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## Nutritional and Social Benefits of Foraging in California<sup>1</sup>

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**Abstract** Key trends in California prehistory diverge from those characteristic of other world regions; sophisticated advances in the application of human behavioral ecology to archaeological interpretation help us to understand why. Significant interpretive advances have been stimulated by the on-going “provisioning” versus “costly signaling” debate. We argue that provisioning currently has the upper hand because the diet breadth model is older, better understood, and more easily assessed in light of archaeological data than is costly signaling. Archaeological research outside of California will need to confront issues of provisioning and prestige in their own empirical context and in light of behavioral ecology methods developed here.

**Resumen** Las tendencias clave en la prehistoria de California se separan de esas características en otras regiones del mundo; avances sofisticados en la aplicación de la ecología de la conducta humana a la interpretación arqueológica nos ayudan a comprender por qué. El debate en curso entre “provisioning” y “señalamiento de costo” ha estimulado avances significativos en la interpretación. Expongamos que provisioning tiene actualmente la ventaja, porque el modelo de anchura de dieta es más viejo, mejor comprendido, y más fácilmente valorado que el señalamiento de costo en la perspectiva de datos arqueológicos. La investigación arqueológica fuera de California deberá confrontar los asuntos de provisioning y prestigio en su propio contexto empírico y en la perspectiva de los métodos de la ecología de la conducta que se desarrollaron aquí.

**California has had little impact** on North American archaeology—even less on world archaeology. The list of North American marquee sites and societies makes this clear. Any knowledgeable Old World archaeologist is familiar with Clovis, Mesa Verde, and Cahokia, as well as the Anasazi, Inuit, and probably the Iroquois, but likely not Emeryville, Point St. George, Hotchkiss, or Topanga Canyon, nor the Patwin, Yokut, or Cahuilla. Among Paleolithic specialists Calico *might* ring a bell, but more likely Meadowcroft; complex forager specialists might know of the Chumash, but more likely the Kwakiutl. The anthropology most important to California specialists obviously does not figure prominently to their counterparts elsewhere around the globe.

This is unfortunate because aboriginal California has features that require non-traditional ways of thinking about the human trajectory and the world's past. These features ought to intrigue serious archaeologists anywhere. Perhaps foremost among these is ethnic diversity. Of the 390 groups tallied in Binford's hunter-gatherer compendium (Binford 2001), 55 (14%) lived in California. Australia has almost that many (54), but it is almost 20 times larger. This diversity is in part a function of environment. However, California's hunter-gatherers also confined themselves to postage stamp territories. The territories of hunter-gatherers on California's north coast (e.g., the Yurok) are a third the size of those in the adjacent Northwest Coast (e.g., the Haida). Why were there so many groups in so little space? Fortunately, relatively late European settlement meant this diversity was often seen first hand, or recorded from the memories of those who lived it, by first class observers, providing us with a richly detailed ethnohistoric framework for analyzing and interpreting the archaeological record with reference to this and other issues.

California should likewise fascinate because it seems at variance with patterns observed in the better known Old World. California shares with the Levant a classic Mediterranean environment. California hunter-gatherers were intensive users and storers of plants, as were those of the early Holocene Levant. Why then, did agriculture develop and flourish in the Levant but not in California? Population cannot be the answer. Hunter-gatherer California was more densely populated than any other part of North America—three times more densely than the agricultural Southwest, a third more than the much-vaunted Northwest Coast (Ubelacker 2006: Table 1). Again, however, these densities did not lead to things we expect. Whereas there were large, complex social formations in the Southwest, and intricately calculated systems of prestige and social position on the Northwest Coast, there is little of either in California. The evolutionary processes leading to complexity and hierarchy elsewhere evidently took a different route here, where the emphasis almost everywhere kept groups small and thwarted authority that impinged on individual and family autonomy.

It is more important that California be recognized for these interesting and unexpected patterns than for individual sites and cultures. Emeryville, recently the focus of a debate about aboriginal resource conservation and its impact on social evolution, matters less as a site than as an exemplar of something larger. Were it unique, Emeryville would be far less interesting. Unfortunately, the archaeological world has trouble thinking about unexpected processes and patterns that do not automatically spring to life upon a simple viewing of a site (e.g., Lascaux) or its assemblage (e.g., Folsom). We see in the HBE papers in the first three issues of *California Archaeology* reasons for thinking this might change—that California archaeology is working in directions that others elsewhere will want to follow. The problems and challenges here are unusual, but the analytical methods at play will be essential to the explanatory toolkit archaeologists everywhere will need to use.

The principle issue motivating the papers that we discuss here is an old one in anthropology: Were the economies of Native California societies shaped predominantly by the quest for food, in order to feed hungry people, or were they formed by the quest for social standing and prestige that could be leveraged to attract mates and allies? Dealing with what we will term the *provisioning versus prestige* debate requires new analytical tools, methods and interpretations, if we are to explain the archaeological record of any location in a more thorough and compelling fashion. The papers discussed here are evidence this is being put into a form that world archaeology will no longer be able to ignore. They demonstrate creative uses of theory, method, and data to inform a vigorous debate about the adaptive goals that shaped the prehistory of California and, to an unknown extent, the rest of the world. In the process these papers define new and challenging directions for research.

These papers do not settle the provisioning versus prestige debate; each side relinquishes as much ground as it takes. The papers do, however, show how that debate is stimulating significant advances in the interpretive possibilities of behavioral ecology. Two articles muster novel means of combining different data sources to appraise a common behavior. Faunal and isotopic analyses provide complementary insights into subsistence economy (diet breadth and composition) within the context of the diet breadth model (Bartelink 2009). Likewise, genome diversity can be matched to faunal analysis of taxonomic abundance to examine population history of resource species (Beck 2009). Another two articles present means of combining different HBE models in ways that achieve deeper insight. The model of technological intensification is used to explain changes in subsistence and fishing techniques along the south central coast (Coddington and Jones, this issue) while a combination of foraging models is matched to costly signaling to argue that the latter alone can explain inland transport of shellfish (Hildebrandt et al. 2009). Whitaker (2009) shows the value of simulation in determining the likelihood of

localized extirpation of artiodactyl populations, Wohlgenuth (this issue) shows the importance of precise paleo-ecological reconstruction of habitat distribution and value.

Several papers argue for expanding the conceptual arena of the provisioning-prestige debate in order to make it more holistic and, not incidentally, also more testable. Cannon (2009) recasts costly signaling in terms of parental effort, thus entailing predictions related to women's roles and group size. Morgan (2009) uses a central place foraging analysis to show that women's harvesting of pine nuts and acorns effectively minimized the opportunity costs of transport and processing relative to seasonal settlements, thus facilitating opportunities for costly signaling among males.

In this summary, we highlight some interpretive points raised in these contributions. There is no space here for detailed individual article commentaries, so we restrict ourselves to synthetic statements about behavioral ecology theory and issues raised by the provisioning-prestige debate. Our objective is that of improving the explanation of human behavior, social form, and social evolution throughout prehistory. Indeed, the substantial contributions to that goal found throughout the papers in these first three issues of *California Archaeology* are the basis for our claim that California prehistory has greater and greater claim to broad general significance.


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### Diet Breadth for Archaeologists

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Resolving the intensification, provisioning, and prestige debate requires that we know what economically rational provisioning should look like in light of the diet breadth model. How should optimal foraging appear in the archaeological record? We offer some guidelines to complement an alternative perspective developed in earlier work on the subject (Grayson and Delpech 1998; Grayson et al. 2001).

Archaeologists attempt to answer this question by assessing the correspondence between the diet breadth model predicted frequency of harvesting various resources and their observed archaeological frequency (controlling, of course, for differential preservation, a taphonomic issue that is largely irrelevant to the following discussion). Because archaeological data are mixed or conflated over time, they average short-term behavioral changes, clouding the association. A forager operating in ecological time likely will change diet breadth in response to seasonal or inter-annual changes in search or pursuit and handling costs. Decisions to pursue also can change much more quickly. By making stalking almost impossible, a windless day or a series of such days may lower pursuit success of moose hunting sufficiently to drop this normally high-ranked species from the optimal diet of a

Resource types by net kcal return on pursuit and handling	Sets determined by rank, relative to the margin establishing the optimal "diet breadth"	Relative frequency (number) in diet & (taphonomic biases aside) the archaeological record
Cell #1 1 highest ranking  	Cell #2 Always in optimal diet (n = 1 or more)	Cell #5 Archaeological incidence matches encounter rate, or the relative density in the environment within the set of other resource types always in the optimal diet.
	Cell #3 Conditionally in optimal diet (e.g., for a limited period of time such as a season).	Cell #6 Archaeological incidence matches encounter rate only for the conditional period, thus under-matches relative density in the environment (calculated as above and over the full annual cycle).
	Cell #4 Never (virtually never) in the optimal diet.	Cell #7 Archaeological incidence represents opportunistic, low-cost encounter, accident, or contamination and should be quite rare relative to resource type's relative density.
<i>k</i> very low ranking		

**Figure 1.** Prey Rank in the Diet Breadth Model in Relation to Dietary Representation and the Archaeological Record.

Cree hunter. Lumped or averaged archaeological data confound this short-term variation and imply an interpretation at odds with what actually happened. How common a problem is this, and how and to what degree might we circumvent it?

Consider Figure 1, representing interpretation of the diet-breadth, or encounter-contingent, resource selection model (MacArthur and Pianka 1966; Stephens and Krebs 1986). We make the usual assumptions of the diet breadth model: uniform foragers, random distribution of resource types within a single homogenous patch, and the like, with further discussion to follow. Prey are ranked by their net return rate (profitability) for post-encounter pursuit and handling; the optimal diet is set by the last ranked prey type with a profitability greater than the return on foraging for all items of higher rank.

We elaborate by reference to the numbered cells. As is standard, resource types are ranked from 1 to *k* (Cell 1), by net acquisition rate for time spent post-encounter (i.e., in pursuit and handling). To make a general argument, we deliberately leave unspecified how many types occur in each of the categories of the next column to the right. We refer to "resource types" because the features relevant to ranking (pursuit success rate, time to capture or harvest, net kcals returned) are

independent of categories such as plant, animal or, indeed, species. Thus, a species may represent more than one resource type; two or more species with identical pursuit and handling characteristics are, effectively, one type. Although the species is the same, salmon taken in weirs, in nets, by spear, or simply by hand, have different expected rates of return (probably, ranking high to low: hand > spear > net > weir). They are correctly treated as different "resource types." A group that takes salmon by all four means does not have the same "diet breadth" as a group that takes them only by hand.

Some set of resources, a minimum of one, is always in the diet (Cell 2). These resources will be harvested and archaeologically represented in proportion to their relative densities (Cell 5). This prediction is based on fine-grained (random) encounter; it assumes the zero-one rule (see Stephens and Krebs 1986) and the equal likelihood of successful pursuit. In this case, a proportional match between archaeological incidence and ecological density is consistent with optimal diet selection (see exceptions below).

However, there likely will be another set of somewhat lower ranked resources, a set conditionally in the diet (Cell 3), depending on any of the resource or forager qualities that might cause diet breadth to vary (Winterhalder and Goland 1997). A resource type might cross the "margin" into the optimal diet if its pursuit and handling become more efficient (its rank goes up), or if higher ranked resource types become less dense or accessible, causing the foraging return rate margin to drop. This might happen day-to-day, seasonally, or inter-annually for some set of resources, which then are taken or not taken depending on ephemeral environmental or behavioral conditions.

These conditionally harvested resources generate the greatest ambiguity for archaeological interpretation (Cell 6). It is here that the short-term actions of the forager are most obscured by the conflation inherent in the archaeological record. The matching rule for incidence:density no longer applies. A resource type harvested upon encounter for, say, two months of the year, will have one-sixth the relative incidence in the archaeological record of one taken year-round. Without adjustment for ephemeral periods of harvest, we no longer have a clear or direct relationship between the archaeological and environmental abundance, obscuring claims of optimal foraging.

Finally, there is a set of resource types that will never (or virtually never) occur in the optimal diet, due to very low value or high pursuit and handling costs (Cell 4). These will never (or very rarely) enter the archaeological record through routine foraging, although they may get there by other, more incidental means (Cell 7). An unusually propitious encounter might provide a desirable catch, such as a beached whale or a pre-salted windrow of locusts (e.g., Madsen and Kirkman 1988). Or

such resources might accidentally contaminate the archaeological record, but otherwise they should be reliably absent.

Confounding factors are possible. Most importantly, the assumptions of the diet breadth model may not reflect the relevant constraints or opportunities. Resources may not be randomly distributed, but may be associated with more than one environmental patch, or foragers may differ in their skills and other relevant attributes. Two possibilities seem especially important. The first is patchy distribution of resource types. The diet breadth model assumes that on each foraging trip all resource types have encounter likelihoods set only by their relative densities; they are evenly mixed in the space covered by a search path. By contrast, if resources are patchy in distribution, this assumption may be violated. Suppose that one subset of resource types occurs together in one habitat and the balance in another. We would then expect encounters proportional to density *within* patches, but conditioned by the frequency with which those patches are visited (cf. Smith 1991).

A second confounding factor is sex-age differences in the opportunity costs that govern the marginal trade-off of the encounter-contingent forager. Pursuing a suboptimal resource type is costly because of the lost opportunity to forage more efficiently for higher ranked types. In applying this logic we usually imagine our forager to be a skilled, highly mobile, prime-age adult. The opportunity costs would obviously be different for an individual who is very old, very young, or temporarily infirm. Given few highly productive options, say in the immediate environment of a settlement, this individual has a quite different optimal diet, and might efficiently spend time foraging for low-ranked but accessible resources, including those ignored by our prime adult. The remains of these resources will enter the archaeological record in some measurable frequency, and may mislead our interpretation of the foraging economy if we assume they were put there by prime adult foragers.

Since ephemeral harvesting and confounding behaviors always are likely, we need a guide indicating whether a change in archaeological abundance reliably signals an increase or a decrease in diet breadth. More specifically, what archaeologically visible measures of floral or faunal remains will reveal on-the-ground behavior with the greatest fidelity? Least reliable will be a simple count of species or resource types, generally presented as a measure of “richness.” By definition, richness includes any type from 1 to  $k$  that appears for whatever reason in the archaeological record at least once. Including without adjustment a resource type from Cell 3 will be wrong for at least part of the time; including one from Cell 4 will virtually always be wrong. A measure by species will undercount resource types if, as in the case of hand- versus hook-caught salmon, a species comprises more than



one resource type. In short, richness and like measures are highly sensitive to systematic errors in the archaeological record.

Also of low reliability are measures of diversity like the Shannon-Weiner Diversity Index. This is partly because this measure confounds richness or diversity with evenness of representation. Adding a new species to the diet always increases species richness, but in indices like Shannon-Weiner it can actually *decrease* derived diversity. For example, when there are two equally common prey in the diet, the Shannon-Wiener Index equaling 0.69; adding a third prey type that is 100 times more common than either of the more highly ranked prey types increases diet breadth but *decreases* diversity, the Shannon-Wiener Index equals 0.11. A more appropriate index would measure variety and, rather than evenness, a match to relative densities, weighted for conditional cases and for resources never harvested. To our knowledge, such an index has not been created.

More reliable would be an assessment of archaeological incidence in light of the relative density adjustments highlighted in Figure 1. Such a measure would allow that a species may always, conditionally, or never appear in the diet. This procedure would discard the rare instance of a species unlikely ever to be harvested, and it would weigh appropriately the incidence of species harvested conditionally. Yet more accurate would be that kind of conditional matching, with allowances for confounding possibilities, like patchy distribution of resources, or near-settlement harvesting by the elderly or children of resource types that would only appear in the encounter-contingent diet of individuals with limited opportunity costs.

Cell 2 resources provide the most interesting and least ambiguous information to an archaeologist. Cell 4 resources may be unambiguous but they also are relatively uninteresting. Archaeologists might hope for cases without the problem of conditional diet breadths. Without Cell 3, a resource type is always taken or never taken. If this were true, an optimal forager would be recognized by incidence of resource types in the archaeological record that reflect their relative densities in the environment. But this is unlikely given the very dynamic character of diet breadth decisions over the short term. It becomes less likely the longer the period over which foraging behavior is conflated in the archaeological record. Moreover, it would not eliminate the low reliability of richness or diversity measures that pick up the anomalous incidences described in Cell 7.

One way to solve this is to calculate proportional species representation (i.e., in the environment) for all possible diet breadths (e.g., first ranked only; first and second ranked; first, second, and third ranked, etc.) and use this information to determine the likely contribution of different diet breadths to given faunal assemblages. That prey density, hence encounter rate, is closely correlated with prey size makes this possible (Waguespack and Surovell 2003; see also Bettinger 2006).

For example, suppose we know from body size that the second ranked prey would have been encountered twice as often as the first ranked prey. While diet breadth limited to just the first ranked prey would obviously produce faunal assemblages representing the remains of only the first ranked prey, diet breadth that included both the first and second ranked prey would produce remains representing twice as many individuals of the second ranked prey as the first ranked prey (i.e., first ranked = 0.33, second ranked = 0.67).

On that logic, a faunal assemblage in which both prey types are equally represented would correspond to a subsistence pattern in which diet breadth was limited to just the first ranked prey 25% of the time and included both prey types 75% of the time: first ranked prey =  $[(1.00 \times .25\%) + (0.33 \times 75\%)] = 50\%$ ; second ranked prey =  $[(0.00 \times 25\%) + (0.67 \times 75\%)] = 50\%$ . Because there will be as many possible diet breadths as there are prey types, determining their individual contributions to a particular set of remains quickly grows cumbersome but can be solved by linear programming. The same approach has been used to determine the likely dietary contribution of different resources by using their individual staple isotope signatures and determining from that the proportions in which each would have to have been consumed to account for the stable isotope values observed in human skeletal remains (Little and Little 1997; Little and Schoeninger 1995).

Whatever methods we choose, there are going to be complications. More than anything else, our elaboration of the diet breadth model in archaeological terms highlights the advantages of having at least two complementary sources of information about the same behavior, information about multiple behaviors reflecting a larger strategy, or samples drawn from several points in time, in comparisons that control for potential anomalies.

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### Costly Signaling in Theory

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Examples of behavior that appear extravagant or wasteful have prompted some in archaeology and related social sciences to invoke interpretations based on costly signaling (Hildebrandt and McGuire 2002, 2003; McGuire et al. 2007). Imprudent expense is, in fact, a theme of the early work of Zahavi (1975, 1977) and others. But the theory of costly signaling has developed and it now is recognized that high cost in itself is neither necessary nor sufficient to assure honest signaling, in that “...even unrelated individuals with conflicting interests can communicate honestly by using cost-free or very cheap signals. Contrary to the “handicap principle,” waste is not required to ensure honest signals” (Lachmann et al. 2001:13189; italics in original). Getty (2006:87) put it this way: “Absolute costs are not sufficient for understanding how differences in viability-fecundity tradeoffs stabilize the signaling in sexual

selection.” The fitness advantage goes not to the individual with the most costly signal, but to the individual most efficient at converting a signal of a given cost into fitness. If honest signals can be cheap, evolution should not favor extravagant, wasteful signals but rather the least expensive signal system possible. Again, “[t]he evolution of sexually selected signals is not a missing piece of Darwin’s puzzle, involving selection for waste, it is an integral piece of the process of evolution by natural selection, involving selection for efficiency” (Getty 2006:87).

Contrary to what has become the working premise of this literature in anthropology, high cost itself—the presumed handicap—is not necessary to assure signal honesty. The relationship between honesty and cost depends on the form of the function relating the quality of the signaler to the cost of signal production. When there is flexibility in that relationship, cheap, even cost-free, honest signals can occur even among individuals with conflicting goals. Language is the pivotal example, sending reliable signals at very low cost because receivers can impose quite high penalties on “signalers who send ‘wrong’ signals” (Lachmann et al. 2001:13190). Signal honesty is maintained by very high out-of-equilibrium costs that punish dishonest signalers; this means that signal costs will be low at equilibrium, the *dishonest* signal being the most costly.

We should expect low-cost, honest signaling any time the receiver can cheaply establish the integrity of the message of the sender. This is easy if the two share coincident interests. For example, if sender and receiver are related, or they rank prospective outcomes in the same order, neither will have any incentive to cheat, even if the payoffs are inequitable (e.g., sender benefits more than receiver). Even when unrelated senders and receivers have noncoincident interests and receive inequitable payoffs, honest signals are possible if the signal can be easily verified (“I can beat you to a pulp”), the interaction is repeated (the boy who cried “Wolf”), or the benefits for fraudulent signals are less than the penalties receivers can impose on fraudulent signalers (again, the boy who cried “Wolf”). As Lachmann et al. (2001:13193) noted, “Because of the social context in which human linguistic communication often occurs (structured populations with repeated interactions), much of human communication falls into the ... [low or no cost signal] ... domain.”

We have similar problems with the “provisioning threshold” concept, the related argument that once subsistence reaches a given level of security—i.e., procurement becomes efficient enough—females will increasingly do the provisioning while males will find ways to gain prestige through costly signaling. Hunter-gatherer specialists will recall the analogous “potlatching threshold” as the environmental possibilist’s explanation for potlatching on the Northwest Coast. To the question, “Why do the Southern Kwakiutl potlatch?” the possibilist answers, “Because they can.” Natural selection, however, provides no reason to think pro-

visioning will ever reach either a potlatching or provisioning threshold. However abundant resources are, a woman alone cannot provision nearly as well as she and her husband could together. So, the provisioning threshold really amounts to this: At what point will families find it in their interest to limit their offspring to numbers wives can provision mostly on their own, permitting husbands to divert their energies from provisioning to status-seeking that leads to extramarital mating opportunities and social alliances? The opportunity costs are potentially significant here, since families more willing to limit family size risk replacement by families less willing. In any event, husband's and wife's interests are not the same and we need to keep both in mind.

Suppose a wife can convince her husband to provision along with her, while she occasionally engages in extramarital matings with costly signalers who hunt and freely distribute costly but much desired big game. As a result, the couple's offspring receive better treatment and survive longer. The woman thus benefits both from her husband's provisioning and the increased fitness of children she has through extramarital showoff matings. This is the crux of what has been termed the "showoff" — or more coarsely, "meat for sex" — model (Hawkes 1990, 1991) that inspired a good deal of current archaeological thinking about costly signaling (Broughton and Bayham 2003; Hildebrandt and McGuire 2002, 2003). Unfortunately, the showoff model has serious shortcomings, the greatest being that it considers only a portion of the relevant costs and benefits for the minimal set of players, usually the net advantages for the showoff and potential female liaisons. It does not take account of net effects via the liaison's husband or the show off's spouse, which must be negative. Indeed, since the showoff is foraging inefficiently by definition, the net effect for all of these individuals must be negative. We might imagine that the showoff can coerce a favorable outcome, but the equilibrium price of doing so would offset the advantages.

In the real world, societies may well limit family sizes and reward wasteful male prestige seekers exactly as envisioned in the provisioning threshold concept and showoff model — but not because these are evolutionarily likely outcomes of natural selection. Rather, as we know from what is termed the "folk theorem" in game theory (Fudenberg and Maskin 1986), any kind of social convention can be stable if enough people adopt it and punish those who do not. Thus, showing that a particular costly signaling scenario is stable (e.g., Gintis et al. 2001) does not mean that it is particularly likely vis-à-vis other possible scenarios.

Prestige seeking is doubtless important in human societies and may explain seemingly irrational economic behavior — feast food carried exorbitant distances, for example. But, as costliness is neither necessary to stabilize honest signals nor sufficient to assure that a signal is occurring, then costly signaling does not

provide a reliable, off-the-shelf answer to the puzzles presented by cases of apparent waste. Other factors must be present: conflict of interests, opaque underlying quality, one-shot (i.e., nonrepeating) interactions, and limited ability to sanction fraudulent signalers. We suspect these factors are quite rare in the small-scale societies to which the costly signaling idea has been most frequently applied.

Dizzy Dean once said, “It ain’t bragging if you can back it up,” and hunter-gatherers are generally in a position to know whether their fellows can. Information about the environment and the people living in it is the stock in trade of the hunter-gatherer world. Hunter-gatherers carefully ticket this information, and it bulks large in their critical life choices — with whom to live, marry, and hunt. Prestige and social standing were achieved under careful scrutiny, over lifetimes. It is likely not by chance that among hunter-gatherers the youngest females generally marry older males, whose behavior and abilities are well known from their whole body of work. A multitude of practices (e.g., bride service) tests these skills. While Aranda men become marriageable upon initiation into their totemic clans sometime between the ages of 14 and 16, they achieve social prominence only if granted access to critically important sacred clan rites, chants, privileges, and paraphernalia, which occurs much later (between the ages of 25 and 40) and only if they continue to act generously and with appropriate deference (Strehlow 1947:97, 121, 122).

Among most hunter-gatherers most of the time, there would be little point in sending a signal to advertise a quality that everyone already knows or can easily verify. With indexing information so freely available, costly signals may not be required to attract allies — individuals who, if they do not already know it, can learn the quality of an advertised alliance. The same goes for mates, if provisioning or other material considerations (e.g., child care) are in question. Indeed, the only plausible rationale for costly signals would seem to be advertising hidden genetic quality (good genes), the “go-to” explanation of much costly signaling. Apart from its inherent ambiguity (what are quality genes?) and difficulty of testing, we find nothing wrong with that argument. Still, these genetic qualities ought to play out in the lives, and over the life spans, of individuals. If good genetic quality is signaled by good hunting, isn’t that the point — good hunting?

Much work on costly signaling takes evolutionary theory to an implausible extreme while largely ignoring a whole body of work on cultural transmission processes that do a pretty good job, via more explicit models, of explaining the kind of seemingly exaggerated cultural behaviors that interest proponents of costly signaling (e.g., Richerson and Boyd 2005:259-271). For example, in a process called *indirectly biased* cultural transmission, individuals pattern their behavior after that of social models selected on the basis of an observable indicator (e.g., hunting success). Indirect bias in cultural transmission can produce a positive feedback loop

between preference and indicator traits exactly like runaway sexual selection in the biological world (Bettinger 1991:200-201).

In brief, imitating the most successful hunter results in acquiring his or her preferences, including the higher than average value he or she assigns to hunting. This will increase both the effort individuals invest in hunting and their preference for successful hunters as social models, potentially leading both to become exaggerated through “runaway” feedback. On this count, the cultural world presents a close analog to the biological world, where exaggerated traits like the peacock’s tail might be a handicap and thus a costly signal of good genes or the result of runaway sexual selection, or some combination of the two (Kokko et al. 2003; McElreath and Boyd 2007:305-326). In the cultural world, prestige hunting might be a costly signal or the result of runaway cultural transmission, or both, and distinguishing these possibilities is likely to be difficult.

When the dust settles, we suspect there will be three eras of modeling costly signaling:

*The Zahavi era* (1975-1990), in which this pioneer advanced an ingenious but at the time not awfully plausible variation on sexual selection (Zahavi 1975, 1977). Few took it seriously (Dawkins and Krebs 1978; Maynard Smith 1976).

*The Grafen/Godfray era* (1990-2000), in which formal mathematical treatment made the idea respectable and the obscurity of the math made metaphorical interpretation attractive (Godfray 1991; Grafen 1990a, 1990b). Applications flourished in biology and, after some delay, in ethnography and archaeology (Bird et al. 2001; Gintis et al. 2001; Hildebrandt and McGuire 2002; Smith and Bird 2000).

*The Lachman/Bergstrom/Getty era* (post-2000), a period of rapid modeling advances inside evolutionary biology still not widely recognized in the social sciences (Bergstrom and Lachmann 1997, 1998; Bergstrom et al. 2002; Getty 2006; Lachmann and Bergstrom 1998; Lachmann et al. 2000, 2001). This period marks a retreat from some metaphorical excesses, especially references to extravagance and wastefulness. This era is still very much in process, leaving us with an intriguing idea that does not yet have the analytical stability of the diet breath model.

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## Conclusions

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In our introduction, we claimed that the papers discussed here, representing work in California and the surrounding region using a behavioral ecology perspective, should attract the attention of an archaeological world that otherwise has

neglected the state. We mentioned several features that eventually will link work in California to issues of much broader importance. While topics like the origins of agriculture, the evolution of social inequality, resource conservation and exploitation, and proliferation of socio-linguistic diversity, etc., are not their immediate subjects, the papers presented here make theoretical, conceptual and methodological contributions that are going to be essential to understanding these problems, in California and elsewhere.

We return finally to the question: What explains foraging, and from this element of economy, other aspects of social evolution and diversification in California? Is it predominantly provisioning, prestige, or some mix? And, what socio-ecological circumstances predict the relative importance of these causal possibilities? Analyses focused on nutritional benefits have the advantage of history. The diet breadth model has been refined and applied for over 40 years; we have a pretty secure sense of the model and its interpretation (Figure 1 and associated text). The significant advances for the diet breadth model in the papers discussed here are typically analytical and focused on how we recover from prehistory the kind of information that will allow us to feel secure about foraging theory interpretations based in nutritional or provisioning benefits. By contrast, the costly signaling model is young, and we cannot securely identify what it requires to be applicable and what it means when it is. We aren't yet in a position to construct a conceptual map of the idea, as we show in Figure 1 for the diet breadth model. Consequently, we likewise are less sure how archaeological data can be mustered to substantiate a costly signaling interpretation. Given the historical importance of subsistence provisioning and social prestige in the broader realm of social theory, it's a sure bet this debate over California prehistory will be a model for similar analyses in other regions of the world.

### ***Editor's Note***

1. This paper provides commentary on the following papers published in the Human Behavioral Ecology section of *California Archaeology* in the first three issues (2009 issues 1 and 2 and the current issue): Bartelink (2009), Beck (2009), Cannon (2009), Codding and Jones (this issue), Hildebrandt et al. (2009), Morgan (2009), Whitaker (2009), and Wohlgenuth (this issue). All of these papers were originally presented at the 2007 annual meeting of the Society for California Archaeology in the symposium, "Human Behavioral Ecology and California Archaeology," organized by Adie Whitaker and Deanna N. Grimstead.

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**References Cited**

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Bartelink, Eric J.

- 2009 Late Holocene Dietary Change in the San Francisco Bay Area: Stable Isotope Evidence for an Expansion in Diet Breadth. *California Archaeology* 1:227–252

Beck, R. Kelly

- 2009 The Molecular Genetics of Prey Choice: Using Ancient DNA to Infer Prehistoric Population Histories. *California Archaeology* 1:253–268.

Bergstrom, Carl T., and Michael Lachmann

- 1997 Signaling among Relatives. I. Is Costly Signaling *Too* Costly? *Philosophical Transactions: Biological Sciences* 352:609–617.

- 1998 Signaling among Relatives. III. Talk is Cheap. *Proceedings of the National Academy of Sciences* 95:5100–5105.

Bergstrom, Carl T., Szabolcs Számadó, and Michael Lachmann

- 2002 Separating Equilibria in Continuous Signaling Games. *Philosophical Transactions: Biological Sciences* 357:1595–1606.

Bettinger, Robert L.

- 1991 *Hunter-Gatherers: Archaeological and Evolutionary Perspectives*. Plenum Press, New York.

- 2006 Agriculture, Archaeology, and Human Behavioral Ecology. In *Foraging Theory and the Transition to Agriculture*, edited by Douglas J. Kennett and Bruce Winterhalder, pp. 304–322. University of California Press, Berkeley.

Binford, Lewis R.

- 2001 *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. University of California Press, Berkeley.

Bird, Rebecca Bliege, Eric A. Smith, and Douglas W. Bird

- 2001 The Hunting Handicap: Costly Signaling in Human Foraging Strategies. *Behavioral Ecology and Sociology* 50:9–19.

Broughton, Jack M., and Frank E. Bayham

- 2003 Showing Off, Foraging Models, and the Ascendance of Large-Game Hunting in the California Middle Archaic. *American Antiquity* 68:783–789.

Cannon, Michael D.

- 2009 When Should We Expect to See Hunting as Mating Effort? *California Archaeology* 1:79–92.

Dawkins, Richard, and John R. Krebs

- 1978 Animal Signals: Information or Manipulation? In *Behavioural Ecology: An Evolutionary Approach*, edited by John R. Krebs and N. B. Davies, pp. 282–309. Blackwell, Oxford.

Fudenberg, Drew, and Eric S. Maskin

- 1986 The Folk Theorem in Repeated Games with Discounting or with Incomplete Information. *Econometrica* 54:533–556.

Getty, Thomas

- 2006 Sexually Selected Signals are not Similar to Sports Handicaps. *Trends in Ecology and Evolution* 21:83–88.

Gintis, Herbert, Eric A. Smith, and Samuel Bowles

- 2001 Costly Signaling and Cooperation. *Journal of Theoretical Biology* 213:103–119.

Godfray, H. C. J.

- 1991 Signaling of Need by Offspring to Their Parents. *Nature* 352:328–330.



Grafen, Alan

- 1990a Biological Signals as Handicaps. *Journal of Theoretical Biology* 144:517–546.
- 1990b Sexual Selection Unhandicapped by the Fischer Process. *Journal of Theoretical Biology* 144:473–519.

Grayson, Donald K., and Françoise Delpech

- 1998 Changing Diet Breadth in the Early Upper Paleolithic of Southwestern France. *Journal of Archaeological Science* 25:1119–1129.

Grayson, Donald K., Françoise Delpech, Jean-Philippe Rigaud, and Jan F. Simek

- 2001 Explaining the Development of Dietary Dominance by a Dingle Ungulate Taxon at Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 28:115–125.

Hawkes, Kristen

- 1990 Why Do Men Hunt? Benefits for Risky Choices. In *Risk and Uncertainty in Tribal and Peasant Economies*, edited by Elizabeth Cashdan, pp. 145–166. Westview Press, Boulder, Colorado.
- 1991 Showing Off: Tests of an Hypothesis About Men's Foraging Goals. *Ethology and Sociobiology* 12:29–54.

Hildebrandt, William R., and Kelly R. McGuire

- 2002 The Ascendance of Hunting during the California Middle Archaic: An Evolutionary Perspective. *American Antiquity* 67:231–256.
- 2003 Large-Game Hunting, Gender-Differentiated Work Organization, and the Role of Evolutionary Ecology in California and Great Basin Prehistory: A Reply to Broughton and Bayham. *American Antiquity* 68:790–792.

Hildebrandt, William R., Jeffrey Rosenthal, and Glenn Gmoser

- 2009 Shellfish Transport, Caloric Return Rates, and Prehistoric Feasting on the Laguna de Santa Rosa, Alta California. *California Archaeology* 1:55–78.

Kokko, Hanna, Robert Brooks, Michael D. Jennions, and Josephine Morley

- 2003 The Evolution of Mate Choice and Mating Biases. *Proceedings of the Royal Society of London, Series B* 270:653–664.

Lachmann, Michael, and Carl T. Bergstrom

- 1998 Signalling among Relatives. II. Beyond the Tower of Babel. *Theoretical Population Biology* 54:146–160.

Lachmann, Michael, Carl T. Bergstrom, and Szabolcs Számadó

- 2000 The Death of Costly signalling? *Sante Fe Institute Working Papers* 00-12-074.

Lachmann, Michael, Szabolcs Számadó, and Carl T. Bergstrom

- 2001 Cost and Conflict in Animal Signals and Human Language. *Proceedings of the National Academy of Sciences USA* 98:13189–13194.

Little, Elizabeth A., and Margaret J. Schoeninger

- 1995 The Late Woodland Diet on Nantucket Island and the Problem of Maize in Coastal New England. *American Antiquity* 60:351–368.

Little, John D. C., and Elizabeth A. Little

- 1997 Analyzing Prehistoric Diets by Linear Programming. *Journal of Archaeological Science* 24:741–747.

MacArthur, Robert H., and Eric R. Pianka

- 1966 On Optimal Use of a Patchy Environment. *The American Naturalist* 100:603–609.

- Madsen, David B., and James E. Kirkman  
 1988 Hunting Hoppers. *American Antiquity* 53:593–604.
- Maynard Smith, J.  
 1976 Sexual Selection and the Handicap Principle. *Journal of Theoretical Biology* 57:239–242.
- McElreath, Richard, and Robert Boyd  
 2007 *Mathematical Models of Social Evolution: A Guide for the Perplexed*. University of Chicago Press, Chicago.
- McGuire, Kelly R., William R. Hildebrandt, and Kimberly L. Carpenter  
 2007 Costly Signaling and the Ascendance of No-Can-Do Archaeology: A Reply to Codding and Jones. *American Antiquity* 72:358–365.
- Morgan, Christopher  
 2009 Optimal Foraging Patterns in the Sierra Nevada, Alta California. *California Archaeology* 1:205–226.
- Richerson, Peter J., and Robert Boyd  
 2005 *Not by Genes Alone: How Culture Transformed Human Evolution*. University of Chicago Press, Chicago.
- Smith, Eric A.  
 1991 *Inujjamiut Foraging Strategies: Evolutionary Ecology of an Arctic Hunting Economy*. Aldine de Gruyter, New York.
- Smith, Eric A., and Rebecca L. Bliege Bird  
 2000 Turtle Hunting and Tombstone Opening: Public Generosity as Costly Signaling. *Evolution and Human Behavior* 21:245–261.
- Stephens, David W., and John R. Krebs  
 1986 *Foraging Theory*. Princeton University Press, Princeton, NJ.
- Strehlow, Theodor G. H.  
 1947 *Aranda Traditions*. Melbourne University Press, Melbourne.
- Ubelaker, Douglas  
 2006 Population Size, Contact to Nadir. In *Environment, Origins, and Population*, edited by D. Stanford, B. D. Smith, D. Ubelaker, and E. Szathmary, pp. 694–701. Handbook of North American Indians, vol. 3, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.
- Waguespack, Nicole M., and Todd A. Surovell  
 2003 Clovis Hunting Strategies, or How To Make Out on Plentiful Resources. *American Antiquity* 68:333–352.
- Whitaker, Adrian R.  
 2009 Are Deer Really Susceptible to Resource Depression? Modeling Deer (*Odocoileus hemionus*) Populations under Human Predation. *California Archaeology* 1:03–108.
- Winterhalder, Bruce, and Carol Goland  
 1997 An Evolutionary Ecology Perspective on Diet Choice, Risk, and Plant Domestication. In *People, Plants, and Landscapes: Studies in Paleoethnobotany*, edited by Kristen J. Gremillion, pp. 123–160. University of Alabama Press, Tuscaloosa.
- Zahavi, Amotz  
 1975 Mate Selection, A Selection for a Handicap. *Journal of Theoretical Biology* 53:205–213.  
 1977 The Cost of Honesty (Further Remarks on the Handicap Principle). *Journal of Theoretical Biology* 67:603–605.

