tools, but not with the same intensity as FFT, given a lack of maintenance and investment in tool edges. The decrease in edge frequency and increase in edge shape diversity seen in Samples B and C implies that the use of these tools was more specific than in Sample A. RET were quickly fashioned from a basic, preferred flake outline and used for a limited range of tasks, then discarded without being maintained.

Table 7.8. Retouched Flake Attributes by Sample

			Sample A	Sample B	Sample C
Total			5	40	7
Condition	Whole		.80	.82	.71
	Fragment		.20	.18	.29
Flake Type	Cortical		.40	.22	.29
	Interior		.60	.78	.71
#Edges	1		.60	.87	.71
	2		.40	.13	.29
	3		.00	.00	.00
	Total # Edges		7	45	9
Edge Shape	Concave	Regular	.00	.00	.10
		Irregular	.00	.02	.10
	Convex	Regular	.00	.07	.10
		Irregular	.14	.80	.40
	Straight	Regular	.14	.00	.10
		Irregular	.72	.02	.10
	Beak	Regular	.00	.00	.00
		Irregular	.00	.00	.00
	Notched		.00	.00	.00
	Denticulate	Regular	.00	.07	.00
		Irregular	.00	.00	.00
	Drill		.00	.02	.10
Edge Damage	Unifacial Chips		.14	.07	.66
	Bifacial Chips		.14	.29	.22
	Grinding		.00	.02	.22
	Battering		.00	.00	.00
	Unifacial flaking		.44	.31	.66
	Bifacial Flaking		.28	.38	.00
	Step Fracture		.00	.00	.00
	Ground Face		.00	.00	.00

7.2.1.5 Simple Flake Tools

Analyzed SFT total 143, including 79 from Sample A, 51 from Sample B, and 13 from Sample C (Table 7.9). The analysis of SFTs shows that these tools were less diverse and used with less intensity later in time.

Monterey chert is the most common material used for SFT. Not considering small amounts of other local materials, Sample A SFT are composed of 65.0% Monterey chert, 35.0% Franciscan chert. In Sample B, 44.0% of SFTs are Franciscan chert and 56.0% are Monterey chert. For Sample C, 73.0% of SFTs are Monterey chert and 27.0% are Franciscan chert. SFTs from all samples show a similar trend; Franciscan chert SFTs are on average a 0.31 cm shorter and 0.78 cm narrower than SFTs made from Monterey chert. Thickness readings are very similar, averaging 1.07 cm for Franciscan chert SFTs and 0.95 cm for Monterey chert SFTs. Along with the difference in size, cortical flakes from all samples are less common among SFTs made from Franciscan chert (17.0%), while Monterey chert SFTs include 43.0% that were made on cortical flakes. The smaller size and reduced occurrence of cortical flakes for Franciscan chert SFTs is probably the result of this material being imported in a more reduced form, resulting in smaller, interior flake detachments that could be used as incipient tools.

Despite differences between raw material, a regression on length and width for SFT of all samples returned an adjusted R^2 value of 0.72 (intercept = 0.87, slope = 1.18), meaning that there is a high degree of consistency in flake dimensions selected for use as incipient tools regardless of material type. Splitting the samples up only increased the adjusted R^2 value, due to small sample size and larger outliers from Sample C.

Edge frequency can be used as a proxy for SFT use intensity. Approximately 70.5% SFTs in Sample A and B had a single edge, while 92.0% of Sample C SFTs had a single edge. Of the edge shapes that could be quantified, most edges on Sample A SFTs are either straight (31.0%) or convex (42.0%), while Sample B SFTs are dominated by convex shapes (59.0%) (see Table 7.9). Only nine edges from Sample A SFTs could be characterized for edge shape regularity and just three of these are irregular. In contrast, Sample B edges were all characterized for edge regularity with 51.0% being irregular—i.e., not used with enough regularity/intensity to produce an regular edge shape through attrition.

Table 7.9. Simple Flake Tool Attributes by Sample

			Sample A	Sample B	Sample C
Total			79	51	13
Condition	Whole		.38	.88	.85
	Fragment		.62	.12	.15
Flake Type	Cortical		.22	.31	.54
	Interior		.78	.69	.46
#Edges	1		.70	.71	.92
	2		.24	.29	.08
	3		.05	.00	.00
	6		.01	.00	.00
	Total # Edges		111	66	14
Edge Shape	Concave	Regular	.11	.03	.00
		Irregular	.00	.09	.00
	Convex	Regular	.34	.26	.21
		Irregular	.08	.33	.29
	Straight	Regular	.29	.08	.14
		Irregular	.02	.09	.07
	Beak	Regular	.04	.05	.00
		Irregular	.00	.00	.00
	Notched		.00	.02	.00
	Denticulate	Regular	.00	.05	.00
		Irregular	.09	.00	.00
	Drill		.02	.00	.29
Edge Damage	Unifacial Chips		.45	.55	.21
	Bifacial Chips		.19	.42	.36
	Grinding		.13	.17	.21
	Battering		.11	.00	.00
	Unifacial Flaking		.14	.16	.14
	Bifacial Flaking		.01	.01	.07
	Step Fracture		.00	.00	.00
	Ground Face		.01	.00	.14

Note: *, Retabulated from Levulett et al. 2000 (no information on edge regularity, or of the multiple ancillary edges).

Approximately 29.0% of all Sample C edges are incipient drills and could not be characterized by regularity. Excluding drill edges in Sample C, 50.0% are irregular.

Related to edge regularity, edge damage was more common and diverse among Sample A SFTs (see Table 7.9). Sample B and C SFTs have a lower occurrence of edge damage in general, attesting to reduced use intensity. Notable differences include a lack of battering and grinding and an increase in bifacial microchipping among Sample A and B SFTs (see Table 7.9).

The decreased intensity in SFT use implied by form and edge attributes is related to their decreased importance later in time. This indicates that SFT edge reliability (e.g., the ability of an unmodified flake edge to cut something) was paramount to manufacturing efficiency (i.e., producing a consistent flake shape to be used as tools).

7.1.2.6 Debitage

A total of 11,785 pieces of analyzed debitage provide insight to flakedstone manufacturing techniques and strategies. Debitage from SBA-54 (n=3832) was retabulated from Levulett et al. (2000) because the same debitage typology was used during their analysis. All other debitage (n=7953) was analyzed directly for this research. Sample A contains 5447 pieces of debitage, Sample B contains 5037 pieces of debitage, and analyzed debitage from Sample C totals 1301 (Table 7.10).

Raw material profiles for debitage reveal important differences after the bow arrives (i.e., comparing Sample A and B). In Sample A Monterey chert accounts for 60.0% of the debitage and Franciscan chert 36.6%. In Sample B, Monterey chert accounts for 74.8% of all debitage, and Franciscan chert 21.3%; there are negligible amounts of other materials from each time period. The geographic situation of sites partially account for these differences. In Sample A, SBA-54 is comprised of 45.3%

Monterey chert and 50.1% Franciscan chert, while SBA-71 contains 80.1% Monterey chert and 18.3% Franciscan, and SBA-1808 is almost exclusively Monterey chert. Not surprisingly, SBA-54 is farthest east from abundant outcrops of Monterey, the latter being readily available near SBA-71 and SBA-1808.

Table 7.10. Analyzed Debitage by Sample and Site for the Santa Barbara Region

	Sample A				Sub-total	**Sample B**			Sub-total	**Sample C**	**Grand Total**
Site (SBA-)	54*	71	1808	1856		72	117	73N		1731	
Basalt							12		12		12
Franciscan Chert	1918	69	7	122	2116	796	95	183	1074	96	3286
Fused Shale						7	27		34		34
Granitic							1		1		1
Igneous	18				18		5	2	7	2	27
Monterey Chert	1737	302	1230	299	3568	1347	1342	1080	3769	676	8013
Mudstone	13				13						13
Metavolcanic						2			2		2
Obsidian	41	5			46	33		9	42		88
Quartz	60			3	63		1		1		64
Quartzite	44	1	1	86	132	9	16	4	29	14	175
Rhyolite	1			1	2					1	3
Sedimentary										1	1
Siltstone						16	49		65		65
Sandstones							1		1		1
Grand Total	3832	377	1238	511	5958	2210	1549	1278	5037	790	11785

Note: *, Retabulated from Levulett et al. 2000

In Sample B, regional differences are less clear. Monterey chert is available in local outcrops at SBA-117, debitage there is dominated by Monterey chert (86.6%), with small amounts of Franciscan chert (6.1%). In contrast, SBA-72 has 61.0% Monterey chert and 36.6% Franciscan chert, and SBA-73N has 84.5% Monterey chert and approximately 18.0% Franciscan chert. Given that all sites in Samples A and B are located closer to Monterey chert quarry areas than they are to Franciscan chert quarries, the increased use of Monterey chert overall in Sample B is probably related to an increased cost of acquisition for Franciscan chert, whether direct or through trade. The same pattern in raw material use is also present among flakedstone tools.

In addition to the dominant chert types, Sample B debitage includes 4.0% of 11 kinds raw material other than chert, compared to 3.4% of six different raw materials in Sample A. The increased diversity and quantity of non-chert local stone in Sample B (albeit slight), may also signal changes in procurement costs for higher quality chert. The increase in Monterey chert in Sample B is associated with much higher levels of cortical debris, from 2.0% in Sample A to 7.0% cortical flakes in Sample B (see Table 7.11).

Raw material profiles for Sample C continue the trend noted above. Sample C debitage is defined primarily by Monterey chert (75.0%), with just 17.0% Franciscan chert; 8.0% is local quartzite with insignificant amounts of other materials. Similar to Sample B, debitage in Sample C includes 7.0% cortical flakes, indicating intensive reduction of locally available raw material in cobble form (see Table 7.11). Within Sample C, cortical flakes account for just 2.0% of Franciscan chert debitage while 4.0% of Monterey chert debitage includes cortical flakes and 8.0% of quartzite debitage consists of cortical flakes. Thus, Sample C debitage points to more intensive reduction of local raw materials.

The increased use of local raw materials in Samples B and C correlates with a shift in debitage size. Approximately 84.0% of all Sample A debitage is less than 1.0 cm in size. Comparatively, debitage less than 1.0 cm in size drops in proportion to 70.1% for Samples B and C. The decreased proportion of small debitage relative to larger debitage for Samples B and C is due to the on-site reduction of locally available cobbles. This fits with the assumption that extralocal materials should be transported in reduced form to minimize carrying costs, thereby resulting in smaller debitage overall.

Debitage raw material and size patterning contradicts, to some degree, debitage type profiles. The increased use of lower quality local materials and a resulting increase in the proportion of cortical flakes and larger flakes would seem to suggest that less care was being taken in flakedstone reduction. However, all samples contain relatively equal proportions of finishing/pressure flakes (see Table 7.11). If finishing lakes are combined with other fine-tuning debitage, such as early and late biface thinning flakes and early interior flakes (many of which are probably biface thinning flakes), the samples are very similar: the combination of these flake types accounts for approximately 42.3% of each sample (see Table 7.11). The similarity in proportion of debitage related to tool finishing is an indication of a very similar reduction strategy that typifies each sample—biface thinning.

Table 7.11. Debitage Types by Site and Sample

		Debitage Type											
	SITE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**Total**
Sample A	54*	.00	.01	.03	.02	.00	.05	.14	.23	.00	.01	.50	1.00
	71	.01	.00	.02	.04	.00	.07	.25	.14	.00	.00	.47	1.00
	1808	.02	.00	.09	.19	.00	.01	.01	.17	.00	.04	.46	1.00
Millingstone	1856	.01	.00	.09	.22	.00	.04	.06	.35	.01	.00	.23	1.00
Sample A Total		.01	.01	.05	.06	.00	.04	.12	.21	.00	.01	.49	1.00
Sample B	72	.01	.00	.03	.02	.00	.01	.26	.28	.00	.00	.38	1.00
	117	.15	.05	.10	.09	.00	.06	.08	.00	.00	.06	.41	1.00
	73N	.01	.00	.01	.01	.00	.03	.18	.17	.00	.00	.58	1.00
Sample B Total		.05	.02	.05	.04	.00	.03	.18	.17	.00	.02	.44	1.00
Sample C	1731	.05	.02	.14	.24	.00	.04	.07	.07	.00	.04	.33	1.00
Grand Total		.03	.01	.05	.07	.00	.04	.14	.19	.00	.02	.45	1.00
	N	342	130	642	831	2	459	1662	2238	12	189	5278	11785

NOTE: *, Tabulated from Levulett et al. 2000; Type: 1, primary decortication; 2, secondary decortication; 3, early interior; 4, late interior; 5, linear interior; 6, early biface thinning; 7, late biface thinning; 8, finishing /pressure; 9, bipolar; 10, cortical chunk; 11, cortical flake fragment ; 12, percussion shatter.

That flakedstone reduction included a significant bifacial thinning component is supported not only by the large numbers of projectile points and bifacial tools, but also by the fact that half of all analyzed cores were bifacial. Non-bifacial cobble-core reduction was also practiced, however, cobble-core reduction was used in a more limited sense than in the San Diego region. In the Santa Barbara region, cobble-core reduction relates to the splitting and partial thinning of a cobble to produce smaller masses that were then bifacially reduced. That most arrow points were made from small flakes with strong curvature supports the idea that these were struck from prepared bifacial platforms.

The large proportion of tool finishing debitage—a proxy for time invested in tool manufacture—in Samples B and C is best characterized by the Lithic Waste Index (LWI). The LWI value for Sample A is 0.47, compared to 0.46 for Sample B, and 0.37 for Sample C. The minimal difference between Samples A and B is probably a factor of shifting efforts from finely made dart points to arrow points and drills. However, the drop in LWI values between Samples B and C indicates that noticeably greater care was taken in the manufacture of flakedstone tools.

7.2.2 Groundstone

The groundstone analysis included 827 artifacts: 383 handstones, 160 millingstones, 122 pestles, and 162 mortars (Table 7.12). A total of 387 artifacts were intensively analyzed, including 169 handstones, 72 millingstones, 78 pestles, and 68 mortars. In addition, 440 artifacts were inspected for shaping but these were not subject to intensive analysis: 214 handstones, 88 millingstones, 44 pestles, and 94 mortars (see Table 7.12). The cursory inspection was conducted to get basic information on tool formality—i.e., whether artifacts were shaped or not, at the same time keeping an eye on wear facet condition. The decision to not intensively analyze some artifacts was based on initial observations and completed analyses that indicated shaped tools are almost always associated with intensively used wear facets (see also Hale 2001). Access constraints also factored into the analysis. Shaping can be considered a proxy for intensive groundstone use (though not a good substitute for intensive use-wear analysis in all situations, see Chapter 4).

The following discussion begins with descriptions of variation in groundstone formality. This is followed by descriptions of use-wear attributes for each kind of groundstone tool. Groundstone use-wear and shaping attributes are generally consistent with trends in assemblage composition in that groundstone tools become more formal and were more intensively used later in time (i.e., in Samples B and C).

Table 7.12. Analyzed Groundstone by Sample in the Santa Barbara Region (Includes Cursorily Inspected Groundstone).

		Handstones	**Millingstones**	**Pestles**	**Mortars**	**Total**
Sample A	SBA-16*	136	13			149
	SBA-71	19	1	12	15	6
	SBA-53*	60	68	43	69	240
	SBA-54*	18	4	1	4	27
	SBA-142	73	45	4	1	123
	SBA-1808	8				8
	SBA-1856	42	17	3	1	63
	Subtotal	356	148	63	90	657
Sample B	SBA-72	7	3	14	15	
	SBA-73	10	4	22	20	56
	SBA-117			4	7**	11
	Subtotal	17	7	40	42	106
Sample C	SBA-46	4	2	14	12	
	SBA-1491	6	3**	5	18**	31
	Subtotal	10	5	19	30	64
Total		**383**	**160**	**122**	**162**	**827**
	Analyzed	169	72	78	68	387
	Inspected	214	88	44	94	440

Note: *, SBA-16, -53, -54, and-46 groundstone tools were cursorily inspected but not subject to intensive analysis. **, from SBA-1491, 3 millingstones and 15 mortars were cursorily inspected, and from SBA-117, 7 mortars were cursorily inspected.

7.2.2.1 Groundstone Formality

An increase in assemblage formality is implied by the larger proportions of mortars in Samples B and C, and this fits with manufacturing trends. Shaped and unshaped millingstones, handstones, mortars, and pestles are tabulated for a select number of sites in Table 7.13. While the proportion of shaped groundstone tools varies by site the overall Sample A GFI value of 0.54 is significantly lower than the GFI value for Samples B (0.76) and C (0.74) (see Table 7.13).

Within Sample A, three sites have low GFI values: SBA-1808 has no formal groundstone tools (GFI = 0), SBA-16 has a GFI value of 0.39, and SBA-142 has a GFI value of 0.49. Each of these sites has an assemblage that could be characterized as a Millingstone Horizon site; SBA-142 (Glenn Annie Canyon) is considered an archetypal Millingstone Horizon site in the Santa Barbara area (see Hale 2001, Owen et al. 1964). While low for Sample A, the GFI value of 0.49 for SBA-142 is much higher than Millingstone sites for the San Diego region (0.34), and is equal to the highest GFI value of 0.50 for Transitional sites in the San Diego region (see Chapter 5). If Millingstone Horizon sites across southern California are considered part of a generalized processing strategy, the difference in GFI values is evidence that the Santa Barbara region had a more intensive economy earlier in time than did the San Diego region.

Table 7.13. Shaped and Unshaped Groundstone by Site and Sample

	Millingstone	Handstone	Mortar	Pestle	Total	GFI

	Millingstone	Handstone	Mortar	Pestle	Total	GFI
Sample A						
SBA 142						
Formal	12	46	1	1	60	0.49
Informal	33	27		3	63	
SBA-16						
Formal	9	41			50	0.36
Informal	4	95			99	
SBA-1856						
Formal	9	23		3	35	0.58
Informal	5	18		2	25	
SBA-53						
Formal	19	46	70	21	156	0.65
Informal	49	14		22	85	
SBA-54						
Formal	1	10	4	1	16	0.64
Informal	3	6			9	
SBA-1808						
Formal						0
Informal		8			8	
SBA-71						
Formal		14	12	7	33	0.75
Informal	2	5		4	11	
Sample A Formal	50	180	87	33	350	**0.54**
Sample A Informal	96	173		31	300	
Sample B						
SBA-72						
Formal		2	16	6	24	0.69
Informal	3	4		4	11	
SBA-73						
Formal	4	4	23	14	45	0.76
Informal	2	6		6	14	
SBA-117						
Formal			7	4	11	1
Informal						
Sample B Formal	4	6	46	24	80	**0.76**
Sample B Informal	5	10		10	25	
Sample C						
SBA-1491						
Formal		1	18	5	24	0.77
Informal	3	3		1	7	
SBA-46						
Formal		2	13	9	24	0.71
Informal	2	2		6	10	
Sample C Formal		3	31	14	48	**0.74**
Sample C Informal	5	5		7	17	

Note: Table does not include specimens that could not be classified for shaping.

The large numbers of cobble mortars and shaped handstones from SBA-53, -54, and -71 in Sample A produced the highest GFI values of 0.65, 0.64, and 0.75, respectively (see Table 7.13). Despite the large numbers of mortars at these sites, the presence of shaped handstones indicates that traditional processing techniques were still important. Specialized processing is implied by the presence of cobble mortars that were costlier to make than millingstones.

The most striking aspects of Samples B and C is the greatly reduced numbers of handstones and millingstones (see Table 7.13). This trend was also identified at the regional level (see Table 7.2). Mortars and pestles not only become dominant in frequency, but they are also better shaped. Mortars increase in diversity from simple cobble and hopper mortars in Sample A to large, boulder-sized bowls with decorated rims in Sample B, including flowerpot mortars (see Section 7.2.2.5). Sample C essentially mimics Sample B in mortar styles, including the presence of flowerpot mortars. The manufacture of flowerpot mortars was so time and energy intensive that they were probably owned by individuals with higher social status. Pestles also show more effort in shaping with decorated proximal ends and highly formal outlines—these first appearing in Sample B (i.e., SBA-117) and becoming more common thereafter.

Not included in this analysis are the numerous stone vessels fashioned from steatite and other relatively soft stone materials. Vessels include cooking tablets (comals), bowls with lids, small dishes, and various other forms. Such items are rare in the San Diego region, limited to just a few pieces. Unlike ceramics, the manufacture of stone vessels probably required much more energy and care, considering that one false blow or chisel motion could sever the artifact preform. In fact, efforts to manufacture and maintain these stone vessels probably required a substantial amount of time and energy, especially considering that steatite vessels and raw cobbles were mostly imported from the Channel Islands (see Heizer and Treganza 1944; Hudson and Blackburn 1986; Meighan 1980). Like decorated mortars and pestles, stone vessels imply a high degree of technological specialization due to high manufacturing costs.

7.2.2.2 Handstones

The analysis of handstones revealed that use intensity declined over time, from Sample A to Samples B and C. Despite the smaller numbers of Sample B and Sample C handstones, the patterns match overall observations of cursorily inspected handstones (see Section 7.2.2.1).

A large proportion of Sample A handstones are moderately to highly shaped (58.0%), compared to 40.0% for Sample B and 44.0% for Sample C (Table 7.14). The drop in handstone shaping is correlated with a drop in use intensity. As use intensity increases, the number of facets per handstone should increase. For Sample A, 88.0% of all handstones have two or more wear facets, dropping to 82.0% for Sample B, and 60.0% for Sample C. Sample B and C handstones lack specimens with three or more surfaces (see Table 7.14).

Correlated with a drop in the number of facets per handstone is an increase in wear facet irregularity. Sample A wear facets include 94.0% that were smooth, 97.0% with polish, 58.0% with striations, and 74.0% that were pecked (Figure 7.9). The large proportion of surfaces that were pecked indicate regular maintenance of handstones to maintain efficiency. Sample B handstones were less intensively used, with 68.0% smooth textures, 94.0% polished, 48.0% striated, and 52.0% that were pecked. This trend is continued in Sample C with 44.0% smooth surfaces, 50.0% polished, 38.0% striated, and 44.0% pecked. (see Figure 7.9).

Table 7.14. Handstone Attributes by Sample

	Sample A	Sample B	Sample C
# Specimens	142	17	10
Condition			
Whole	.39	.59	.60
End	.33	.24	.20
Margin	.26	.12	.10
Interior	.01	.06	.10
Shaping Degree			
0	.27	.60	.22
1	.15	.00	.33
2	.29	.20	.11
3	.29	.20	.33
Indeterminate	1	2	1
# of Surfaces			
1	.14	.18	.40
2	.74	.82	.60
3	.14	.00	.00
Total # Surfaces	290	31	16
Surface Shape			
Flat	.39	.23	.50
Convex	.61	.77	.50
Texture			
Smooth	.94	.68	.44
Irregular	.06	.32	.56
Polish			
Present	.97	.94	.50
Absent	.03	.06	.50
Striae			
Present	.58	.48	.38
Absent	.41	.52	.63
Pecking			
Present	.74	.52	.44
Absent	.26	.48	.56
Secondary Use	.54	.59	.20

Correlated with a drop in the number of surfaces is an increase in wear facet irregularity. Sample A wear facets include 94.0% that were smooth, 97.0% with polish, 58.0% with striations, and 74.0% that were pecked (Figure 7.9). The large proportion of surfaces that were pecked indicate regular maintenance of handstones to maintain efficiency. Sample B handstones were less intensively used, with 68.0% smooth textures, 94.0% polished, 48.0% striated, and 52.0% that were pecked. This trend is continued in Sample C with 44.0% smooth surfaces, 50.0% polished, 38.0% striated, and 44.0% pecked. (see Figure 7.9).

Handstones are a generalized processing tool, able to be used for horizontal grinding and vertical pulverization. In Sample A, 43.5% of all handstones are end battered, consistent with the vertical pounding motion of a pestle. After mortars and pestles become more common in Samples B and C, end battering is much less common—just 17.6% of Sample B handstones and 20.0% of Sample C handstones are end battered. The decreased use of handstones for vertical pulverization is evidence that pestles were specialized processing tools—their high numbers reducing the need for generalized handstones.

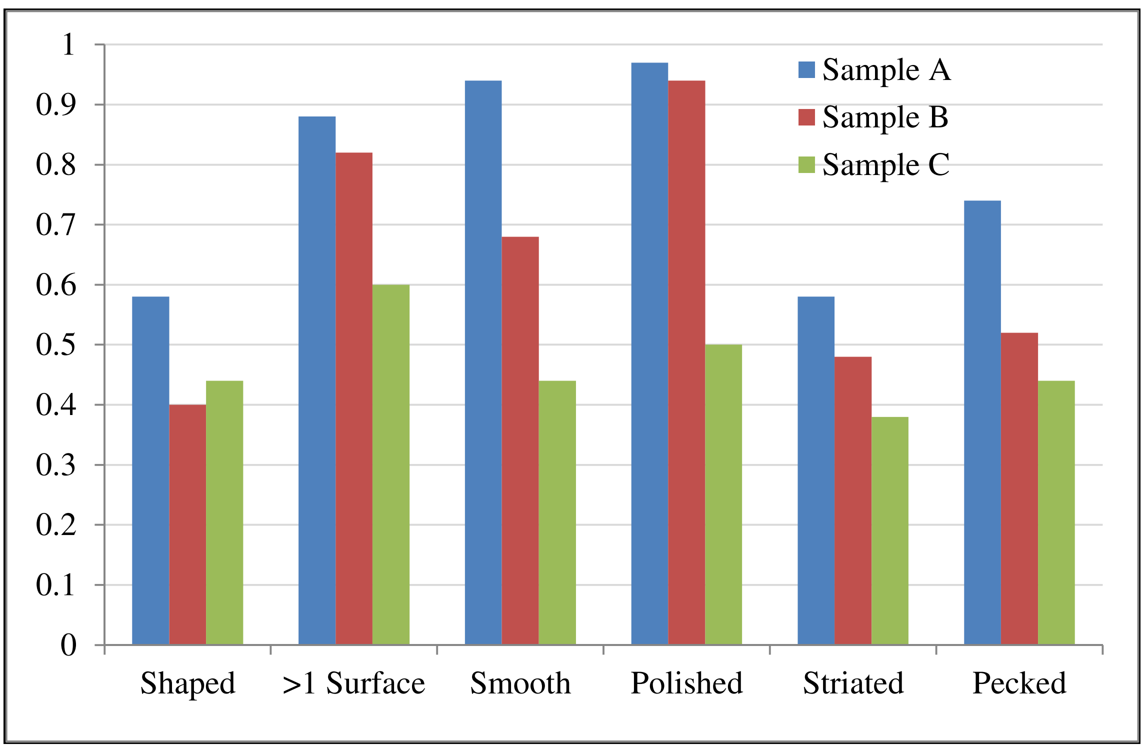


Figure 7.9. Proportion of handstone attributes by sample for the Santa Barbara region.

Overall, handstone manufacturing effort and use intensity declines from Sample A to Samples B and C. This drop in handstone use intensity is probably related to their decreased economic importance in processing after the mortar and pestle become more common in Samples B and C. Reduced use in secondary contexts implies that functional generality was less important than reliability, given the high numbers of pestles in Samples B and C.

7.2.2.3 Millingstones

The analysis of millingstones is essentially limited to Sample A (n=73), since just seven millingstones were analyzed for Sample B and two for Sample C. The limited number of millingstones in Samples B and C is due to the rarity of these tools in sites selected for detailed analyses of groundstone tools. The sampling problem is not a problem since the focus of the millingstone analysis is to determine the formality and use intensity of Sample A millingstones, compared to mortars for Samples B and C. Additionally, the handstone analysis indirectly informs on millingstone use intensity since these tools are counterparts.

Millingstones from Sample A include 11 whole basined millingstones, 13 end fragments, 36 margins, and 13 interior fragments; none of these refit. A relatively large proportion of millingstones (23.0%) from Sample A have two opposing surfaces. Flat and basined surface shapes are relatively equal in proportion at 52.0% and 48.0%, respectively. Overall, surfaces were intensively used, with 89.0% that have smooth textures, 94.0% that exhibit polish, 54.0% with striations, and 86.0% that are pecked. That nearly all surfaces were pecked is evidence of prolonged use and regular maintenance. Thus, Sample A millingstones were used intensively and regularly, and were probably retained in toolkits for long periods of time, cached at locations that were frequently reoccupied (see Hale 2001).

Comparisons between Sample A and Samples B and C millingstones hold little significance. Regardless, smooth surface textures in Sample B and C are less common at 86.0% and 67.0%, respectively. Additionally, surface pecking is much less common in Sample B (57.0%) and Sample C (67.0%). These differences are not surprising, given the decrease in handstone use intensity. It is likely that additional analyses on Sample B and C millingstones would reveal a small subset of millingstones that were reused over time, having regular surface shapes and wear patterns, and a larger component of incipient millingstone surfaces that were also used for secondary purposes. In fact, burning (use as cooking platforms), anviling, and abrading grooves are not uncommon on Sample B and C millingstones.

7.2.2.4 Pestles

Similar to other groundstone tools, pestles become more formal, specialized, and more intensively used over time. Considering shaping, 53.0% of Sample A pestles are moderately or highly shaped, compared to 73.0% shaped pestles for Samples B and C (Table 7.15). Decorated pestles are known for several sites not included in this analysis. However, 3.0% of Sample B pestles and 15.7% of Sample C pestles are decorated. Decoration motifs include rings around a finely tapered proximal end and cogged proximal ends. Other kinds of decoration were also identified. The relatively high proportion of decorated pestles in Sample C parallels the increase in mortar decoration on flowerpot mortars.

Table 7.15. Pestle Attributes by Sample

	Sample A	Sample B	Sample C
# Specimens	15	37	19
Condition			
Whole	.27	.43	.53
End	.73	.43	.42
Margin	.00	.08	.05
Interior	.00	.05	.00
Shaping Degree			
0	.20	.27	.26
1	.27	.00	.00
2	.20	.11	.26
3	.33	.62	.47
# of Surfaces			
1	.47	.76	.84
2	.13	.11	.05
3	.40	.08	.05
4			
Total # Surfaces	29	45	25
Surface Shape			
Pestle End	.52	.87	.84
Convex	.48	.13	.16
Blunted Pestle End			
Yes	.41	.78	.56
No	.59	.22	.44
Handstone Surfaces	14	6	4
Texture			
Smooth	.50	.33	1.00
Irregular	.50	.67	.00
Polish			
Present	.79	1.00	1.00
Absent	.21	.00	.00
Striae			
Present	.50	.33	.50
Absent	.50	.67	.50
Pecking			
Present	.43	.00	.75
Absent	.57	1.00	.25

The increase in shaping over time is consistent with a decrease in pestle generality. Processing generality on pestles is indicated by the presence of handstone surfaces on the pestle margins—these are called handstone-pestles (HSPs). In Sample A, HSPs account for 40.0% of analyzed pestles. Sample B contains just 3.0% HSPs, and Sample C contains 10.0% HSPs. HSPs in Sample C are small objects that appeared to be used mostly for asphaltum processing (asphaltum coats the distal end)—these may have originated as incipient handstones that were later scavenged to process asphaltum. The commonality of HSPs in Sample A is evidence that earlier pestles were more general than later, Sample B and C pestles—the latter being specialized processing tools.

Later pestles were more intensively used than Sample A pestles, indicated by blunted distal ends. Only 41.0% of Sample A pestles were used with enough intensity to blunt the distal ends. In contrast, 78.0% of Sample B pestle ends and 56.0% of Sample C pestle ends are blunted (see Table 7.15). If small asphaltum coated pestles are excluded from Sample C, 100.0% of all pestle ends are blunted.

None of the pestles from SBA-53 in Sample A were intensively analyzed. However, a cursory inspection of pestles from this site revealed that many are large—greater than 30.0 cm long and 8.0 cm thick—and have extremely blunted ends, despite minimal shaping. The intensity of vertical pulverization needed to produce such end wear indicates that processing was also very intensive, and might have been better suited to use with the large number of cobble mortars in the collection that have exceptionally thick bases and sidewalls.

7.2.2.5 Mortars

The analysis of mortars is much different than for other groundstone tools. Since all mortar surfaces are manufactured, all have smooth, polished surfaces prior to use. Additionally, the primary role of mortars and pestles is vertical pulverization, rather than horizontal grinding, meaning that rejuvenation of a mortar surface through pecking is usually not necessary (i.e., it doesn't matter how smooth the surface is). For these reasons, mortars are characterized by relatively few attributes related to overall formality and function. Section 7.1.2 and 7.2.2.1 review mortar formality, however, additional details can be gleaned from exterior shaping efforts. In Sample A, 69.0% of all mortars were moderately or highly shaped on the exterior (the rest were cobble mortars). Comparatively, 92.0% of Sample B mortars and 93.0% of Sample C mortars were moderately or highly shaped (Table 7.16).

Table 7.16. Mortar Attributes by Sample

	Sample A	**Sample B**	**Sample C**
# Specimens	16	36	15
Condition			
Whole	.25	.03	.00
Rim	.63	.61	.47
Base	.13	.14	.07
Interior	.00	.19	.47
Blank	.00	.03	.00
Shaping Degree			
None	.25	.03	.07
Light	.06	.06	.00
Moderate	.31	.36	.33
High	.38	.56	.60
Class			
Small Cobble	.31	.11	.13
Large Cobble	.13	.00	.00
Small Bowl	.06	.03	.07
Medium Bowl	.31	.28	.33
Large Bowl	.19	.47	.33
Flowerpot	.00	.11	.13

The proportion of shaped mortars is related to changes in mortar class. Sample A includes 44.0% cobble mortars (i.e., those with a relatively natural exterior), while Sample B and C mortars include just 11.0% and 13.0% cobble mortars, respectively (see Table 7.16). Small and medium-sized bowl mortars (abstract, intuitive categories) are relatively equal in proportion in all samples. However, large bowl mortars are much more common in Samples B and C. Additionally, Samples B and C include 11.0% and 13.0% flowerpot mortars (see Table 7.16). Flowerpot mortars commonly exhibit decorative rings, flared margins, incisions, and other decorations on the rim. The incidence of flowerpot mortars in Samples B and C would be much higher if these artifacts were not so vulnerable to theft and scavenging. Numerous flowerpot mortars exist at the UCSB repository that cannot be assigned to a specific site because they were looted and then gifted to the museum.

The most important finding of the mortar analysis was also the most obvious—the incredible formality of Sample B and C mortars. Finely made, large bowl mortars and decorated flowerpot mortars indicate a significant investment in the manufacture of these tools. That they are less frequent than smaller cobble mortars throughout the sequence is not surprising—it is expected that expensive tools will be less common, and curated for longer periods of time. Potential sample biases in this analysis relate to the fragmentary nature of the assemblage. Small cobble and bowl mortars tend to resist breakage more so than medium and large bowl mortars, and flowerpot mortars. Thus, bowl and flowerpot mortars could be overrepresented in the assemblages. The lack of refit of any fragments within a single site (or a single excavation unit with a site) reduces the sample bias to some degree. Regardless of these problems, the increased proportion of larger, shaped mortar fragments and the drop in absolute frequency of unshaped cobble mortars fits the overall trend of increasing formality.

7.3 SUBSISTENCE

Numerous detailed faunal analyses have been conducted for Santa Barbara region assemblages (e.g., Bowsher 1993; Colten 1989; Erlandson et al. 1993; Erlandson 1994;

Glassow and Wilcoxon 1988; Glenn 1990; Johnson 1980a, 1980b; Landberg 1975; Rick 1997; Rick and Erlandson n.d.; Rick and Glassow 1999; Salls 1988; Santoro et al. 1993). Detailing the results of these studies is not in the scope of this research, nor is it the intent. The following discussions of vertebrate and invertebrate faunal remains from the Santa Barbara region summarize broad trends in subsistence in an effort to provide additional context for technological change described in preceding sections.

7.3.1. Vertebrate Remains

A total of 13,619g of identified vertebrate remains was tabulated from existing reports for this research (Table 7.15; Figure 7.10). Reporting practices vary widely with faunal data presented in terms of weight, frequency (i.e., NISP), minimum number of individuals (MNI), or combinations thereof. Another common practice in the Santa Barbara region is to convert faunal remains into meat weight, using multipliers (see Erlandson and Rick 2002: Table 10.2). The benefit of using protein yield estimates is that the relative contribution of vertebrates and invertebrates can be compared in a single diet, and it minimizes the effect of heavy versus light bone (i.e., sea mammal versus fish). For the purposes of this analysis, faunal remains were summarized by weight, as this was the most common method of reporting faunal data (see Table 7.15).

At first glance, for all samples combined, sea mammal remains constitute 41.0% of the total vertebrate assemblage, followed by undifferentiated mammal bone (28.0%) and fish bone (25.0%) (see Table 7.15, Figure 7.10). Identified terrestrial mammals account for just 6.0% of the total assemblage.

Terrestrial mammals are most common in Sample A assemblages, totaling 29.0%—of this, 21.0% is large mammal bone (see Table 7.15). Other significant vertebrate remains in Sample A include 16.0% sea mammals and 45.0% fish. The large amount of terrestrial mammal bone, especially large mammals, is consistent with the high frequency of dart points, especially at SBA-53 (see Harrison and Harrison 1964). However, fish in Sample A comprise 45.0% of the assemblage—more than any other sample. The large majority of Sample A fish were caught in a bay/estuarine habitat, although nearshore schooling fishes (i.e., mackerel, herring, and sardine) were also present in lower, but significant amounts (see Rick and Glassow 1999).

The Sample B vertebrate faunal profile is much different. Sea mammals in Sample B account for 49.0% of the total weight, while terrestrial mammals total just 4.0% (see Table 7.15). Fish remains are the next most common identified category at 17.0%, more than two and a half times less than the proportion of fish remains in Sample A. Undifferentiated or unidentified mammal bone constitutes 29.0% of the total weight of faunal remains in Sample B. Sea mammal remains in Sample B primarily derive from two sites at Tecolote Canyon (SBA-72 and-73), totaling 48.1% of Sample B vertebrate faunal remains (4209.76 grams). However, a large proportion of identified bone from the other Sample B tabulated site (SBA-117) also consists of sea mammals (34.6%), with fish amounting to 38.2%.

The Sample C vertebrate faunal profile is different than both Samples A and B. Sea mammals drop in proportion to 30.0% of the assemblage by weight, while fish double in proportion to 38.0% (see Table 7.15). Identified terrestrial mammals in Sample C are uncommon, and undifferentiated mammal remains account for 28.0% of the assemblage (similar to Sample B). Essentially, the changes from Sample B to Sample C include an approximate 17.0% decrease in the proportion of sea mammal bone and a 17.0% increase in fish bone.

Within Sample C, vertebrate faunal profiles are quite different for each tabulated assemblage. The SBA-1491 assemblage is dominated by fish remains by weight (89.8%), while SBA-1731 includes 42.1% sea mammals and 21.6% fish. Both sites are located on the western Santa Barbara coast, however, SBA-1491 is closer to Point Conception and SBA-1731 is located 20 km east at the coastal terminus of a large drainage. The difference in faunal assemblages is less pronounced when comparing the percent of meat weight. Erlandson and Rick (2002: Table 10.2) report that SBA-1731 fish remains are equivalent to 43.0% protein yield, while 31.0% of the protein yield derives from fish (their dietary reconstruction included shellfish). In contrast, fish remains at SBA-1491 account for 75.0% of the protein yield, and sea mammals just 4.0%. Though different, the protein yield estimates for fish and sea mammal still show strong differences between SBA-1491 and SBA-1731. Regardless of the method of comparison (i.e., weight or percent of protein yield), the difference in vertebrate faunal profiles between these two sites is evidence that subsistence along the Santa Barbara coast was somewhat locally specific. This is especially true considering that sea mammal rookeries and haul-outs are much less frequent than productive fishing areas.

Overall, vertebrate faunal profiles show a reliance on marine foods, including sea mammals and fish, in Samples B and C. Terrestrial mammals are present in significant quantities only in Sample A. The paucity of terrestrial mammal remains, especially in Samples B and C (i.e., after the bow and arrow is adopted), is a phenomenon that eludes explanation, given the large numbers of dart and arrow points present in all samples (see

Glassow et al. 2008). It is not likely that the bow and arrow was used just for warfare since arrow points show evidence of use (i.e., impact fractures), and it is difficult to imagine that such damage is due solely to interpersonal warfare or incidental damage.

Table 7.15. Proportion of Weight for Identified Vertebrate Remains in the Santa Barbara Region

	Sea Mammal	Terrestrial Mammal			Misc. Mammal	Bird	Fish	Reptile	% of Total	Total (g)
		Large	Medium	Small						
Sample A	.16	.21	.00	.08	.06	.02	.45	.01	.06	776.07
Sample B	.48	.04	.00	.00	.29	.01	.17	.00	.64	8750.82
Sample C	.30	.00	.02	.01	.28	.01	.38	.00	.30	4092.39
% of Total	.41	.04	.01	.01	.28	.01	.25	.01	1.00	
N	5633.7	486.39	94.54	129.16	3753.64	125.32	3371.38	25.15		13619.28

Note: Adapted from: Bamforth 1983; Erlandson et al. 1993; Erlandson et al. 2008; Glassow 1992; Harrison and Harrison 1964, Levulett et al. 2000, Moore and Imwalle 1988; Santoro et al. 1993

The presence of large amounts of deer bone and small amounts of fish bone at a protohistoric/ ethnohistoric Chumash site, SBA-167, in the Santa Ynez Valley indicates that large terrestrial mammals were present in the general region. Large amounts of lagomorphs at Xonxon'ata, an ethnohistoric village in the Santa Ynez Valley, is further evidence that terrestrial mammals were intensively exploited (see Hildebrandt 2004). Both of these last two sites have very different faunal profiles, a common trend among all sites located along the Santa Barbara coast.

Fish remains were not distinguished by habitat in this analysis, although such a distinction is commonly made in published faunal analyses. For the middle Holocene (i.e., Sample A), Rick and Glassow (1999) state that bay/estuary fishes were exploited most intensively at SBA-53 on Goleta Slough, with a sharp increase in the importance of nearshore open coast fishes late in time (i.e., Samples B and C) (see also Moss 1983, Glenn 1990). In addition to the importance of bay/estuary fish, fish from the kelp zone also comprised a significant portion of Sample A fish remains at SBA-53 (Rick and

Glassow 1999). In a comparison with other Sample A assemblages (SBA-1807 and SBA-2057), Rick and Glassow (1999) note that all sites are dominated by bay/estuarine fish but that SBA-53 contained relatively much higher amounts of mackerel, herring, and sardine (nearshore open coast) than SBA-1807 and –2057. The last two sites are located on the coast while SBA-53 is in an estuary, indicating that the capture of nearshore open coast fishes was not simply due to geography. However, another Sample A site, SBA-1, is dominated by nearshore open coast fish, with much smaller amounts of bay/estuarine fish remains (Johnson 1980). Such a difference probably does have something to do with the fact that SBA-1 was farther from a productive middle Holocene bay/estuarine habitat, resulting in exploitation of locally abundant species.

Sample B and C fish remains indicate increased exploitation of nearshore schooling fishes, as well as pelagic fish taken individually in kelp forest habitats (see cf. Erlandson and Rick 2002; see also Glenn 1990, Rick and Glassow 1999, Johnson 1980). Bay/estuarine fish decline in proportion in Samples B and C, and at least part of this decline is due to the destruction of estuarine habitats through infilling during the middle Holocene.

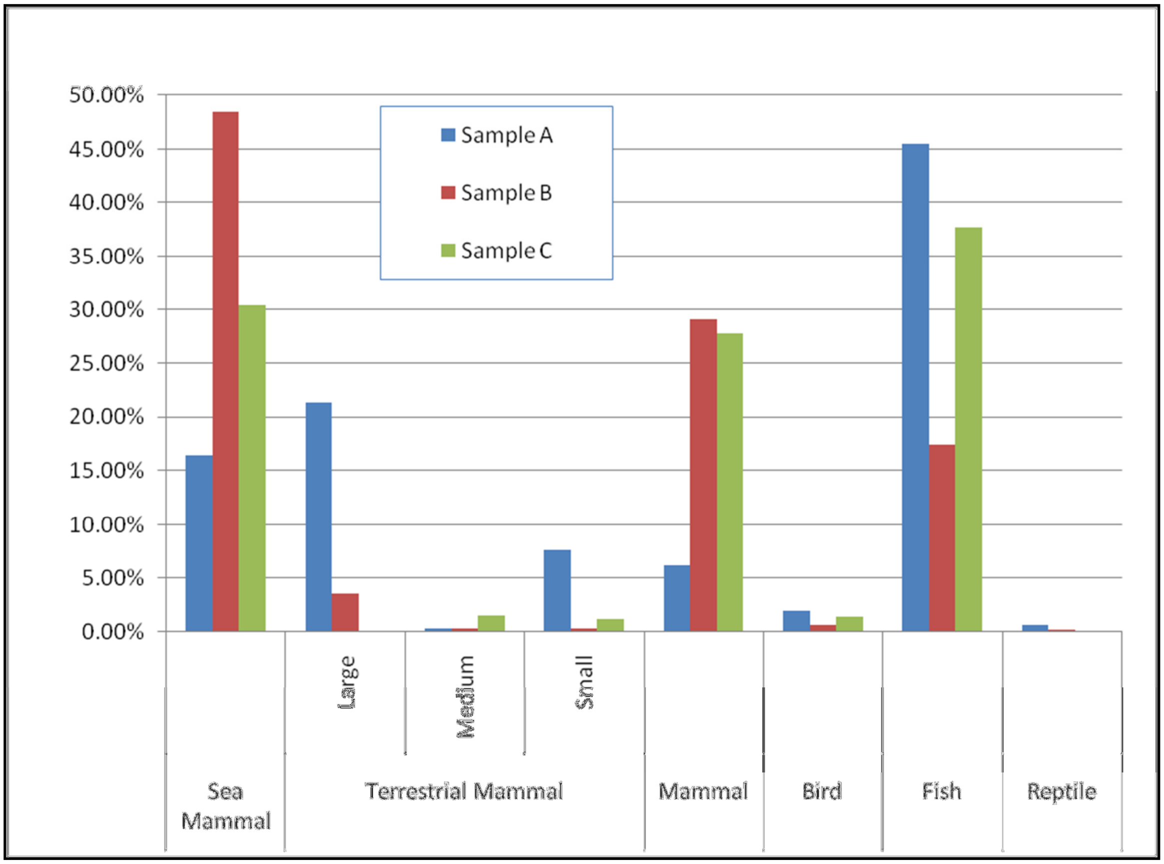


Figure 7.10. Vertebrate Fauna by Proportion of Weight and Sample

7.3.2. Invertebrate Remains

Invertebrate remains from the Santa Barbara region were tabulated by weight, totaling 178,263.99g (Table 7.16). Considering total shell weight, there is a significant bias in Sample B, containing 93.0% of the total amount of tabulated shell. Within Sample B, four sites were tabulated: SBA-117, -72N, -73, and –46 (SRS 1985). The majority of shell from Sample B derives from SBA-72N (96,237.3g), followed by SBA-46 (58,247.0g), and SBA-73 (11,805.67g); only 89.72 g of shell was tabulated from a column sample at SBA-117. The difference in tabulated shell is due to biases in reported shellfish data (i.e., a sample of the total shell recovered), recovery methods, and because some sites contained more shell than others.

Significant shifts occur between each sample in the kinds of shellfish exploited. Considering just identified taxa, *Tivela* accounts for a large majority (77.0%) of the Sample A assemblage, with small amounts of *Mytilus* and *Chione* (see Table 7.16 and Figure 7.11). In Sample B, *Tivela* accounts for 39.0%, with larger amounts of *Chione* (22.0%), *Mytilus* (25.0%), and *Protothaca* (13.0%). Similarly, Sample C contains just 7.0% *Tivela*, with trace amounts of *Chione*, 37.0% *Mytilus*, and 54.0% *Protothaca* (see Table 7.16). Thus, despite sample size, there is an overall trend of decreasing exploitation of *Tivela*, with an increase in *Mytilus* and *Protothaca*.

Tivela is mostly found on open coast sandy beaches, while *Chione* and *Protothaca* are found primarily on sandy bottoms in quiet waters. *Mytilus* are mussels that grow on rocky substrates in the intertidal zone. The approximate 10.0% increase in *Mytilus* across all samples suggests a gradual increase in rocky intertidal exposures along the Santa Barbara coast. The rise in sea level and drying trend over the Holocene is thought to have contributed to the destruction of estuaries (i.e., infilling) and the erosion of coastal bluffs, resulting in the exposure of rocky substrates at the coastal margin. However, substantial stretches of sandy beach continue to line the Santa Barbara shoreline, particularly along the eastern Santa Barbara coast. The presence of *Tivela* and *Chione*, even in trace amounts, confirms this. However, the increase in *Mytilus* was as much a factor of increased availability as it was a matter of preference, considering the ease with which mussels can be removed from a rocky substrate (see Jones and Richman 1995).

Overall, the more diverse shellfish profile of Sample B assemblages is probably the result of more intensive shellfish exploitation. The shift in species profiles in Sample

C probably resulted from more casual exploitation of locally abundant taxa, especially *Mytilus* and *Protothaca*, given that Glassow et al. (2007) note the declining economic importance of shellfish later in time due to a larger reliance on marine fish.

Table 7.16. Relative Proportion of Invertebrate Faunal Remains by Weight and Sample

	Chione	*Mytilus*	*Protothaca*	*Tivela*	Subtotal	Misc.	% of Total	N
Sample A	.06	.16	.01	.77	1.00	.12	.04	6591.1
Sample B	.22	.25	.13	.39	1.00	.09	.93	166559.69
Sample C	.02	.37	.54	.07	1.00	.63	.03	5113.2
% of Total	.19	.22	.12	.36	.89	.11	1.00	
N	34312.72	39726.77	21469.93	63713.72	159223.14	19040.85		178263.99

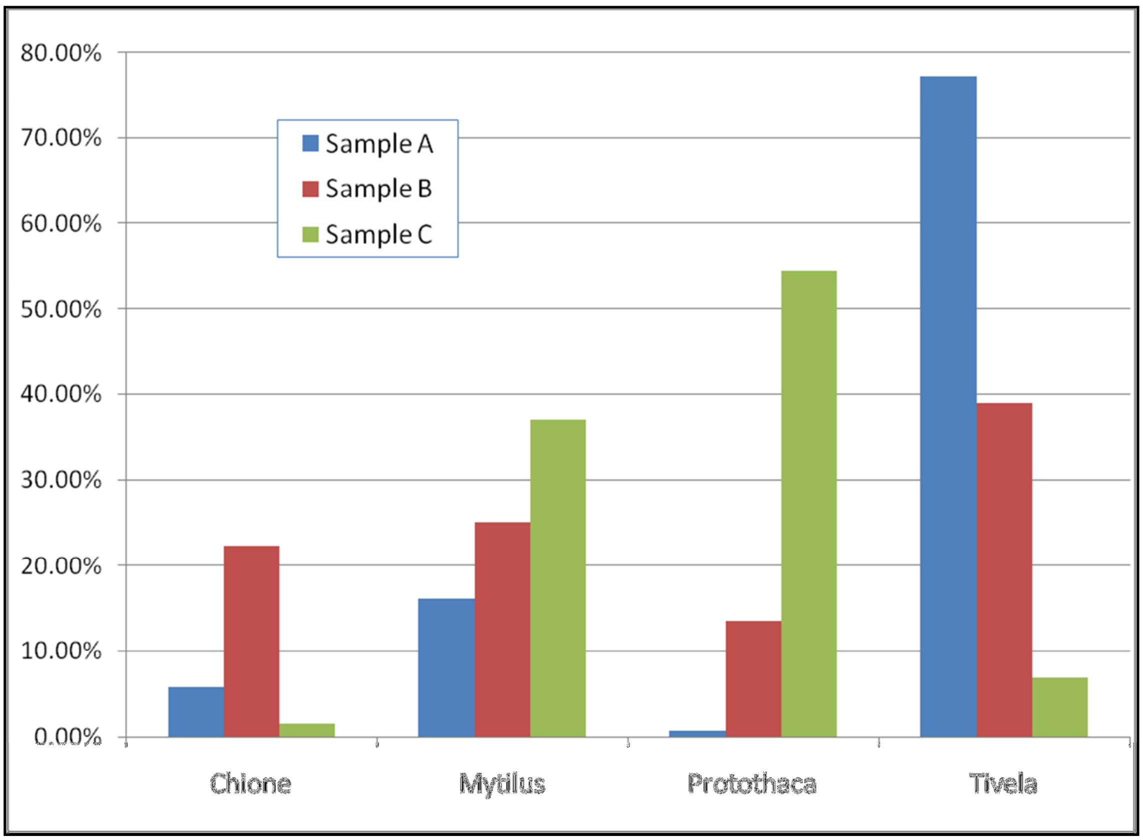


Figure 7.11. Invertebrate Fauna by Proportion of Weight and Sample. Adapted from: Bamforth 1983; Erlandson et al. 1993; Erlandson et al. 2008; Glassow 1992; Harrison and Harrison 1964, Levulett et al. 2000, Moore and Imwalle 1988; Santoro et al. 1993.

7.4 SUMMARY

Assemblage formality in the Santa Barbara region is relatively high for much of the Holocene, beginning in the Millingstone Horizon and increasing steadily thereafter. Changes in assemblage composition show a shift from millingstones and handstones to mortars and pestles, and the appearance of single piece fishhooks in Sample A, followed by an increase in formal flakedstone tools. Darts are gradually replaced by arrow points in Sample B, at the same time, various drills emerge indicating specialized technologies used to manufacture and maintain plank canoes, shell hooks, and beads. Additionally, Sample B mortars show increased investment in exterior form and larger size. Sample C is a continuation of these trends. These patterns are borne out in assemblage level data, formality indices, and manufacture/use-wear patterning on flakedstone and groundstone tools. Interpretations of assemblage patterning for the Santa Barbara region are explored in Chapter 8.

8. INTERPRETATION OF THE SANTA BARBARA REGION DATASET

This chapter evaluates predictions of the Tmin-Emax model against data generated for the Santa Barbara region. Changes in formality indices provide the most clarity for model predictions. Formality indices are supported by overall patterns in assemblage composition and more detailed analyses of flakedstone and groundstone artifacts. A brief discussion of faunal remains is also integrated as supporting evidence. In large measure, data from Santa Barbara region assemblages fit with expectations that an Emax economy should increase tool manufacturing effort across the board when new technologies are adopted, and when subsistence intensifies.

8.1 THE ORIGINS OF ENERGY MAXIMIZING IN THE SANTA BARBARA REGION

The Tmin-Emax model predicts that an Emax economy will have higher FFI and GFI values than a Tmin economy, and that these values should increase further over time (Table 8.1). Energy maximizers are expected to invest more in subsistence technology in an effort to ensure high yields, and as a byproduct of social ideology that emphasizes the significance of such tools (i.e., decorated mortars and pestles may reflect the importance of acorn processing). It is not the primary goal of this research to determine when an energy maximizing strategy appeared in the Santa Barbara region since large amounts of data support the presence of such an economy by at least 1000 B.C.. However, a brief comparison of assemblage formality indices from the different subsets of Sample A (i.e., Samples A1, A2, and A3) show clear differences, implying a shift to an Emax economy prior to arrival of the bow and arrow at around A.D. 500.

Table 8.1. Model Expectations for Fundamental Differences Between Tmin and Emax Economies

	Tmin	Emax
Model Prediction	Spend less time in subsistence	Spends more time in subsistence
Archaeological Prediction		
Lithic Formality Index	Lower	Higher
Lithic Waste Index	Lower	Higher
Groundstone Formality Index	Lower	Higher

8.1.1 Assemblage Formality Indices

Sample A1 (Millingstone) sites tend to be less formal than other contemporary sites due to their lack of formal flakedstone tools and because they have large amounts of expedient cobble tools and groundstone. Formality index values reflect this. Sample A1 has an FFI value of 0.43, and a GFI value of 0.54 (Table 8.2). In contrast, non-millingstone Sample A2 sites have a FFI value of 0.46, and a GFI value of 0.67. The increase in flakedstone and groundstone formality is the result of larger numbers of bifaces, formed flake tools, and mortars. Particularly important in this comparison is the large increase in GFI values because mortar surfaces—regardless of exterior finish—require more time to manufacture than do millingstone surfaces and exteriors. Sample A3 shows a continuation of this trend with an increase in the FFI value to 0.54 (now 11.0% greater than Sample A1); no GFI value could be calculated for Sample A3 (see Table 8.2).

The increase in LWI values from 0.23 in Sample A1 to 0.49 in Sample A2 is the result of mass production of dart points and other flakedstone tools in Sample A2, thereby contributing to larger amounts of debitage than in Sample A1 that has low numbers of flakedstone tools overall. The same is true for the increase in the LWI value in Sample A3 to 0.53.

As discussed in Chapter 7, SBA-53 contains large amounts of mortars and formal flakedstone items. If this assemblage is removed from the comparison, the FFI value in Sample A2 increases to 0.66. This 20.0% increase in flakedstone formality more than overshadows the 5.0% drop in GFI values in Sample A2 when SBA-53 is excluded (i.e., when the large number of mortars is excluded).

Table 8.2. Formality Index Values for Samples A1, A2, and A3, prior to A.D. 500

	Flakedstone Formality FFI	**Flakedstone Waste LWI**	**Groundstone Formality GFI**
Sample A1 Millingstone Pre 1000 B.C.	0.43	0.23	0.54
Sample A2 Non-Millingstone Pre 1000 B.C.	0.46	0.49	0.67
Sample A3 1000 B.C.-A.D. 500	0.54	0.53	NA

These differences between Sample A1 and Samples A2 and A3 are enough to infer that a different economic strategy was practiced at Sample A2 and A3 (i.e., non-Millingstone) sites—a strategy that valued relatively costly tools. Sample A2 sites (in particular, SBA-53) probably reflect the emergence of energy maximizing behavior in the Santa Barbara region. Greater emphasis on fishing seems to have followed more intensive processing, inferred from the appearance of mortars. In fact, single-piece (i.e., j-shaped) fishhooks first appear in Sample A3, just after 1000 B.C. (see Rick et al. 2000). The timing of greater exploitation of marine fish after intensified processing is not surprising. In this sense, a high yield resource, such as acorns, would have supplied the energetic basis for pursuing fat-poor/protein-rich marine fish (see Cordain et al. 2000, and Chapter 2).

8.2 PREDICTIONS OF THE TMIN-EMAX MODEL FOR THE INTRODUCTION OF THE BOW AND ARROW

The Tmin-Emax model predicts that an Emax economy should respond differently than a Tmin economy to the introduction of a new, more efficient technology (Table 8.3). With a strong preference for more food at the expense of free time, an Emax economy is expected to use the time saved by employing the bow and arrow to get more energy. This should result in higher flakedstone and groundstone formality index values, and a decrease in the lithic waste index (see Table 8.3). That is, the increased efficiency of the bow should free up time that can be used to invest in the manufacture of other subsistence tools, thereby increasing their reliability and efficiency, or that can be directly used for foraging. Because of increased efforts to finish flakedstone tools, the LWI value should decrease. Additional efforts to make tools efficient through formalization should lead to more specialized tools, and a reduction in multi-use tools. On the contrary, a Tmin economy is expected to offset the investment in bow and arrow manufacture by decreasing time spent making other subsistence tools. This should result in lower FFI and GFI values (see Table 8.3).

Table 8.3. Archaeological Predictions of the Tmin-Emax Model Following Introduction of the Bow and Arrow

	Tmin	**Emax**
Model Prediction	Spend less time in subsistence	Use time saved by using bow to get more energy
Archaeological Prediction		
Flakedstone Formality Index	⇩	⇧
Lithic Waste Index	⇩	⇩
Groundstone Formality Index	⇩	⇧

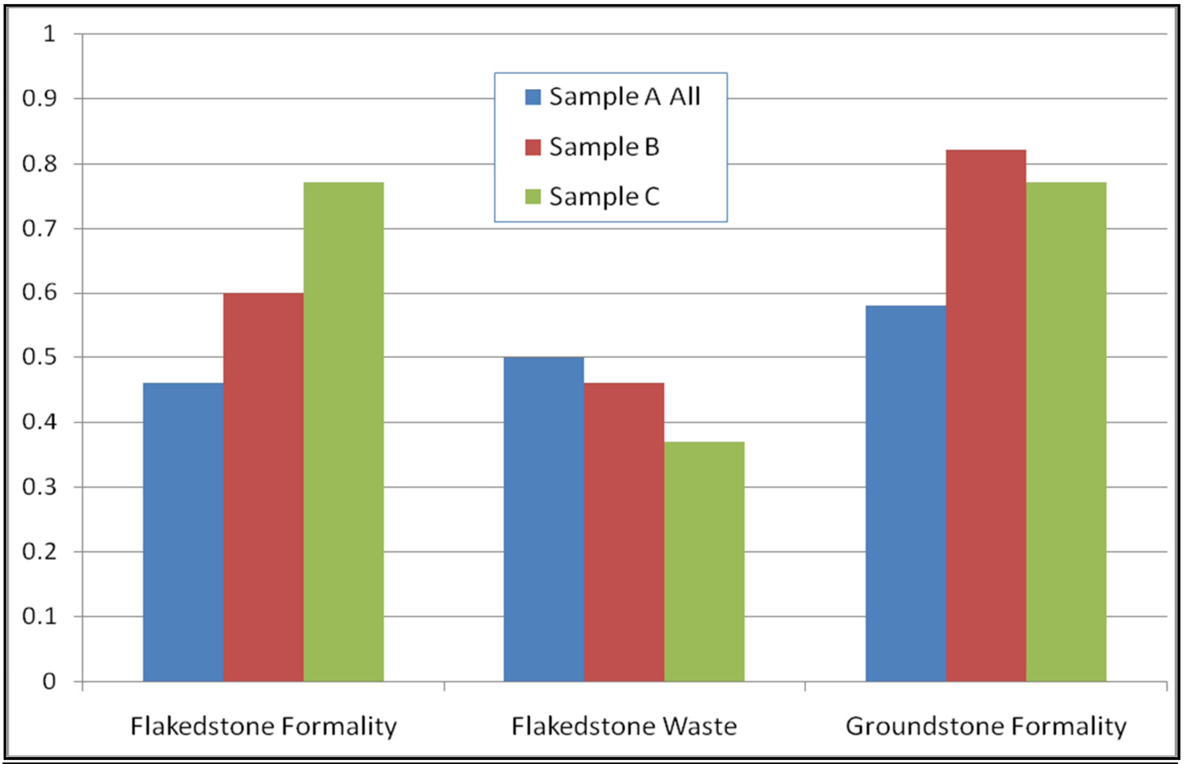
8.2.1 Assemblage Formality Indices

Changes in formality indices imply a strong Emax response to the introduction of the bow and arrow. FFI values change from 0.46 in Sample A to 0.60 in Sample B (Figure 8.1). The 15.0% increase in the FFI value is due to the increased proportion of bifacial tools and FFT. The 0.60 FFI value is higher than during any period in the San Diego region excepting Transitional (Sample IIIB) sites—these were interpreted as initial Emax sites (see Chapter 6). Included in the high FFI value of Sample B is the relatively large number of specialized drills and borers; these tools were used to make other specialized artifacts, including fishhooks, beads, and plank canoes.

The LWI values drop from 0.50 in sample A to 0.46 in Sample B. The slight drop in the LWI value is probably due to the fact that, in Sample A, dart points and other finished flakedstone tools were an integral part of the toolkit, producing almost as much finishing debitage as was produced after arrow points replaced darts in Sample B.

Groundstone formality increases sharply from 0.58 in sample A to 0.82 in Sample B (see Figure 8.1). This is due to the higher proportion of shaped mortars and pestles in Sample B and a decline in the abundance of handstones. Millingstones and handstones remain common, implying continued use of the more generalized processing equipment. However, the high frequency of mortars, including large, shaped bowl mortars, suggests technological specialization occurred to improve processing efficiency.

Assemblage formality indices support predictions of the Tmin-Emax model regarding an energy maximizing response to the introduction of the bow and arrow. Higher FFI and GFI values indicate that investment in the manufacture of subsistence tools increased sharply.



Index	Flakedstone Formality	Flakedstone Waste	Groundstone Formality
Sample A All	0.46	0.50	0.58
Sample B	0.60	0.46	0.82
Sample C	0.77	0.37	0.77

Figure 8.1. Assemblage formality index values by sample for the Santa Barbara region.

8.3 PREDICTIONS OF THE TMIN-EMAX MODEL FOR SUBSISTENCE INTENSIFICATION

Measuring intensification in the archaeological record, especially regarding stone tools, is not as direct as measuring the response to the appearance of a superior technology. However, the Tmin-Emax model predicts that energy maximizers should intensify differently than time minimizers. While both Tmin and Emax economies spend more time in subsistence during intensification, it is expected that stable preference structures cause divergence in how this time is spent. The model predicts that time minimizers should try to maintain energetic yields by decreasing the amount of time spent in activities related to subsistence, such as manufacturing stone tools. This should result in lower FFI values and higher LWI values; the assumption is that expedient tools should be used to accomplish the same tasks as formal tools since an increase in the overall energetic yield is not the primary goal (Table 8.4).

An Emax economy should intensify in a much different way. Preferring higher energetic yields, an Emax economy should invest more up-front time manufacturing subsistence tools increasing technological efficiency, and possibly leading to technological specializations. Emax economies are more likely to invest ideology in subsistence tools, producing decorative motifs. All of this should be manifest as higher FFI and GFI values, and a decrease in the LWI value, given more care exercised in tool manufacture and maintenance (see Table 8.4).

Table 8.4. Archaeological Predictions of the Tmin-Emax Model For Subsistence Intensification

	Tmin	**Emax**
Model Prediction	Invest more time in subsistence to maintain yields	Invest more time in subsistence to increase yields
Archaeological Prediction		
Lithic Formality Index	⇩	⇧
Lithic Waste Index	⇧	⇩
Groundstone Formality Index	⇧	⇧

8.3.1 Assemblage Formality Indices

Changes in assemblage formality index values are consistent with expectations for an intensified Emax economy. Considering flakedstone, the FFI value increases from 0.60 in Sample B to 0.77 in Sample C (see Figure 8.1). This 17.0% increase in flakedstone formality is greater than during any period in the San Diego region. The greater proportion of formal flakedstone tools in Sample C is largely due to the low numbers of expedient RET and SFT, along with larger numbers of bifaces and FFT.

Supporting the increase in tool finishing is the drop in the LWI value from 0.46 in Sample B to 0.37 in Sample C (see Figure 8.1). The shift in LWI value is due to an increase in the proportion of diagnostic finishing flakes compared to non-diagnostic shatter. More effort spent finishing flakedstone tools should increase the proportion of finishing debitage relative to non-diagnostic shatter (i.e., decrease the LWI value).

GFI values drop slightly from 0.82 in Sample B to 0.77 in Sample C. The slight drop in GFI value is mainly due to sampling error. It is possible that additional analysis of groundstone from sites that postdate A.D. 1350 (i.e., Sample C sites) would make the GFI values between Samples B and C more equitable, if not make the Sample C GFI value higher. Flowerpot mortars and decorated pestles reported for sites that postdate A.D. 1350 strongly suggest that efforts spent manufacturing groundstone tools after this time did not wane.

Thus, the comparison of formality index values for Samples B and C indicate increased assemblage formality. This is the expected response for an intensified Emax economy. These trends, and those identified by comparing Samples A and B, are confirmed in the following descriptions of detailed analyses for flakedstone and groundstone tools. Existing interpretations of faunal data provide additional support for model predictions.

8.4 SUPPORTING EVIDENCE

Analyses of flakedstone, groundstone, and debitage provide support for the validity of assemblage formality indices and additional insights into the intent of tool manufacture and use. Analyses showed a trend of increasing technological specialization for flakedstone and groundstone tools from Sample A to Samples B and C. Additionally, traditional expedient tools show less intensive wear later in time (i.e., in Samples B and C). Subsistence information is largely drawn from the interpretations of past researchers in the Santa Barbara region, but the overall trend is an increase in the exploitation of high-cost or specialized resources. These trends are summarized in the following sections.

8.4.1 Flakedstone

Flakedstone tools in the Santa Barbara region show a trend of increasing formality and specialization over time—exactly opposite the trend in the San Diego region. The earliest increase in tool formality in the Santa Barbara region is in Sample A. Sites from Sample A2 have large numbers of finely made dart points, bifaces, and FFT. One site in particular (SBA-53) contains such large numbers of darts and other bifacial implements that it was used as the type site for the definition of the Santa Barbara Hunting Culture (Harrison and Harrison 1964). However, the site also contains large numbers of expedient flakedstone tools (SFT and RET) for any Sample A assemblage. Darts are largely replaced by arrow points in Sample B, but darts continue to be present in quantities large enough to negate the argument that they were scavenged from earlier sites or were keepsakes later in time. In fact, a spear armed with a dart tip was probably more efficient than the bow at dispatching large sea mammals. In any case, Sample B dart points are less formal than Sample A dart points, in terms of biface stage category. Additionally, Sample B and C dart points were mostly made from flake blanks while Sample A dart points were made from large biface blanks, and were thus thicker.

Arrow point form throughout the sequence is itself an indicator of specialization. The contracting stem, convex base, and concave base arrow points likely originated in the

Santa Barbara region as local expressions of the bow and arrow complex. Despite vague similarities to other, extralocal point forms, the Canalino points (convex and concave base) are not Cottonwood Triangular points, or a simple variant thereof.

All arrow points were made from flake blanks. On many arrow points, enough of the parent flake bulb of percussion and original flake curvature was present to infer that the original blank was a biface thinning flake. The reduction of a bifacial core is a specific process that has greater potential to generate flakes of predictable size and shape. Use of the bifacial core reduction technique is much different than the much simplified cobble-core technology that dominates the San Diego region for all of prehistory. Bifacial core reduction implies more care and time invested in the reduction process. The debitage analysis identified a significant amount of biface thinning flakes, confirming the use of this technique.

Sample B and C bifaces include a larger number of finely made, hafted bifacial knives and scrapers. The finely made hafted bifaces speak for themselves in terms of specialization. These were curated tools that were manufactured to fit a specific haft and were thus likely to have been used sparingly, when extra leverage and cutting/scraping efficiency was a priority.

The analysis of flake-based tools revealed the most obvious evidence for technological specialization. Formed flake tools included a new category in Samples B and C: large drills and microdrills. Large drills typically had three bifacial margins and were probably used to bore holes in wood planks for canoes as well as to produce shell fishhooks in mass quantities (see Bamforth 1983, 1990). The large drill category also included finely made, trapezoidal bifaces that were longer and thinner than the bulky, short drills. These fine drills were specialized borers, probably used for canoe repair. Whether the fishhook or the canoe, these specialized drills were manufactured to create another specific tool. Microdrills are just as specialized (see Arnold 1992). These items were manufactured from higher quality chert (including material from Santa Cruz Island). Most microdrills were made from microblades, with a small drill tip fashioned from the distal end. Microdrills were made specifically for the manufacture of shell beads.

Other, non-drill FFT show an increase in the kinds of edge shapes and use wear. These attributes indicate that edges were increasingly manufactured to suit a specific task, and were used more intensively. Conversely, Sample B and C expedient SFT and RET were used less intensively than those in Sample A. The decreased use of expedient flake tools fits with increased investment and use of formal tools.

8.4.2 Groundstone

Technological specialization is obvious in the groundstone category, beginning in Sample A. Mortars first appear in large numbers in Sample A2, increasing in assemblage proportion and formality in Samples B and C. Sample B contains significant numbers of large, shaped bowl mortars, as does Sample C. The appearance of highly specialized and decorated flowerpot mortars takes investment in this technology to an extreme. Pestles follow the same trend, with shaped and decorated pestles found in Samples B and C. Aside from typical refinement of form to enhance processing efficiency, expression of symbolic attributes on groundstone tools is a strong indication of the socioeconomic importance of these tools and their role in society.

Millingstones and handstones decline in frequency and assemblage proportion in Samples B and C. Additionally, use wear and formalization attributes indicate that these tools became more expedient later in time. That millingstones and handstones continued to be used throughout the prehistoric sequence suggests that traditional processing techniques continued to have some utility, albeit expedient.

While not analyzed for this research, the common occurrence of cooking and storage vessels made from soft stone (i.e., steatite) is another form of technological specialization. Manufacturing thin-walled vessels from stone requires significant amounts of time and energy, especially considering the time lost when a boulder being shaped into a bowl is broken during manufacture.

8.4.3 Subsistence Remains

Vertebrate faunal remains from the Santa Barbara region vary widely by sample. Sample A bone is composed primarily of large mammals and fish. Conversely, Sample B and C vertebrate remains are dominated by sea mammals and fish with very little evidence for terrestrial mammal exploitation. The decreased proportion and frequency of terrestrial mammals in assemblages that postdate the arrival of the bow and arrow (i.e., Samples B and C), is hard to explain. Large numbers of dart points correlate well with the bulk of terrestrial mammals in Sample A. However, even with high frequencies of arrow points and darts in Samples B and C, terrestrial mammals pale in comparison to sea mammals and fish, fitting with a region wide picture of localized subsistence. Sites such as Xonxon'ata (see Levulett et al. 2000) further inland suggest that coastal foods were transported to inland areas and may indicate some form of subsistence trade.

Given that fish make up a large component of each sample, the attention paid to differences in taxa represented in site assemblages is deserved. Studies of fish remains have generally determined that Sample A sites are dominated by bay/estuarine taxa but also contain open coast taxa in smaller but significant proportions. Open coast schooling fishes and fish that reside in kelp forests, even if seasonally, are more common in Samples B and C (Glassow and Rick 1999; see also Glassow et al. 2008). These results generally correlate with the increased use of fishhooks, as well as with the appearance of the grooved shank circular hook. As fishing became more important, technologies to capture fish became more formal.

Overall, vertebrate faunal remains indicate that marine foods were one of the most economically significant resources in sites from all samples, whether sea mammals or fish. Invertebrate faunal remains only add to this trend. Compared to traditional Millingstone Horizon sites, shellfish exploitation was less important later in time, despite large amounts of shell recovered from Sample B sites. Shifts in shellfish taxa indicate that shellfish exploitation was also location specific. Over time, *Tivela*, an open coast, sandy beach species became less important than rocky substrate *Mytilus* and sandy bottom-dwelling *Protothaca*. The shift in taxa is probably due to the ease of capture and local abundance.

Plant remains are noticeably rare in archaeological assemblages from the Santa Barbara region. However, the importance of plant foods to local diets cannot be understated, based on the large amounts of groundstone tools in each sample. The increased commonality and formality of mortars and pestles, especially considering flowerpot mortars, indicates that plant processing was one of the most important subsistence activities. Given the success with which most small seeds and roots/tubers can be processed using traditional millingstones, the replacement of millingstones and handstones with mortars and pestles signifies a specialization on high cost-high return resources, probably acorns.

8.5 SUMMARY

The Tmin-Emax model predicted that an Emax economy should invest more time formalizing tools used in subsistence when a new technology arrives and during intensification. These predictions stand firm on the data generated from Santa Barbara region assemblages. An Emax economy appears to take hold early in the prehistoric sequence with Sample A2 sites showing large numbers of formal flakedstone and groundstone tools, in addition to the appearance of single-piece fishhooks. The commonality of mortars and pestles in Sample A, commingling with millingstones and handstones, is evidence of subsistence specialization. These trends are perpetuated after the bow appears in Sample B. Aside from arrow points, flakedstone tools become more formal and specific, including hafted scrapers/knives, large drills, and microdrills. Not only were these tools specialized in terms of function, but drills were used to manufacture other specialized artifacts, including fishhooks, plank canoes, and beads. Another form of specialization is the presence of finely made steatite vessels used for cooking and storage. Assemblage patterning in Sample C is similar to Sample B, with assemblage formality increasing further because of a reduction in expedient flakedstone and groundstone tools, and with the appearance of the refined, grooved shank circular, hook. Subsistence remains provide a strong undercurrent for the trend of economic specialization. Particular evidence for this is the increased capture of single fish using fishhooks.

9. DISCUSSION AND CONCLUSION

9.1 A COMPARISON OF ASSEMBLAGE TRAJECTORIES BETWEEN SAN DIEGO AND SANTA BARBARA

This research compared archaeological assemblages from the San Diego and Santa Barbara regions, revealing that assemblage formality in the San Diego region declines over time in the last 3,500 years, while assemblages become more formal in the Santa Barbara region during this same time frame. Assemblages from each region were separated into samples that date before and after the introduction of the bow and arrow at around A.D. 500, and those that signal intensification later in time. Several indices reflect the different trajectories in assemblage composition (Simpson's Diversity Index and evenness), and assemblage formality (Flakedstone Formality Index—FFI, Lithic Waste Index—LWI, and Groundstone Formality Index—GFI).

9.1.1 ASSEMBLAGE COMPOSITION AND SIMPSON'S DIVERSITY INDEX

Changes in assemblage composition across samples in each region show different trajectories (Table 9.1). In the San Diego region, assemblage composition becomes more generalized over time from Sample I to Sample IIIA, while assemblages in the Santa Barbara region become more specialized. This is best characterized by the Simpson Diversity Index. The details of calculating the Simpson Diversity Index were discussed in Chapter 5. Suffice it to say that Samples I through IIIA in the San Diego region had the same richness because there was at least one specimen for each kind of tool in each sample. The same is true for the Santa Barbara region for Samples A through C. Thus, evenness was calculated separately for each sample by dividing the Simpson Diversity Index value by the maximum number of tool classes present.

Table 9.1. Stone tool proportions for the San Diego and Santa Barbara regions.

	San Diego				Santa Barbara		
Sample	**I**	**II**	**IIIA**	**IIIB**	**A (All)**	**B**	**C**
Arrow Point	.00	.05	.07	.13	.00	.11	.11
Dart	.01	.00	.00	.00	.04	.02	.02
Preform	.00	.03	.06	.03	.01	.09	.08
Biface	.01	.05	.06	.10	.08	.16	.17
Formed Flake Tool	.08	.02	.01	.09	.13	.21	.36
Retouched Flake	.05	.13	.05	.01	.04	.03	.03
Simple Flake Tool	.18	.07	.13	.08	.21	.22	.13
Cobble Tool	.12	.10	.07	.04	.06	.04	.00
Heavy Scraper	.09	.06	.00	.00	.00	.00	.00
Hammerstone	.10	.09	.11	.03	.09	.03	.04
Millingstone	.06	.09	.23	.20	.08	.01	.01
Handstone	.28	.29	.13	.11	.22	.02	.01
Mortar	.00	.02	.03	.18	.03	.04	.02
Pestle	.01	.00	.04	.00	.02	.03	.01
Total Stone Tools	5410	1216	535	158	3942	1773	1110
Simpson	6.27	7.06	8.10	7.73	7.36	6.86	5.07
Evenness	0.45	0.50	0.58	0.70	0.57	0.53	0.39

A comparison of assemblage diversity and evenness between samples from the San Diego and Santa Barbara regions clearly shows divergent trends (Figure 9.1). In the San Diego region, diversity and evenness increase over time from Sample I to Sample IIIA, with a drop in diversity for Sample IIIB (see Figure 9.1). In the Santa Barbara region, however, assemblage diversity and evenness are highest in the earliest sample (Sample A) and decrease in Sample B, with Sample C having the lowest diversity and evenness of any sample (see Figure 9.1).

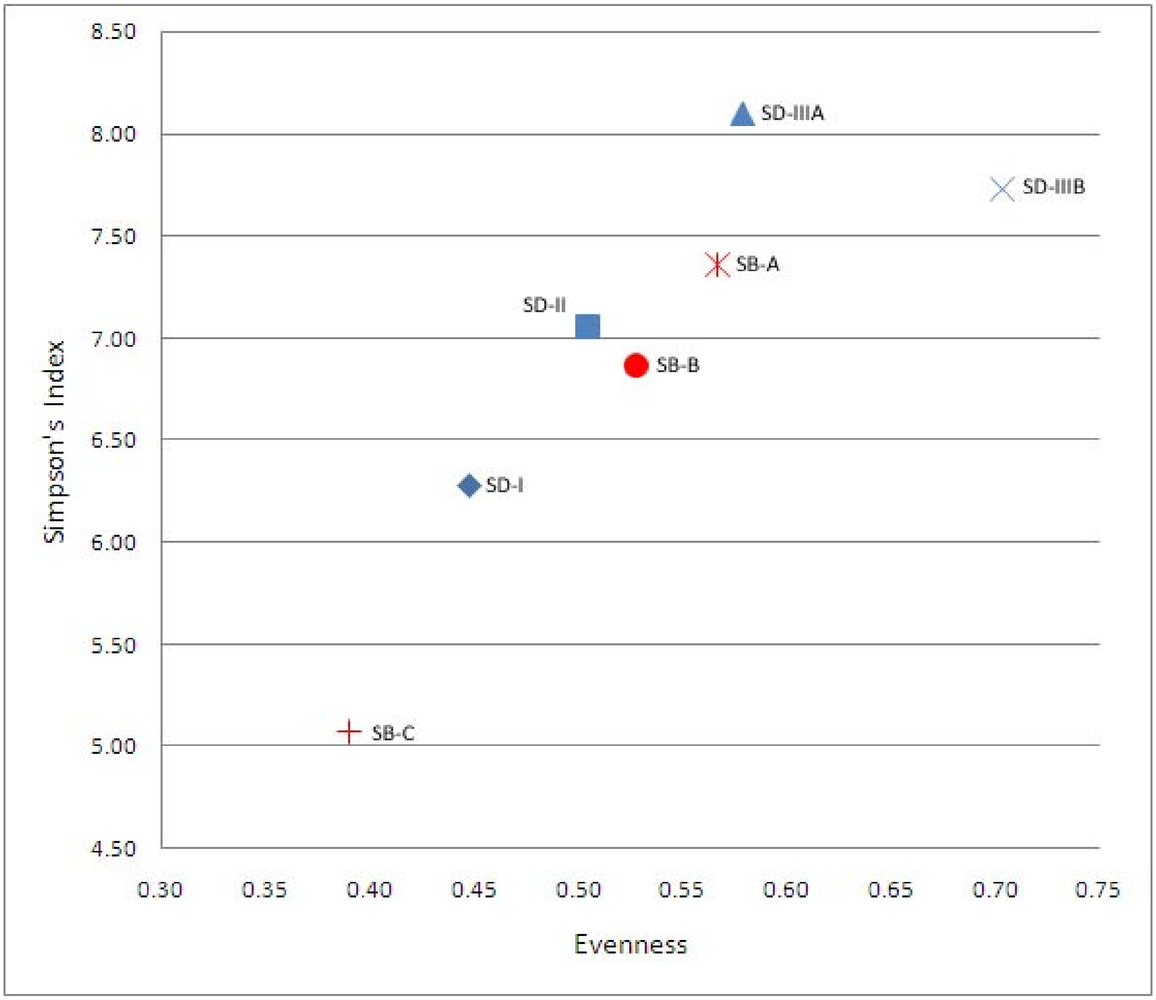


Figure 9.1. Simpson's Diversity Index and evenness values for the San Diego and Santa Barbara regions.

The Santa Barbara trend of decreasing diversity and evenness is due to large numbers of specialized tools and a decrease in generalized tools (especially cobble tools, handstones, and millingstones) later in time. The opposite trend of increasing diversity and evenness in the San Diego region is due to intensified use of generalized, expedient flaked and groundstone tools through time, with the exception of the bow and arrow. Sample IIIB (Transitional) assemblages in the San Diego region reverse the trend somewhat due to an increase in formal flaked and groundstone tools, while generalized tools remain.

9.1.2 ASSEMBLAGE FORMALITY INDICES

Changes in the formality of flakedstone tools provide one of the clearest measures of the technological divergence between San Diego and Santa Barbara. In the San Diego region, Flakedstone Formality Index (FFI) values are low early on, slightly decrease after the bow and arrow arrives, and remain low during intensification (Figure 9.2). Only Sample IIIB (Transitional) sites have a high FFI value. In contrast, FFI values in the Santa Barbara region are relatively high in early (Sample A) assemblages, and increase steadily by approximately 23.0% in Samples B and C (see Figure 9.2).

A more in-depth look at flakedstone tools revealed that expedient flake tools dominate assemblages from the San Diego region, these generally lacking bifacial knives and other formal tools. On the other hand, early (Sample A) assemblages from the Santa Barbara region have large numbers of bifacial tools; these increase in assemblage proportion through time, as do formed flaked tools and specialized drills (large drills and microdrills). Thus, San Diego assemblages become less formal and more general later in time (not including Sample IIIB), while Santa Barbara assemblages become more formal and more specialized.

The Lithic Waste Index (LWI) measured the relative abundance of non-diagnostic shatter, loosely taken as a measure of the care taken in flakedstone tool production. A low LWI value indicates a relatively low proportion of shatter to diagnostic flakes, while a high LWI value means that the assemblage has larger amounts of shatter. Intensified efforts to refine and shape flakedstone tools produce larger amounts of diagnostic flakes relative to shatter. Thus, a higher FFI value should correlate with a lower LWI value. This trend is clearest in the Santa Barbara region (Figure 9.3). LWI values for the Santa

Barbara region are highest in Sample A and decrease over time in Samples B and C. Recall that over these same samples, FFI values steadily increase (see Figure 9.2).

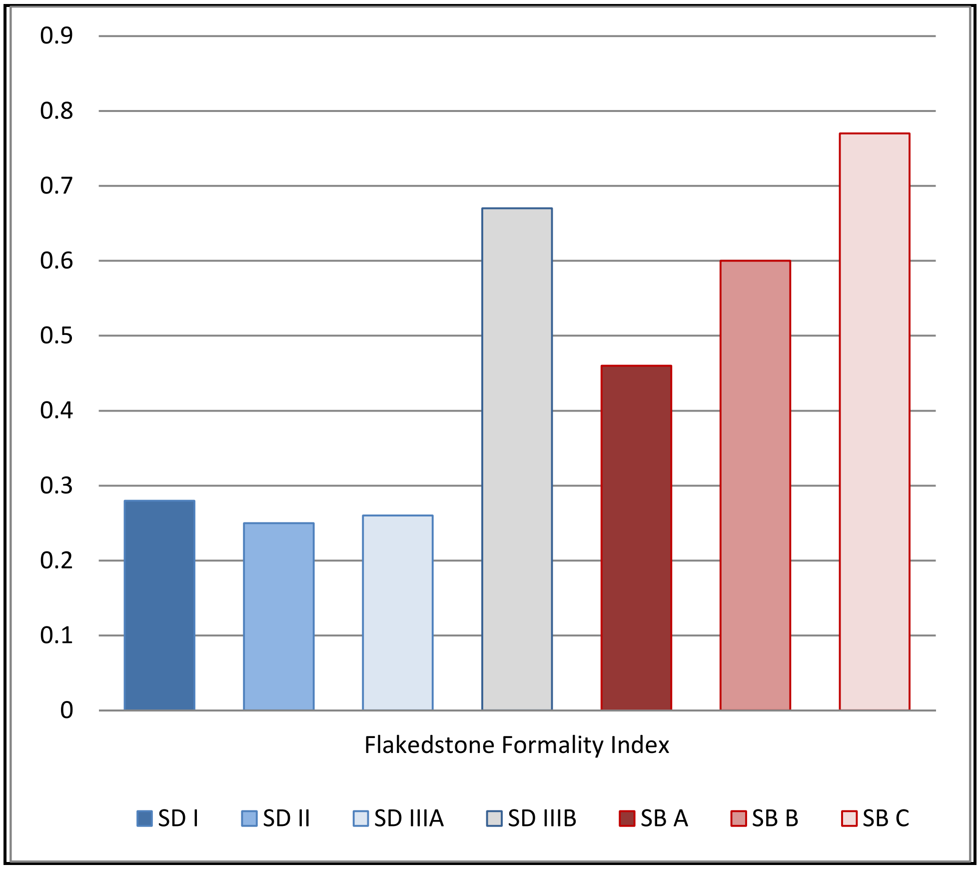


Figure 9.2. Flakedstone Formality Index (FFI) values by sample for the San Diego and Santa Barbara regions.

Debitage from the San Diego region exhibits a different pattern. LWI values in the San Diego region are high early on (Sample I), dramatically decrease after the bow arrives (Sample II), and then increase sharply again in Sample IIIA (see Figure 9.3). The drop in the LWI value after the bow arrives occurs because arrow points are produced in mass quantities resulting in much more diagnostic debitage relative to shatter. The subsequent increase in the LWI value for Sample IIIA is the result of intensified production of stone tools overall during subsistence intensification using the same expedient, cobble-core reduction technique. That LWI values decrease again for Sample IIIB sites correlates well with a high FFI value for Sample IIIB and indicates more effort spent refining flakedstone tools (see Figures 9.2 and 9.3).

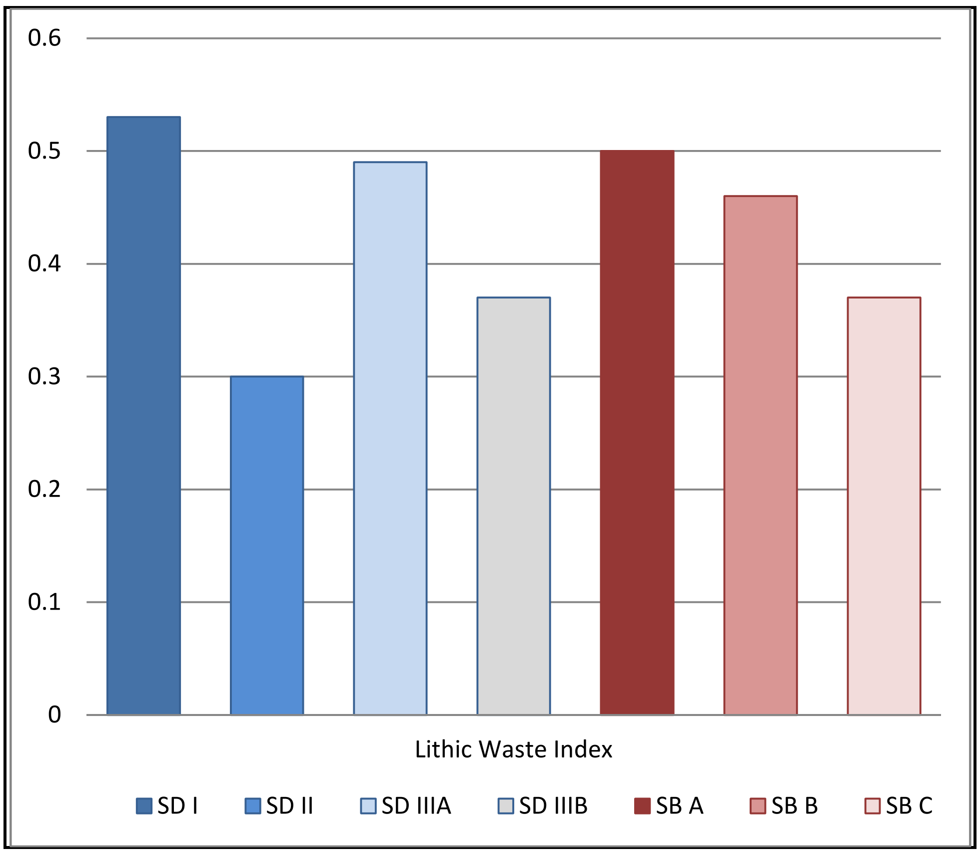


Figure 9.3. Lithic Waste Index (LWI) values by sample for the San Diego and Santa Barbara regions.

Changes in the Groundstone Formality Index (GFI) parallel those for flakedstone tools. In the San Diego region, the GFI value is relatively low before and after the bow arrives (Samples I and II), and decreases during subsistence intensification (Sample IIIA (Figure 9.4). A sharp increase in the GFI value occurs in Sample IIIB, consistent with a high FFI value—both indices reflecting more time and energy spent refining subsistence tools. The trend of decreasing groundstone formality in the San Diego region is opposite that of the Santa Barbara region. Early Santa Barbara assemblages (Sample A) have a relatively high GFI value due to the large numbers of mortars. GFI values increase by 30.0% in Sample B, reflecting more time spent refining groundstone tools, including the decoration of mortars and pestles. Sample C assemblages in Santa Barbara are also highly formal, with a GFI value close to that of Sample B (see Figure 9.4).

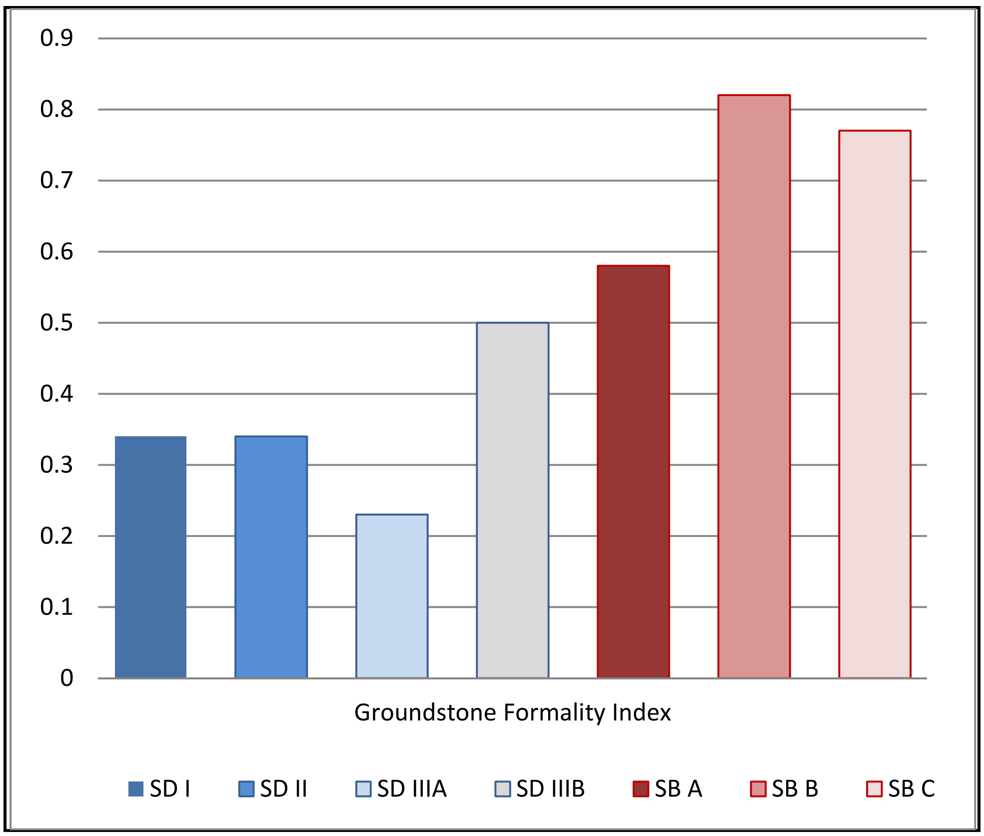


Figure 9.4. Groundstone Formality Index (GFI) values by sample for the San Diego and Santa Barbara regions.

In Sum, assemblage formality indices show divergent trends in manufacturing effort for subsistence tools between the San Diego and Santa Barbara regions. The San Diego region is characterized by low assemblage formality that generally declines after the bow arrives at approximately A.D. 500, and during intensification after A.D. 1400, with most tools becoming more general over time. The Santa Barbara region, however, exhibits high assemblage formality in all Samples, increasing after the bow arrives and during subsistence intensification after A.D. 1300. The technological divergence evident between the two regions reflects fundamentally different strategies for the allocation of time and energy during subsistence that is best explained by the Time Minimizing-Energy Maximizing model.

9.2 TIME MINIMIZING, ENERGY MAXIMIZING, AND SOCIOECONOMIC DIVERGENCE IN SOUTHERN CALIFORNIA

In the Time Minimizing-Energy Maximizing (Tmin-Emax) model, a Tmin strategy minimizes the time spent on subsistence in exchange for more non-subsistence time, and an Emax strategy maximizes energetic yield at the expense of free time. Value-reinforcing social institutions stabilize preference structures—i.e., a Tmin preference for more free time and an Emax preference for more food.

The Tmin-Emax model predicts that time minimizers and energy maximizers will differ in their response to new technologies and to subsistence intensification. Time minimizers will use a new technology to save additional time during subsistence. In the same way, time minimizers should decrease the overall time spent during subsistence to maintain return rates during intensification. Archaeologically, assemblage formality (i.e., the amount of time invested in subsistence technology) should decrease after the bow arrives and during intensification. The archaeological record of the San Diego region generally fits these predictions, implying that hunter-gatherers there practiced a Tmin adaptive strategy until ethnohistoric times.

On the other hand since the main preference for an Emax economy is for more food, energy maximizers should use a new technology to increase subsistence yield. Additionally, energy maximizers should invest more time in subsistence to increase energetic yields during intensification, pursuing increasingly high cost-high yield resources. This results in higher assemblage formality after the bow arrives and during intensification. The trajectory of increasing assemblage formality and technological specialization in the Santa Barbara region fits with expectations of an Emax economy.

Adaptive strategies in the Tmin-Emax model are based on preference structures that dictate rational economic decisions to allocate scarce resources (i.e., time and energy). Rational economic decisions are those that match preference structures (Robbins 1932). Shifts in preference structures are abrupt, rather than gradual, because adaptive strategies are stabilized by social rules that co-evolve with preferences, culling irrational behaviors. Such strategies should inherently resist change, thereby stabilizing a Tmin economy until economic behavior is no longer rational—i.e., when economic decisions fail to satisfy minimum requirements for free time.

A modified form of the Ideal Free Distribution (IFD) model clarifies discontinuous change from Tmin to Emax. In the IFD, if an Emax economy is density dependent with a lower initial suitability, a higher maximum suitability, and a greater maximum density, a series of attempts to start an Emax economy should occur prior to a successful adaptive shift. A successful shift to Emax should only occur after conditions in the Tmin economy significantly deteriorate to the point that Tmin tactics to maintain subsistence efficiency fail to satisfy minimum levels of free time. The archaeological implication of the IFD model is that the Emax colonizing events should produce assemblages that reflect Emax behavior—i.e., higher assemblage formality. Four such Transitional (Sample IIIB) sites were found in the San Diego region dating primarily between A.D. 1400 and 1700, these having higher assemblage formality than any other sample in the San Diego region. Interestingly, these Transitional (Sample IIIB) sites are precursors to the ethnohistoric acorn economy present after Spanish contact (Bean and Shipek 1978; see Hale 2005).

9.3 BEHAVIORAL CONTINUA AND ADAPTIVE FLEXIBILITY

The stability of preference structures driving the Tmin-Emax model fundamentally differs from the more popular models based on behavioral continua. In behavioral continua, such as the forager-collector model, adaptive strategies are defined by those that track techno-environmental conditions. When these conditions change, adaptive strategies change to suit. Thus, combinations of mobility, technology, subsistence, and social organization are flexible tools used to accommodate changing conditions, with adaptive strategies shifting from forager-like to collector-like when conditions demand. Adaptive stability is only provided by factors external to the socioeconomic strategy—i.e., the stability of local environments, etc. The drawback of these kinds of models is that they cannot account for socioeconomic stability in the face of changing conditions; there is no context for explaining socioeconomic divergence of two groups in similar technological and environmental settings.

Terrestrial and marine environments of the San Diego and Los Angeles regions are more similar to each other than either are to the Santa Barbara region. Despite this, hunter-gatherers in the Los Angeles region followed a similar trajectory to their northern Chumash neighbors, increasing technological formality and subsistence yield through high cost tactics. Hunter-gathers in the San Diego region did not follow these trends, choosing instead to maintain traditional technologies and low cost subsistence for thousands of years. Thus, behavioral continua cannot explain why hunter-gatherers in the San Diego region did not adopt a high cost-high yield economy in the face of changing technological and environmental conditions.

9.4 IMPLICATIONS OF THE TMIN-EMAX MODEL FOR HUNTER-GATHERER THEORY

A major implication of the Tmin-Emax model is that not all hunter-gatherers are cut from the same cloth. Such a concept is a major departure from current trends in hunter-gatherer theory. The current popularity of behavioral continua in explaining hunter-gatherer behavior arose out of dissatisfaction with historical views that sought a definition of hunter-gatherers as a cultural type. Most early hunter-gatherer research was directed at finding a definition based on social structure or cultural stage. Morgan (1974) and Spencer (1896) viewed hunter-gatherers as primitive cultural forms defined by low cultural complexity. This definition was discarded during the 1960's when hunter-gatherers were celebrated as lay ecologists practicing a Zen economy (see Sahlins 1968; Lee and DeVore 1968). Both perspectives were constantly confronted with hunter-gatherer groups that did not fit the popular definition. In contrast, Kelly (1995) exemplifies the modern approach in which all hunter-gatherer behavior exists on a continuum. Ethnographic hunter-gatherer groups each exhibit a broad mixture of behaviors that resist definition.

Winterhalder's (1996) assertion that hunter-gatherers can be seen as a distinct mode of production in an HBE framework—i.e., a qualitatively distinct behavioral complex—differs from recent trends to resist definitions (e.g. Kelly 1995). Such a perspective is close to the implications derived from this research; that types of adaptive strategies can be real and understood through hunter-gatherer behavior. However, this argument is not the same as early evolutionary typologies that defined kinds of cultures, or more recent attempts to categorize human societies (see Johnson and Earle 2000).

Debating the theoretical validity of making qualitative distinctions between hunter-gatherer adaptive strategies is similar to the typological debate, well-framed by Albert Spaulding (1953) and James Ford (1954). Spaulding (1953) used chi square to demonstrate that cultural traits can co-occur non-randomly (among artifacts in this case). Non-random groupings of traits can represent behavioral tendencies and thus have historical relevance—i.e., types can be real. Spaulding cautions that types only have significance if they share a common context (i.e., time, space, form, function). For Ford (1954), types are unnatural because they require lines to be drawn in a continuum of traits; each trait exists and is selected independently of another. Artifacts are only "convenient collections" of traits at one point in a continuum, and historical association of traits is determined by chance alone. Ford points out that types lose significance when the scale of observation is changed. While not resolved, Spaulding's approach to types has served archaeologists well, since certain classes of artifacts (i.e., projectile points, beads, etc.) can exhibit strong morphological patterning over time.

David Meltzer (1979) constructs an argument about theoretical paradigms that is similar to Ford's (1954) stance on cultural types. Meltzer's argument explicitly counters Khun's (1970) model of paradigm shifts in scientific thought. Khun's model is that a set of covering laws form a paradigm within which observations are made that either support or conflict with the paradigm. As observations increasingly conflict with the covering laws, discontent causes a shift in assumptions and new covering laws are adopted. Such paradigm shifts characterize archaeological thought (Khun 1970). In contrast, Meltzer (1979:654) argues that archaeological thought is contained within a general metaphysic, "the contents of which are characterized by theoretical, methodological, and technological variability." This metaphysic, or general way of thinking, is a linear continuum on which all archaeological "paradigms" exist. According to Meltzer, paradigm shifts in archaeology are arbitrary constructs dependent on each individual researcher's perspective. Similar to Spaulding, Khun's model of paradigms has proved effective in distilling the essential elements of various theoretical perspectives applied to hunter-gatherer and archaeological problems over the past century (see Bettinger 1991).

In line with Spaulding and Khun (and contrary to Ford and Meltzer), this research suggests that two fundamental types of hunter-gatherer adaptive strategies can exist and can be observed in the archaeological record. Such a perspective does not require disposal of continua-based models; these have proven useful in many contexts. In fact, the forager-collector continuum seems to best describe intensifying energy maximizing economies; diminishing returns favors exploitation of high cost/high yield resources, transforming subsistence from forager-like to collector-like. Such a transformation is evident in the archaeological record of Santa Barbara. However, the Tmin-Emax model suggests that once energy maximizing preferences are stabilized by social institutions, a socioeconomic reversal is unlikely without radical change that alters the foundations of social and economic pursuits—such change in the New World could have resulted from introduced disease.

Given that the forager-collector continuum was developed through observations of ethnohistoric hunter-gatherers, it is no surprise that the model is best applied to explaining energy maximizing behavior. Bettinger (1999) suggests that all ethnographic hunter-gatherers were probably energy maximizers and that no good ethnographic correlate exists for a time minimizing economy. Despite this, glimpses of time minimizing behavior can be observed in the ethnographic record. Sharp (1969) states that aboriginal groups in northeastern Australia used the time savings gained from using the more efficient steel axe (in place of traditional stone axes) to sleep, rather than increase production. Other such examples exist in a variety of societies (see Kelly 1995).

9.5 SOCIOECONOMIC STABILITY AND CULTURAL EVOLUTION

The divergent socioeconomic pursuits of Tmin and Emax adaptive strategies can help clarify the debate regarding the rate-limiting factors of cultural evolution. The context for this debate is a macroscopic trend in the global archaeological record of modern humans. Increasing assemblage complexity (specifically, technological complexity) and population density over the last 40,000 years generally fits an exponential curve, with the most rapid changes accumulating after the end of the Pleistocene about 11,000 years ago (see Richerson et al. 1997). Though the whole of cultural evolution is difficult to characterize, social and technological complexity follow this trend, as does human population growth. Evidence suggests that, given their high reproductive potential, humans should have reached much higher population densities and filled nearly all major niches long before it actually occurred (see Richerson et al. 1997). In turn, cultural evolution should have followed suit just as quickly if the characteristic human response to diminishing returns in subsistence is to intensify;

assuming that intensification creates favorable contexts for technological and social innovation.

Much of early anthropological research on cultural evolution has been characterized by searching for correlations between technological improvements and socioeconomic change (see Braidwood 1962, Morgan 1974, Steward 1955, Spencer 1896). However, the role of technology and adaptive strategy in determining the rate of socioeconomic change is poorly understood. This is a classic cultural evolutionary problem that has been addressed primarily through the archaeological record. Early explanations cast cultural evolution in a series of stages brought about by technological innovation. This conceptual trend has waned over the last few decades but still pervades current cultural evolutionary thinking giving new technologies a major causal role (e.g., Johnson and Earle 2000). However, the issue of when and how a new technology can induce socioeconomic change has not been adequately addressed, or much less, resolved.

In a more specific pursuit, Richerson et al. (2001) approach the problem in an attempt to understand the origins of agriculture at the close of the Pleistocene and subsequent development of socioeconomic complexity. They identify numerous factors that can limit the rate and mode of cultural evolution including environment, technological innovation, social organization, and economic trajectory. However, these factors could only be discussed as possibilities due to their macroevolutionary perspective, and because no framework is provided to determine when or how each factor might become important.

The results from this research can be viewed as a test of the idea that the rate of technological innovation limits the rate of socioeconomic change (i.e., cultural evolution). This research measured the response of different hunter-gatherer groups in southern California to the bow and arrow—a major technological innovation. While this research was a test of the Tmin-Emax model, the results strongly supported model predictions and indicate that hunter-gatherers in the San Diego region were time minimizers and those from Santa Barbara were energy maximizers at the time the bow and arrow was adopted. If the rate of technological innovation is the primary limiting factor on the rate of socioeconomic change, the bow and arrow should have elicited a similar response in both regions, regardless of the different socioeconomic contexts—it did not.

Increased assemblage formality in the Santa Barbara region after the bow was adopted indicate that time savings from using the bow was spent in other areas of subsistence, including tool manufacture. In contrast, a decrease in assemblage formality in the San Diego region indicates that hunter-gatherers there offset the cost of bow manufacture by decreasing investment in other tools rather than simply increasing energetic yield. From these results it can be inferred that socioeconomic preference structures have a large effect on the rate and character of adaptive change, and determine the socioeconomic impact of new technologies.

9.6 DIRECTIONS FOR FUTURE RESEARCH

The goal of this research was to explain socioeconomic divergence between hunter-gatherers in two regions of southern California. In particular, adaptive strategies in the San Diego region were conservative compared to their northern Santa Barbara—and Los Angeles—region neighbors. The approach taken here was to evaluate predictions of the Tmin-Emax concept of distinct evolutionary stable strategies against archaeological data. However, many avenues of inquiry remain unexplored.

Exactly how much of an impact qualitative environmental differences along the southern California coast affected the evolutionary history of hunter-gatherer adaptive strategies remains unsolved, even though most research has focused on just this topic (see Jones and Klar 2008; Kennett 2005). It may be true that the geographically circumscribed Santa Barbara Channel mainland, rich in terrestrial and marine resources, would have facilitated relatively rapid population growth such that an early shift to Emax was not only imperative, but favorable given the limited amount of space within which hunter-gatherer groups could organize. The juxtaposition of the Los Angeles basin may have inhibited the transformation to Emax for some time. This research suggested that the similarity of San Diego and Los Angeles region environments—terrestrial and marine—compels an argument that environmental differences had little influence on the overall cultural evolutionary trend in the San Diego region. However, the better comparison for evaluating environmental influence may relate coastal San Diego environments to interior deserts, comparing adaptive strategies in the desert regions with those from the San Diego region. Indeed, such a desert connection has been a popular theme in the San Diego region (see Warren et al. 2004), effectively acting as a catchall explanation for the relatively informal and conservative toolkits.

Investigation of a desert connection may also help explain how a Tmin economy persisted for so long in the San Diego region while bordered by an intensive Emax economy to the north (i.e., Gabrielino territory). It can be inferred that an Emax economy should absorb the resources of a Tmin economy if the two strategies overlap in space or are adjacent to one another. The comparison of Tmin and Emax as modes of production in the Ideal Free Distribution confirmed this inference. Emax economies are inherently suited to larger and continually growing populations, placing a premium on resources and land occupied by less intensive Tmin economies. With more extensive social coordination in subsistence already in place, Emax economies hold a competitive advantage over less structured time minimizers, in subsistence or warfare, and should be able to rapidly displace time minimizing economies.

Despite the theoretical notion that Emax economies should overrun Tmin economies in close proximity, this research pointed out that time minimizers in the San Diego region successfully resisted any possible attempts of an Emax economy to invade for thousands of years. It could be that a connection with interior desert hunter-gatherers who were also time minimizers allowed prehistoric San Diegans to solidify their northern border and resist an Emax invasion through some form of despotism, or other such strategies. Alternatively, it could be that the social institutions of the early Santa Barbara Emax economy were fined tuned to that environment, causing a lag effect as it spread south through the Los Angeles basin as the socioeconomic framework required regional adjustment. Research into the character of desert adaptive strategies (i.e., were desert populations time minimizers?) would help clarify these questions not only for the San Diego region, but also for the connection between the Los Angeles region and the Mojave desert, a short distance to the north.

Finally, archaeologists need to reevaluate the reliance on behavioral continua. The latter are appealing because they can offer nearly any kind of functional argument to account for archaeological variation. Explanations derived from behavioral continua are not all wrong, but they are not universally true either. The conservatism in the San Diego region—in light of significant environmental and technological changes—demonstrates this. In fact, continua-based explanations probably account for minor adaptive shifts in both Tmin and Emax economies—i.e., shifts in mobility, occasional use of storage or practice of agriculture, etc. (see Bettinger 2006). However, understanding broad trends in cultural evolution requires that archaeologists explore the possibility that energy maximizing is a relatively new phenomenon developed during the Holocene, especially in North America. If energy maximizing took root in the Santa Barbara region more than five thousand years ago, what was happening in the coastal Transverse Ranges at this time, or in the Central Valley? The challenge will be identifying time minimizing adaptive strategies, given that time saving tactics are not exclusive to a Tmin economy, nor are the archaeological implications of time savings always direct. A long time scale and substantial assemblage data are requirements for differentiating time minimizing and energy maximizing adaptive strategies.

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