THE IMPLICATIONS OF COALITIONAL ENFORCEMENT AND THE ADOPTION OF THE BOW AND ARROW IN THE PREHISPANIC SOUTHWEST

BY

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THE IMPLICATIONS OF COALITIONAL ENFORCEMENT AND THE ADOPTION OF THE BOW AND ARROW IN THE PREHISPANIC SOUTHWEST

Abstract

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This thesis examines the potential correlation between group size and the introduction of the bow and arrow in the prehispanic U.S. Southwest. I explore a hypothesis proposed by Paul M. Bingham (1999) in which he uses biological, archaeological, and historical data to claim that coalitions of humans universally increased in size following increases in ability to remotely kill a non-cooperator. Coupling a larger group size with the ability to remotely kill a defector, groups are able to reduce risk to the punishers, and gain from the benefits that cooperation and larger group sizes bring. The hypothesis proposes that the "range and performance of [distance weaponry] limit the size and internal structure of cooperative human coalitions" (Bingham 2000:254).

I present archaeological data that tend to support the coalitional enforcement hypothesis, as do behavioral experiments and theory on social dilemmas. One impact of the introduction of the bow and arrow seems to have been to precipitate important changes in coalitional enforcement and, subsequently, coalition size within the prehispanic Southwest.

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1| INTRODUCTION

The introduction of the bow and arrow into the prehispanic Southwest has long been recognized as adaptively significant, yielding a wide range of impacts. Coupled with other cultural practices, including the increased reliance on cultigens, the advantages the bow and arrow brought to hunting and warfare have oft been argued as important in prompting the demographic and organizational changes visible in the mid- to late-first millennium A.D. While such hypotheses may bear weight, they fail to consider the possibility that the bow and arrow played a role in within-group cooperation dynamics, possibly allowed larger settlements and communities to form, and encouraged the emergence of levels of organizational complexity beyond the family group and lineage.

Though resource availability and production are clearly important to human group sizes, maximum group size is limited by other factors as well. One vital factor is cooperative instability. Cooperation, a behavior unique to humans in its sheer scale and complexity, is essential to consider when assessing demographic expansion. As a word that has been defined variably in popular contexts and within the literature, “cooperation” must be outlined clearly in order to be of use. Thus, for the purpose of this argument, West et al.’s definition of cooperation, “a behaviour which provides a benefit to another individual (recipient), and which is selected for because of its beneficial effect on the recipient” (2007b:416) will be applied. This definition encompasses two large classes of cooperative behavior—those providing direct fitness benefits to the actor (outweighing the cost of performing the action), and those providing indirect fitness benefits, by enhancing the fitness of the actor’s kin or other individuals carrying the cooperative behavior. Simply put, cooperation allows for collective actions capable of producing net rewards higher than those obtainable by individuals acting alone. However, some cooperative actions allow the possibility of a "defection" strategy. In these situations, cooperative individuals expend energy to complete the collective action, whereas defectors avoid cooperating and its associated cost, yet strive to receive a portion of the benefit. Defection may often offer a higher net payoff than cooperation. The existence of defectors lowers the cost-benefit ratio to cooperators, and commonly leads to the dissolution of cooperative behavior. Thus, large-scale cooperation is a collective human behavior requiring explanation. Increases in the stability of cooperative behaviors can have several causes, and likewise is expected to have several effects on group complexity, group size, potentially visible in the archaeological record.

In this thesis, I examine the coalitional enforcement hypothesis forwarded by biologist Paul Bingham (1999, 2000), in which he argues that human uniqueness and the high level of ecological dominance that we have achieved are the result of the human ability to enforce high levels of cooperation by cost-effective punishment of those who do not cooperate. The ability to punish at a reasonable cost, he argues, is due to the human ability to punish conspecifics remotely with the use of projectile weaponry. This model has not in general been noticed—or evaluated— by archaeologists. Shea's (2006) work on the origins of projectile points in the Levant, Africa, and Europe is the only previous archaeological research to include a discussion of the coalitional enforcement hypothesis that I have been able to find.

The coalitional enforcement hypothesis deserves an examination for several notable reasons. First, some other mechanisms for ways in which humans have overcome cooperative instability (discussed in Chapter 2) are fairly static across time—these practices would have been as available to ancestral humans as they are to present humans. Archaeologically, earlier groups have tended to practice lower density and simpler forms of organization than later groups. If earlier groups could have solved the problem of defection, then why are larger groups not seen archaeologically until fairly late in human history? Because the coalitional enforcement model relies on available projectile weaponry, it can account for variance in group size and cooperation over time, rather than simply relying on arguments of ecological carrying capacity. Second, the link between projectile weaponry and the coalitional enforcement hypothesis can also be examined archaeologically. Within the prehispanic Southwest archaeologists have researched both the replacement of the atlatl by the bow and arrow, as well as the changes in group size and organizational structure. Should the hypothesis be valid, it should have measurable archaeological effects.

At its base, this thesis is built upon the notion that many aspects of human organizational complexity must be understood through an examination of human cooperation. An underlying assumption is that, to some extent, larger patterns of human behavior may be understood by studying relevant, more discrete parts of behavior. One area of behavior where this type of reductionism can be helpful is the study of the emergence of cooperation. Cooperation in human society is complex, both due to questions surrounding the adaptive benefit of such behavior and due to interaction among groups of individuals as opposed to interactions among individuals. A reductionist approach to examining complexity in terms of the factors that are important in the emergence of cooperation does ignore individuality—perhaps necessarily when that examination is done via the archaeological record. In any case, most of an individual's idiosyncrasies and preferences can only be realized once her basic needs are met. These needs, including a minimum amount of calories and water necessary for survival, underlie and preempt other behavioral intricacies, and should these needs not be satisfied, the individual in question will perish, regardless of personal ethos, intricacies of culture and belief, or subsistence practices. Thus, a very basic part of human life can be understood in a rough quantitative manner, e.g., if an individual's caloric intake is less than the minimum needed to survive, the individual dies. This reductive approach can be applied to studying fitness as well. Not all actions practiced by individuals and groups increase their fitness. Over time, though, actions that do increases the fitness of an individual or a group will be selected for, and should be become more visible. Thus, studying the impacts of the bow and arrow on prehistoric group size—by way of an examination of the economics of cooperation—is valid insofar as it is built on an accurate behavioral base, and can represent those adaptationally significant behaviors that are more likely to appear within the archaeological record.

By understanding cooperation, it is possible to visualize the framework in which organizational complexity may arise. This position is of course not completely original (see Dutta 1989; Fehr and Gachter 2002; Packer 1988; Read 2002). Group size, for example, may not reflect resource carrying capacity, or a group's desired structure. Small, egalitarian groups in environments that could support larger and denser populations may be limited in size by the difficulty paying the monitoring and punishment costs necessary to deter non-cooperation and hoarding were they to grow. A relatively "pure" form of egalitarianism may be impossible beyond a very small group size. A desire to avoid strong forms of inequality inherent in many forms of permanent hierarchy may lead to larger groups that can be described as having an "egalitarian ethos." In some cases such groups may display high levels of intra- and extra-group cooperation and employ a corporate strategy of organization (Feinman 1995, 2000).

Because I examine changes in groups' organizational strategies, generally from less stratified and less complex forms to more stratified, and more complex forms, I will explain how this thesis views "complexity." First, studying complexity through the lens of cooperative behavior will allow us to avoid many issues that plague traditional studies of organizational complexity. Critiques of research on group organizational complexity often argue that comparing differences in group organization often involves an evolutionary or directional emphasis. Some critics worry that groups labeled "simple" or "primitive" have an implied inferiority, while "complex" forms of organization are felt to be both the "goal" and the ideal of human groups. The study of organizational change through changes in cooperative stability avoids these issues by looking at universal needs and limitations on how groups can form and stabilize beyond the level of the family group, and what sizes such groups may attain. The existence of scales in size and complexity does not imply a bias towards the size and complexity of current Western societies. As noted by Price and Brown, "complexity is not a phenomenon limited to societies of advanced agriculturalists" (1985:4). I use "complexity" purely as an indicator of degrees of hierarchy and permanence of a group's organizational structure, and not as an indication of merit.

This thesis begins by providing a brief overview of some recent theories on cooperation that pertain to the general argument (Chapter 2). I then examine human behavioral research, the results of which help establish the universal nature of cooperation and punishment (Chapter 3). I then discuss the archaeological expectations of Bingham's model for the U.S. Southwest (Chapter 4), and conclude by examining the data currently available in this archaeological record to assess the hypothesis relating to the bow and arrow (Chapter 5) and regional demographic and organizational structure changes around the time that the bow and arrow was adopted (Chapter 6).

The transition from atlatl to bow and arrow technology in the Southwest is a central aspect of the archaeological record investigated (Chapter 5) and requires an examination of whether the bow can be considered more efficient than the atlatl. Efficiency is here defined as increased effectiveness in the punishment of defectors, with a resulting reduction in risk to punishers. After considering the differences in these projectile technologies, I discuss the culture history of the groups being examined here, focusing on the time periods and archaeological data that are most relevant to the hypothesis. Finally, I conclude by evaluating the coalitional enforcement hypothesis for the prehispanic Southwest, and suggesting additional research that could build on the work developed here to help better understand the prehistory of the region.

2| Recent Research on the Evolution of Cooperation

This chapter provides an in-depth examination of research on the evolution of cooperation, and discusses how cooperation has been studied. This chapter does not attempt a complete synthesis of the work that has been done on cooperative behavior. It is my goal, however, to provide data that will help clarify how humans have achieved their present high levels of cooperative stability, and how the various mechanisms proposed for such cooperation complement, or undermine, the coalitional enforcement hypothesis.

Basic Structure of Cooperative Actions

Humans display a degree of cooperation among non-kin that is unique among animals (Bingham 1999, 2000; Boyd et al. 2003; Fehr and Fischbacher 2003), which Bingham (1999:134) believes to be "the ultimate source of human ecological dominance." Cooperation allows for collective actions capable of producing net rewards higher than those obtainable by individuals acting alone. Rewards include direct fitness rewards, in terms of immediate payoff, or in rewards from reciprocal altruism as defined by Trivers (1972), and models involving reward, punishment, strong reciprocity, and indirect reciprocity based on reputation.

Rousseau (1755 [1950]) imagined one of the earlier explanations of cooperative behavior. Rousseau described a situation in which individuals join together to hunt a stag, a valuable resource that cannot be taken by a lone hunter. An individual can, during the course of the hunt, abandon the group and opportunistically hunt hare, a less valuable resource, but also one that is less costly to obtain and more numerous. In this way cooperation (stag hunting) also creates a niche for defectors who may get a net payoff higher than that available to cooperators. Defectors seek the benefits of the cooperative action while avoiding the costs associated with cooperation (Bingham 1999:134-135). Consider an individual consuming a public good that they did not help acquire. The cooperative action producing the good was successful, and though the defector paid no cost, he nonetheless reaps a reward. In other situations, such as the stag hunt, should one of the "cooperators" fail to cooperate, the hunt may *not* succeed, and the individuals who participated fare worse than had they foregone the stag hunt and hunted hare (alone), as did the non-cooperator. As these examples illustrate, individuals are often better served by striving for the less risky, though less rewarding, non-cooperative action. Because cooperation is inherently prone to attrition through the pursuit of self-interest, it is, at its base, unstable. The instability has also been envisioned through the powerful metaphor of "the tragedy of the commons." An example of a communal sheep pasture is presented in West et al. (2007a). Each individual shepherd has an incentive to add more sheep to the pasture, as it increases the shepherd's available resources. However, if too many sheep are added, then the pasture becomes overgrazed and the group suffers. Because the benefit of adding more sheep outweighs the individual's share of the cost of an overgrazed pasture, even though this cost may be quite high, an individual is likely to pursue a selfish strategy rather than cooperate in maintaining the resource (West et al. 2007a:R661).

Problems with cooperative instability limit cooperation in most non-human animals, which generally do not cooperate with unrelated individuals. Cooperation throughout the animal kingdom is seen within kin networks, since cooperating with those to whom you are related confers inclusive kinship benefits, defined as the sum of both direct and indirect fitness (indirect fitness being weighted by relatedness) (Hamilton 1964; West et al.

2007b:416). Non-cooperative individuals are referred to in several different ways depending on context, author, or literature type, but for the purpose of this thesis they will be referred to as either “non-cooperators” or “defectors” interchangeably. Defection means only failure to abide by a social contract, and does not signify a “switching of sides”—such as from one group to another. Finally, defection from a social contract does not necessarily indicate complete failure to cooperate. It also includes situations in which the defector cooperates, but contributes a less-than-fair share.

Quantitative Examinations

Before progressing further into recent ideas on cooperation and ways in which humans have achieved an unprecedented level of cooperative stability, we should discuss the underlying methodology common in examining cooperation. Cooperation is often modeled using payoff matrices and systems of dynamic equations in which concepts like “stability” have a precise meaning. These can be useful, as the simplification and standardization they bring lead to better understanding of the forces driving decisions to cooperate or defect. Although I do not use either of these quantitative approaches when examining the coalitional enforcement hypothesis, I review them briefly now as a useful rubric for thinking about cooperation. Okada and Bingham (2008) present a quantitative examination of the coalitional enforcement hypothesis that will not be duplicated here, although it is discussed briefly in the section below on cooperative punishment.

Symmetric Payoff Matrices. Payoff matrices simplify cooperative actions, and are often the easiest to visualize. Along with the commonly used and well-known “Prisoner’s Dilemma” there are three additional social dilemmas whose payoff matrices are sometimes studied. Table 1 presents the construction of a simple payoff matrix. Depending on the game, the payoffs vary. In terms of “Ego”, the payoffs represent mutual cooperation “CC”, unilateral defection “DC”, unilateral cooperation “CD”, and mutual defection “DD” (Poundstone 1992:217). The games shown in Table 2 represents only a fraction of the way that payoff matrices can be varied, depending on context and question being asked, but provides a general feel for how the payoff matrix may be manipulated. All of these situations represent social dilemmas; they all punish unilateral cooperators, but reward mutual cooperation more than mutual defection, thus posing in a particularly clear fashion the dilemma as to whether or not to cooperate. Individuals are prone to defect since unilateral defection provides the highest payoffs in most of these dilemmas.

Table 1: General Cooperation Payoff Matrix.

		Other	
		Coop	Defect
Ego	Coop	CC	CD
	Defect	DC	DD

Table 2: Examples of Cooperation Games and Ordering of Payoffs (from Poundstone 1992).

Game	Payoff
Prisoner’s Dilemma	DC>CC>DD>CD
Stag Hunt	CC>DC>DD>CD
Deadlock	DC>CC>DD>CD
Chicken	DC>CC>CD>DD

The games represented in Table 2 can be used to examine a wide range of social and economic interactions. I refer the reader to other sources for detailed discussion of these games (e.g. Poundstone 1992).

The Prisoner’s Dilemma, probably the most commonly used payoff matrix, has often been illustrated using an allegory of two prisoners. If both of the prisoners cooperate (with each other) and do not confess to their joint crime, then they both receive a reduced sentence as evidence is lacking for a conviction (CC in Table 1, "b-c" in Table 3). If both defect (from the social contract they have with each other) by accusing the other and cooperating with the police, then each receives a reduced sentence (DD in Table 1, "0" in Table 3). However, if only one defects (accuses the other) while the other cooperates (keeps quiet) then the accuser goes free, while the other receives the stiffest sentence possible. This game demonstrates that as long as the payoffs are structured according to those shown in Table 2, mutual defection is the most likely scenario. While the sum of the payoffs to individuals is highest when they cooperate (stay silent) it is nonetheless always in the individual's best interest to defect, as defection holds the promise of the highest individual payoff and avoids the risk of getting lowest. In this case, and used as an argument against easily obtainable cooperation, defection is the stable outcome, despite it being an undesired outcome. Table 3 illustrates such a generalized payoff matrix for the Prisoner's Dilemma.

Table 3: Quantitative Payoff Matrix for a Prisoner's Dilemma

		Other	
		Coop	Defect
Ego	Coop	$\frac{B_c}{n}$ - C_c	- C_c
	Defect	$\frac{B_c}{n}$	0

Here B_c represents the payoff of the cooperative action, C_c its cost, and n the number of individuals. For simplicity, mutual defection has been labeled as "zero", and while possible in these games, it is also possible that mutual defection offers a net loss, or a small net gain. The table could be modified to represent this and still fit the confines of the game by assigning a further element of cost that applies to the cells, including mutual defection.

Payoff matrices provide a way to unambiguously state the costs and benefits of cooperation. In order to predict the long-term behavior of a cooperative system, or to understand under what conditions cooperation may be stable within the system, it is more useful to examine the action in equation format.

Mathematical examinations. Equations are particularly valuable since they may be studied to find situations in which equilibria are achieved. Although equilibria can be understood through the use of payoff matrices—remember, for example, that mutual defection is the likely result in the Prisoner's Dilemma—matrices generally depend upon displaying the data so that the dominant strategies are visible, and not necessarily the tipping points for when different strategies emerge as stable. Although the formulae can vary, as did the values within the payoff matrices, equations 1, 2a, and 3a below show the general cooperation payoff formulas. Equation 1 is that of an individual operating on an individual strategy, outside of the bonds of any sort of collective action. This equation can be ignored for present purposes, as the individual referenced is not engaging in any collective action, and will neither be capable of cooperating nor defecting. Equations 2a and 3a represent alternate ways of calculating payoffs as payoff matrices. These equations are given in terms of "2a" and "3a" as they will be expanded later to include additional variables. None of the equations are specific to a particular game, nor are they particularly valuable for studying cooperation beyond a one-time interaction. The simple payoff for individual action (1), cooperating *c* (2a), and defecting individuals *d* (3a) is expressed as:

$$P_s = B_s - C_s \quad \text{Equation 1}$$

$$P_c = \frac{B_c}{n} - C_c \quad \text{Equation 2a}$$

$$P_d = \frac{B_c}{n} \quad \text{Equation 3a}$$

Here *P* denotes the payoff, *B* the action's benefit, *C* is the action's cost, and *n* the number of individuals sharing the benefit, to the individual/solo (*s*), cooperative (*c*), or defecting (*d*) individuals. It should also be noted, that $B_s < B_c$ for all instances. If this were not the case there would be no benefit to the collective action and everyone would pursue individual strategies.

Examining cooperation mathematically not only allows the examination of complex one-time interactions, but can also be expanded to study interactions over several generations, which is especially valuable when looking for equilibrium points in a cooperative action. The above equations would need a recursive element added in order to study multi-generation cooperative actions. Studying cooperation in this manner is often termed as "quantitative modeling." The use of computer agent based models is increasing and provides a way of studying complex interactions that would be mathematically intractable. The use of both quantitative and computer-based modeling to study cooperation is fairly common (e.g. Hauert and Doebeli 2004; Killingback and Doebeli 2002; Okada and Bingham 2008).

Asymmetries and Equilibria. All the games up to this point have been examples of symmetric games. In these scenarios, the payoff is identical for each participating individual. This is a reasonable design, as many real-life cooperative actions do result in equal distribution of benefits. Some actions, however, do *not* confer equal benefits to all participants/players; these actions can be examined using similar methods, using asymmetric games.

A commonly analyzed asymmetric game is the Hawk-Dove game. Two different strategies are employed in this game—hawk and dove. Hawks always fight over a resource, while doves always avoid confrontation. If two hawks come across a resource they will fight, and one of them is randomly chosen as the winner and receives the resource, while the other is injured and receives nothing. If a dove and a hawk come across the resource, the dove will fly off and the hawk will receive the resource. When two doves come across a resource, one dove will randomly receive the resource and the other will move on. A notable variant of this game, with asymmetric payoffs, includes agents who practice the “Bourgeois” strategy. These agents change their strategy depending on whether they arrive first at a resource or not. If first, they adopt a hawk strategy, if second, they adopt a dove strategy. This strategy performs better than either of the other strategies, and will drive the other strategies to extinction when Bourgeois agents are sufficiently numerous (McElreath and Boyd 2007:55-57). Games with asymmetric payoffs and asymmetric strategies can be very useful in studying cooperative and economic interactions, but are not examined in this thesis. McElreath and Boyd (2007) offer a recent useful guide to mathematical models for social evolution that emphasizes game-theoretic approaches.

Understanding the long-run stability of cooperative actions is one goal of the mathematical approach. Different kinds of strategies must be analyzed in somewhat different ways. Equilibrium analysis (McElreath and Boyd 2007:41-46) makes it possible to determine whether there is an evolutionary stable strategy (ESS) in which one strategy cannot be displaced by another; or whether, alternatively, there can be a stable mix of strategies. An ESS is able to withstand the invasion of another strategy—to a degree. Slight perturbations will cause the system to return to the ESS, but these strategies may fail when a large number of individuals following a different strategy invade. This can cause the system to settle on a different ESS. While there is at least one stable strategy for finite cooperative games, there is not necessarily only one strategy that may prove stable. Further, the strategy that may prove stable may not be the most desirable outcome, as in shown in the tendency for mutual defection in the Prisoner's Dilemma and echoed by Phillip Straffin Jr. when he noted that these equilibrium points may have "strange and undesirable properties" (Straffin 1980 , quoted in Poundstone 1992:99).

Issues with Defection and Possible Solutions

The Problem with Defectors.

Effectively parasites, defectors decrease the benefit relative to the cost of cooperation, either by decreasing the benefits from cooperation or by adding to its costs (Equation 2a). If the benefit of a collective action is shared among all individuals within the group, and not restricted to those who have successfully contributed to the cooperative effort, such as in a public good (originally forwarded as a "collective consumption good" by Samuelson [1954]), then defectors will cause the benefit to be stretched thin—having avoided the cost of the effort, but reaping the benefits—while those who did contribute receive a reduced net payoff as compared with defectors. This can prevent the evolution or spread of cooperation in some cases. Bingham (1999, 2000) breaks cooperative actions into three categories that differ in the impact that defection has on cooperation. *Primary mutualistic* behaviors are those in which only the participating individuals receive any benefit, and include actions such as mating. It should be noted that the terms "mutualistic" and "mutualism" are defined in this thesis as actions that are mutually beneficial, following West et al.'s (2007a:418) wariness of the term, as it has a commonly used and different meaning in ecological literature. *Secondary mutualistic* behaviors are those in which defection does not reduce the net payoff of the cooperative behavior to the point that cooperation is a maladaptive strategy. In these situations, a cooperator will be willing to individually punish a defector up to the point that the collective action would no longer have a net benefit. Examples of this include situations in which it is easy to gather more of a resource than needed, such as in a game drive or fish weir, where a certain amount of theft can be tolerated. *Tertiary mutualistic* behaviors, the focus of this discussion, are low-return cooperative behaviors in which defection erodes the benefit of the action to the cooperator so much as to preclude future cooperation. In these low-return cooperative behaviors an individual does not receive enough benefit from punishing a non-cooperator to warrant accruing the cost associated with punishing. When defection is present, these actions are not beneficial for cooperators. An example can be seen where a collective action generates six units of benefit that can be "stolen" by a defector. Punishment of the defector costs five units of benefit, which thus would reduce the net gains of the collective action to a cooperator down to only one unit benefit—which is likely lower than they could get by engaging in a different action. If several cooperators join in to punish the defector, in what Bingham (1999:135-137) terms "coalitional punishment," the five units of benefit required to punish a defector are shared among the group, increasing the benefit of the collective action for each cooperator up to the point that the collective action is again mutually beneficial. Thus, for a cooperative action to be successful, either: 1) the number of non-cooperators must be low enough that the benefit of cooperation remains high, 2) some other benefit must be in place to reward cooperation, or 3) some sort of structure must be in place to detect and punish, and thereby deter, non-cooperation.

The first case, which refers to primary and secondary mutualistic behaviors, needs little discussion, as defection does not deter future cooperation. The second option speaks to the existence of additional benefits to cooperators aside from the benefit associated with the cooperative action. This possibility has been discussed in several different treatments, and includes ideas such as reciprocal altruism, reputation-based cooperation, and costly signaling. Although the importance of such mechanisms cannot be denied, I assume that option three is a primary solution to the issue of defection, and that specifically, high levels of human cooperation rely on the ability to cost-effectively punish defectors through the use of projectile weaponry. I believe that this position is supported by the archaeological record. Within the prehispanic Southwest, increases in population and organizational complexity are seen following the middle of the first millennium A.D., with groups transitioning from dispersed family and lineage-based groups into larger micro and macroband levels of organization. Within this period, it is unlikely that many additional benefits for cooperation would be available that could account for the demographic changes, whereas the recently introduced bow and arrow may be able to account for the changes.

Altruism and Reciprocity

As discussed briefly above, high levels of cooperative behavior are not seen outside of hominins except among kin. Because of the detriment to continued cooperation brought on by defectors, cooperation is generally maladaptive in cases when it does not bring inclusive kinship benefits. This section details some previous research and ideas on why and how humans are able to cooperate in large groups with unrelated individuals. These concepts have received far more attention and have more empirical testing than the coalitional enforcement model has. Thus, the coalitional enforcement model is sort of a "newcomer" to the field—a discussion of solutions to large-scale cooperation needs to explain the model's place among the more traditional arguments, and why it may be able to account for cooperative stability in situations in which traditional concepts cannot.

One concept forwarded over the last decades that offers a possible solution to the question of why humans cooperate is *reciprocity*. The theory of "reciprocal altruism" (initially forwarded by Trivers [1971] to refer to cases where an individual is able to confer a benefit upon an unrelated other at a cost to the individual) holds a privileged position. When the benefit to the recipient is greater than the cost to the "altruist", and where the recipient is willing to reciprocate and repay the altruist at a later time, selection can favor the altruism. West et al. (2007b:420) rightly note that this does not represent true altruism since the expended cost is dependent on the anticipated eventual benefit. It might better be termed *reciprocity* or reciprocal cooperation (West et al. 2007b:420). "Reciprocal altruism" as used by Trivers is a form of direct reciprocity, and therefore is of limited use in larger groups. As group size increases, it becomes increasingly difficult to monitor each individual and each interaction. Relying upon the reciprocity of a recipient becomes more and more prone to undetected cheating as the number of interactions and individuals associated with each action rises. Fehr and Fischbacher (2003) posit that the capability of humans to accurately detect cheating also indicates that an altruistic baseline is not to be expected. Thus, it is unlikely that reciprocal altruism can account for the level of cooperation seen in very large groups. Boyd and Richerson (1992) show that group size does limit the level of cooperation seen in large groups, except for cases in which the long-run benefit of punishing outweighs the cost of coercing cooperation and in cases where the cost of punishment of defectors and non-punishing cooperators is enacted and severe. In the first case, a mixed set of strategies oscillates around equilibrium and is similar to strong reciprocity (discussed below). In the second, "moralistic" tendencies arise which promote cooperation (Boyd and Richerson 1992:172).

Another argument for cooperative stability comes through the idea of reputation building, which is often discussed as *indirect reciprocity*. This mechanism was originally proposed by Alexander (1987) and later formalized and modeled by Nowak and Sigmund (1998a, 1998b). Indirect reciprocity involves "reputation and status, and results in everyone in the group continually being assessed and reassessed" (Alexander 1987:85). It functions differently from direct reciprocity as individuals do not necessarily expect reciprocation from the individual they have cooperated with, but rather expect reciprocation from the community at large, in proportion to their reputation or status. A donor is more likely to help out an individual who has a history of helping out others in the group, as this increases the chances of future cooperation that will at some point work its way back to their benefit. Nowak and Sigmund (1998b) refer to reputation as an *image score*, which goes up when an individual cooperates and goes down when an individual defects. It is assumed that everyone in the group is able to keep track of everyone else's image score. Nowak and Sigmund offer several strategies they argue are used in cooperative actions. *Discriminators* (DISC) decide to cooperate based on the image score of the recipient, refusing to help those with low image scores. In one-shot (unrepeated) interactions discriminators can resist invasion by defectors. *Indiscriminate Defectors* (ALLD) always defect, while *indiscriminate altruists* (ALLC) always cooperate. When indiscriminate altruists/unconditional cooperators are introduced, defection is found to be the only evolutionarily stable strategy. However, if the initial population of defectors is low enough, then the strategies will cycle around a neutral/mixed equilibrium (Nowak and Sigmund 1998a). A limitation of the discriminator strategy is that a discriminator's image score is lowered when they defect from cooperating with an agent with a low image score. *Standing* has been forwarded as a replacement to image scoring, and is similar in all regards, except that it takes this limitation into account. If an individual refuses to cooperate with a recipient who has a low image score then this is seen as a *justified defection*, and does not reduce the standing score of the donor. *Unjustified defections*—those that are perceived as not having due cause—always lower the donor's standing score (Panchanathan and Boyd 2003; Sugden 1986:116). Panchanathan and Boyd (2003) model standing score using similar interactions as Nowak and Boyd (1988b), and also introduce the possibility that individuals will make errors (these are discrepancies between an agent's intent and his realized action); they find that image scoring with errors does not lead to successful cooperation. Panchanathan and Boyd were able to identify two strategies, in the presence of errors, which can lead to evolutionarily stable cooperation, provided that the initial quantity of defectors is not too high and that the initial mean standing score is not too low. The *reputation discrimination* strategy (RDISC) consists of discriminators who pay attention to justified and unjustified interactions, but otherwise operate as Nowak and Sigmund's discriminators, and *contrite tit-for-tat* (CTFT) consists of agents who operate as reputation discriminators, but pay attention to their own score as well as that of potential donors. When in good standing, the RDISC and the CTFT agents operate the same way, but while in poor standing, the CTFT always cooperates in an attempt to raise its score. Under all parameter settings, CTFT has slightly higher fitness than RDISC (Panchanathan and Boyd 2003:118-124).

Whereas direct reciprocity is dependent upon past interactions to provide information about the likelihood of an individual cheating in a social contract, indirect reciprocity allows actors to be able to predict the likelihood of having a successful interaction with an individual with whom they have never previously interacted. This of course does increase the computational load from the perspective of the agent, and also speaks of a limit to indirect reciprocity—there are only so many people whose reputation an actor can accurately track. Panchanathan and Boyd determined that in situations in which the cost of cooperating was high, and/or very little was known about potential recipients, indirect reciprocity rarely emerged and defection was the more likely outcome (Panchanathan and Boyd 2003:121). As in the case of reciprocal altruism, then, scale (group size) appears to set limits on the effectiveness of indirect reciprocity. Thus, neither direct nor indirect reciprocity are able to stabilize cooperation in large groups to the extent that the coalitional enforcement hypothesis is able to (~150 individuals in a primary coalition).

Punishment and Strong Reciprocity

I take the position in this thesis that none of the mechanisms mentioned above can fully account for the level of cooperation seen in humans. While they may allow cooperative behaviors in small groups, help to stabilize cooperation in larger groups, or apply to specific social situations, none of them can stand alone. Cooperative behavior is seen in situations in which the power of reciprocal altruism and indirect reciprocity should be limited. This thesis argues that the high degree of cooperation seen in human societies may be largely accounted for through punishment of defectors (cheaters, freeloaders). Punishment has been discussed from several perspectives, including that of *strong reciprocity*. Fehr and Fischbacher, among others, argue that *strong reciprocity*—defined as "a combination of altruistic rewarding, which is a predisposition to reward others for cooperative, norm-abiding behaviors, and altruistic punishment, which is a propensity to impose sanctions on others for norm violations" (2003:785) —accounts for the level of cooperative behavior seen in humans. Fehr and Fischbacher argue that strong reciprocators will bear the cost of rewarding cooperation and punishing defection even if there is no individual benefit from their actions. This distinguishes them from reciprocal altruists, who will only cooperate if it is in their own long-term self-interest.

The existence of strong reciprocators among humans is inferred from experimental games such as the ultimatum game, in which one player splits up a sum of money, while another player (the recipient) can choose to accept how the money was split, in which case both players receive the distribution determined by the first player, or the recipient can reject the offer and neither receives any payout. In one-time interactions, it would make most sense for the recipient to accept any offer that was given by the first player, as any payout is better than none. However, Fehr and Fischbacher found that offers of less than 25 percent were rejected with a high degree of probability (2003:785-786). Despite this tendency, analysis suggests that strong reciprocators cannot withstand invasion by defectors when they cannot punish—as when defection is anonymous. If strong reciprocators believe that defection is likely, they too should defect. Fehr and Fischbacher found that “to maintain cooperation in n-person interactions, the upholding of the belief that all or most members of the group will cooperate is thus decisive” (2003:787).

However, they found that if cooperators could punish defectors, not only would they punish, but they also were able to enforce widespread cooperation, even in cases in which strong reciprocators were in a minority (Fehr and Fischbacher 2003:787). Fehr and Fischbacher also found that the ability to gain reputation increased cooperative behavior in an experimental donation game; and that, in situations in which actors could track whether another individual has a history of cooperating or cheating, actors were much more likely to punish those who had defected previously (Fehr and Fischbacher 2003:787).

Strong reciprocity is not without its limitations. One issue lies with how it is defined, which West et al. (2007b:426) argue confusingly mixes both proximal (how) and ultimate (why) solutions to the problem of cooperation. In brief, strong reciprocity explains how cooperation can stabilize (through rewards and punishment by strong reciprocators), but also why people cooperate (to be rewarded/avoid punishment). If resources are limited, there will be many situations in which a strong reciprocator will not be able to reward cooperation. Thus, the number of tertiary mutualistic actions which are mutually beneficial even after strong reciprocators reward other cooperators should be understood to be small. Further, if cooperators withhold cooperation unless they get a reward, then this is better viewed as slight defection. While cooperation will continue for a while, selective pressures will not favor the strong reciprocator who consistently performs slightly worse than the reward-demanding cooperator. On the other hand, in cases where certain cooperators act as punishers and impose a punishment on non-cooperators, the net cost of defection is made greater than that of cooperation, and cooperation can survive. However, in the presence of defectors, punishers operate at a fitness disadvantage because they accrue the costs of providing punishment. Punishment can safely be assumed to have an intrinsic cost, though this cost can be reduced by the addition of more punishers. Those who cooperate, but do not contribute to the punishment of defectors, have been termed "second-order free-riders" (Boyd et al. 2003:3531), as they contribute to the cooperative action, but not to the actions that stabilize future cooperation. When defectors are common and punishers few, punishment is too costly, and cooperation becomes maladaptive. Punishment, then, is a viable strategy only when the number of punishers is high enough that the individual costs of punishment remain low. Such cooperative punishment of defectors has been referred to as *coalitional enforcement* (Bingham 1999:135). Cooperation can only evolve in instances where cooperation can be reliably beneficial, and non-cooperation is not the dominant strategy. Successful cooperation based on punishment of defectors and reliable rewarding of cooperators has been confirmed experimentally (Boyd et al. 2003).

Boyd et al. (2003) determined that groups can only maintain high levels of cooperative behavior when group size is small and punishment is absent. When altruistic punishment (the punishment of defectors resulting in a net loss to the punisher) is common, non-cooperators are excluded (punished), which in turn leads to larger groups effectively achieving and maintaining higher levels of cooperation (Boyd et al. 2003:3533-3534). Moreover, Bingham argues that not only is punishment necessary for stable cooperation, but that the evolution of cooperation resulted from, and was only possible because of hominins' development of the ability to kill or injure conspecifics at a distance. Projectiles reduced the cost of punishing non-cooperators, both in the sense that immediate proximity fighting was avoided, and that, in the cases that a group bands together to punish a non-cooperator, any retaliation is divided among all the participants. Taken together, these conditions increase the number of actions that achieve tertiary mutualism—i.e., are able to become beneficial to cooperators after defectors are punished.

When fighting hand-to-hand, the risk of the punisher being injured/killed is roughly equal to that of the non-cooperator being injured/killed. Even in cases where multiple punishers engage in proximity fighting, only a few can actually engage the defector at any time, and the risk remains high for these individuals. Conversely, when a group of *n* cooperators remotely punishes a single non-cooperator the retaliatory damage from the non-cooperator is divided among the *n* cooperators and the amount of damage dealt to the non-cooperator is increased by a factor of *n*. Thus, by distributing damage received and increasing damage dealt, coalitional enforcement exponentially reduces the risk associated with punishing a single non-cooperator (Lanchester's Square Law) (Bingham 1999:138). This in turn leads to pressure to enforce not only punishment of non-cooperators, but also to punish cooperators who refuse to join in coalitional enforcement. Within this framework, projectile weapons should increase the level of cooperation by decreasing the cost of punishing defectors, in proportion to the quality of the projectile weaponry (Bingham 1999:138-139).

Equations 2b and 3b modifying equations 2a and 3a to include punishment, show the payoffs for defectors and cooperators when punishment is an option:

$$P_c = \frac{B_C}{n} - C_C - \frac{C_X}{n_p} \qquad \text{Equation 2b}$$

$$P_d = \frac{B_C}{n} - (C_X * n_p) \qquad \text{Equation 3b}$$

Here C_x is the cost of punishing/being punished (following Bingham 1999 these are assumed to be nearly equal), C_c the cost of the cooperative action, and n_p is the number of punishers. Equation 1, the payoff of the selfish, non-participating individual, is unchanged as the individual is assumed to remain isolated. The equations above still represent very simple, single-event cooperative actions. The coalitional enforcement hypothesis has been quantitatively modeled by Okada and Bingham (2008), and while the reader is referred to their work for a full description of the model, their equations are reproduced here to provide a better understanding of how this hypothesis works. Equation 4a and 4b represent the payoff to a cooperator who engages in punishment (cooperative fighter, C/F); equation 5, a cooperator who does not engage in punishment (cooperative non-fighter, C/NF), and equations 6a and 6b represent the payoff of a non-cooperator/defector (non-cooperator, NC) (Okada and Bingham 2008:261-263):

$$C/F = \frac{k}{n}b - c - f(l, n-k) \qquad \text{Equation 4a}$$

$$C/F = \frac{k}{n}b + \left(\frac{n-k}{l}\right)\frac{k}{n}b - c - f(l, n-k) \qquad \text{Equation 4b}$$

$$C/NF = \frac{k}{n}b - c \qquad \text{Equation 5}$$

$$NC = \frac{k}{n}b - a(l, n-k) \qquad \text{Equation 6a}$$

$$NC = -a(l, n-k) \qquad \text{Equation 6b}$$

here *n* represents the number of individuals; *k* the number of individuals who decide to cooperate; *n-k* the number of defectors; *c* the cost of the cooperative action, and *b* the benefit of the cooperative action, assuming *b>c*. The number of cooperative punishers is represented by *l*, while *f(l,n - k)* signifies the cost of fighting to a cooperative fighter and *a(l,n - k)* is the fighting cost to a defector. Equation 4a and 6a differ from 4b and 6b in that Okada and Bingham envision 4b and 6b as the result of successful punishment of defectors, while 4a and 6a reflect the payoff's following unsuccessful punishment for punishing cooperators and defectors.. Cooperative punishers are assumed to take the value of the resource gained by the defecting individuals and share it among all other cooperative punishers ($\left(\frac{n-k}{l}\right)\frac{k}{n}b$), whereas all benefit of defecting ($\frac{k}{n}b$) is stripped from defectors.

This framework of coalitional enforcement is different from its representation in this thesis, and is felt to be slightly different than how coalitional enforcement is presented in Bingham's earlier work (Bingham 1999, 2000). It also applies to a much narrower set of behaviors. By allowing cooperative punishers to take the benefit gained by defectors it does avoid many of the problems mentioned for strong reciprocity and second-order freeriding. By allowing cooperative punishers additional benefit ($\left(\frac{n-k}{l}\right)\frac{k}{n}b$), the cost of punishment is defrayed, and in some cases, cooperative punishers could receive a higher payoff than is achieved by the cooperative non-punishers.

Reducing the set of behaviors to which the coalitional enforcement hypothesis applies—to only those in which there can be a reward for punishing—may overly restrict the hypothesis. Situations where the resource represents a public good may not allow differential distribution of resources gained from punished defectors. For example, recall that Bingham (1999) defines tertiary mutualistic behaviors as those collective actions that are not mutually beneficially while defection is present. Allowing cooperative punishers to gain additional resources promotes cooperative punishment—but it may not necessarily promote cooperation. For individuals who cooperate, but do not engage in punishment, there is no difference between situations in which the defector is punished and situations in which the defector is not punished. The tertiary mutualistic collective action still results in a net loss for the cooperative non-punisher, and in subsequent actions they may choose to follow a cooperative punisher strategy, but they also may simply refrain from cooperating in the action. Other cooperative actions might confer more intangible benefits that cannot be reallocated in this way. The baseline logic of the coalitional enforcement hypothesis—that the reduction in the cost of punishment entices more people to punish and raises the cost of defection above the point that it is adaptive—holds true without reassigning cooperative punishers additional benefits. Thus, I consider the framework used by Okada and Bingham to represent one way in which stable cooperation can be achieved via the coalitional enforcement mechanism. Here I will assume the more general coalitional enforcement model as originally developed by Bingham (1999, 2000) which, I believe, applies to a wider variety of behaviors.

Monitoring and Coalition Sizes

All of the paradigms above share a common thread—cooperation cannot continue in the presence of non-cooperators, especially in larger groups, unless some framework is in place to stabilize cooperation and deter defection. Many models for cooperative mechanisms scale the costs of deterring defection according to the number of individuals. The following section discusses the impacts of scale upon coalitional enforcement.

I argue that the introduction of the bow allows the formation of larger social groups by dramatically reducing the cost of punishing non-cooperative behavior (which also of course increases the cost of cheating). By reducing the threat of defection, the group is able to ensure that those who cooperate in communal efforts receive protection of owed resources—whether these resources directly affect fitness, or reputation. Costs of punishment are not the only costs that can limit the feasibility of widespread cooperation. Along with the possibility of defection comes the need to look for the possible presence of defectors. While the cost of monitoring a single individual is very low, monitoring costs may be assumed to scale with the size of the group in question. A small group can rely on its members to all monitor each other and to effectively communicate when a defector is observed. As groups increase in size, it becomes infeasible for each individual to monitor every other individual; the same logic applies to communication regarding when to punish a non-cooperator. If a group cannot monitor itself effectively, it leaves itself open to subversion by defectors, but if it spends too much energy on monitoring, the benefits of cooperation will decrease to the point that it no longer remains viable.

A group will only grow in size so long as the marginal net benefits to cooperation (including the costs of such cooperation, which prominently include detecting and punishing defectors) remain positive. Thus, coalition (group) size should increase only up to the point at which a larger coalition is not capable of governing and monitoring itself, and returns fall below those of a smaller-sized group. Bingham refers to this size of coalition as a *primary* *coalition* (Bingham 1999:153). The upper size limit of primary coalitions should be understood to be both a function of returns, and physical limitations of monitoring. This result is confirmed in the work done by Boyd et al. (2003) who found, experimentally and quantitatively, that the addition of punishment allows cooperation to function in much larger group sizes, allowing them to expand to sizes where the cost of punishing is reduced, up to the point where monitoring costs begin to outweigh the added value of more punishers.

Where the continued existence of a group might depend on its ability to maintain its size or expand on it, as might be the case with inter-group conflict, it is important that punishment of defectors take place commonly and reliably. One way to achieve this is to create a formalized role (such as police) for punishing and monitoring. This reduces the difficulty in communicating the presence of defectors within a larger group, as long as the punishers are adequate to their role, and so long as there is institutionalized acceptance of the decisions made by the punishers. If punishment is not communal, it must have community-wide acceptance. This breeds potential for punishers, who are in a place of some power, and capable of force, to misuse their power for further, unwarranted power, which could be an explanation of some divergences from corporate organizational strategies to hierarchical organizational strategies. Punishing institutions can only exist in situations in which a smaller group of punishers can both increase the cost of defection sufficiently to deter non-cooperation, and receive some sort of payoff for their punishment that makes them willing to punish for the larger group.

Primary coalitions can only increase in size to a certain extent, at which point monitoring becomes too costly. Further increases in social scale are done by cooperation among different primary coalitions. As it is not possible for large groups to have dialog among all members, large social organizations, such as the United States, depend on cooperation among its various states. The states themselves depend in part on counties and cities to cooperate without defection, etc. Different layers of nested groups still function with the same basic requirements of cooperation that exist between just a few individuals—the cooperation has to be beneficial, and there has to be some protection against those who would defect to the detriment of the larger entity. Bingham defines *secondary coalitions* as formed by cooperation among different primary coalitions. The existence of secondary coalitions often is coupled with group sizes (tribes and larger) large enough for the emergence of widespread specialization, another characteristic of more complex social organizational strategies.

Early weaponry, prior to the advent of projectile weaponry, likely severely limited the potential of groups to expand in size much past family and lineage units. These weapons would likely not have reduced the individual cost of punishment sufficiently to allow cooperation to be stable beyond a primary coalition, and probably could not have supported coalitions up to the maximum size of a primary coalition (~150). As projectile weaponry was introduced and progressed, the ability of primary coalitions to punish other free-riding primary coalitions became possible, thus allowing for cooperation to arise and stabilize among primary coalitions. With each significant increase in weaponry and social-monitoring technology, the coalitional enforcement ability of a society increases, allowing additional increases in the level of cooperation and in group size and complexity. Bingham states: "With the ambiguous exception of early Mesoamerica…I am unaware of any significant evidentiary contradiction of the predicted correlation between weaponry performance and social complexity throughout the paleontological, archaeological and historical records" (1999:156). The purpose of this thesis is to evaluate this claim for the northern areas of the U.S. Southwest following the adoption of the bow and arrow.

Violence Avoidance Strategies

One more aspect of the coalitional enforcement hypothesis needs to be discussed. Bingham's hypothesis, attached to projectile weaponry as it is, is subject to accusations of over-emphasis on violence as a means to stabilize cooperation. Of course not all non-cooperative/defector interactions are violent in nature, and in many situations, various mechanisms exist to deter non-cooperation. **Error! Hyperlink reference not valid.**Thus, a brief discussion of violence avoidant strategies' place within the coalitional enforcement hypothesis is warranted. Bingham (1999) argues that institutional devices designed to deter non-cooperators may exist only as long as the threat of more extreme measures remains real and credible. A sanction against a defector can only work if it is able to stand against a harsh, potentially violent, response to the sanction. In consideration of this, Read (2002) states "failure to cooperate…can and does lead to social sanctions being imposed on the transgressing individual. But sanctions can be imposed only when there is an already agreed upon understanding of what constitutes proper behavior, and the latter is culturally specified" (2002:7253). A key element of the continuation of social norms is that violation of the norms be punished by everyone, not just those that are directly affected by the violation (Fehr and Fischbacher 2003:786). Working from a bottom-up approach, cooperation within small groups larger than the size at which inclusive-fitness is an effective predictor of cooperation would be entirely dependent on the *potential* use of physical punishment as a response to defection. The existence of social institutions that are able to punish defectors is dependent on a level of cooperation having been established. Only after defection had been sufficiently curbed, due to acts and threats of physical response to defection, would group selection (selection for traits which benefit the group fitness at large—irrespective of individual benefit/cost) and group stability allow the emergence of social institutions and alternate means of dealing with defection. Small groups expanding beyond the size at which inclusive-fitness could be an effective guarantor of cooperation might have been more dependent on the use of physical punishment as a response to defection, as very few social institutions would be available. After long periods of inter-group selection for cooperative norms, and after the availability of technologies which reduce the cost of punishment, cooperation might only have to be backed up by occasional resort to physical violence.

It is not expected that groups would be able to maintain a strategy in which all threats of punishments are largely bluffs. This has been established in part through work done by Grafen (1990), who constructs a quantitative examination of the handicap principle. This principle, similar to ideas of costly signaling, argues that the form of a signal should be explicable in terms of what they signal (Grafen 1990:541). Grafen finds that, as should be expected in coalitional enforcement, the cost of a threat correlates inversely with the strength of the threat, where "strength" relates to the cost of being punishment to the defector. In short, it is more costly for a weak group to make severe threats than for a strong group to make similar threats (Grafen 1990:531). Should a group transition from, to bend the proverb, "speaking softly and carrying a big stick," to just speaking softly, it loses its ability to enact a credible threat and defectors will be able to invade the system and the cooperative institutions will collapse. The need for a credible threat behind successful cooperation has long been recognized, including in Hobbes' *Leviathan* in which he writes "Covenants, without the sword, are but words" (1904 [1651]:17.2).

Upon nearing the point at which any increase in group size reduces the benefit of group collective actions, either through increased difficulty in monitoring or unchecked invasion by defectors, several strategies besides violence may be available. The group can implement practices that maintain a stable group size, which could include strategies such as restrictions on immigration, reproductive control, or group fissioning. Fissioning was common in prehistory, especially prior to circumscription. In this case, groups responded to stress—either scalar stress, or to the machinations of aggrandizing individuals—by fissioning into daughter groups. Situations such as circumscription, high levels of investment in the landscape, or warfare increased the cost of fissioning, and prompted the formation of higher-level integrative social structures (Bandy 2004; Carneiro 1967, 1988). In an examination of fissioning in the Formative Period in the Titicaca Basin, Bolivia, Bandy states:

> In conditions of relatively low population density and relatively egalitarian social organization, conflict can be resolved by splitting the local group. This ease of fissioning is also thought to act as a check on the aspirations of ambitious leaders. The social dynamics of early village societies are therefore thought to have been fundamentally structured by fission or by the possibility of fission [2004:322].

Fissioning essentially allows a means for individuals within a group to split and re-establish a smaller coalition in which the cost of monitoring is reduced and defection more easily deterred. From this we can see that the threat of defection, whether it be defection in an action or defection from an ethos, does not necessarily need to be addressed through violent measures. However, the reduction of the cost of punishment through the use of projectile weaponry does allow an option other than fissioning when dealing with intra-group stress—either by increasing the stability of an integrative institution, or by dealing with a defector in a more pointed fashion.

These expectations fit well with Price and Brown's factors common to complex hunter-gatherers, in which they expect "…societal circumscription, abundant resources, and higher population" (1985:8). The authors note that population does not cause intensification, nor modify behaviors, but instead introduces further stress into the group. Social circumscription is, as discussed above, often a catalyst for the rise of large-scale cooperation, and abundant resources are a prerequisite of survival for a large, socially circumscribed group. Social circumscription increases the cost of fissioning and may prompt situations in which a group has more need to solve the problem of defection, but it does not guarantee successful emergence of complex and stable organizational strategies. Thus, I argue that if defection is common and the cost of punishing is high, cooperation will fail, regardless of the violence-avoidant strategies in place. Cooperative stability in groups of increasing size relies on ever-increasing means of reducing the cost of punishment. Only after cooperation has stabilized can violence-avoidance strategies become feasible.

Review

This chapter briefly surveyed recent theory on cooperation emphasizing aspects of those theories that pertain to Bingham's (1999, 2000, 2008) coalitional enforcement hypothesis. Research (Boyd et al. 2003; Fehr and Fischbacher 2003; Fehr et al. 2002) has shown that in the absence of punishment, it is commonly in an individual's best interest to defect from a social contract. Through punishment, which is costly, groups can overcome the problem of defection, and thus enhance the benefits of cooperative actions that the group can undertake. Only through the reduction of the cost of punishment, however, can groups cost-effectively impose punishment on defectors. This solution, dependent on the capabilities of projectile technology, allows for basic group stability, upon which other social complexity can be built.

3| BEHAVIORAL DATA

In this chapter I discuss some additional research that examines the place the coalitional-enforcement hypothesis holds in relation to observed and tested human behavior. This work has been largely within the evolutionary psychology field, and may help bolster the plausibility of Bingham's coalitional-enforcement hypothesis. While the data presented in this chapter do not represent the full range of sources and discussion on these issues, they do serve as an introduction to arguments about general human behavior, and an examination of the plausibility of Bingham's model. I focus on studies that can best address certain doubts about Bingham's model, and the implications that various behavioral traits have for the coalitional-enforcement model. After examining the data, I feel that the coalitional enforcement hypothesis is plausible given behavioral data suggesting the universal and low-cost nature of human monitoring, cheat detection, and formidability assessment, and behavioral causation of anger. These data help bolster the likelihood of the propagation of coalitional enforcement, and their evolution makes sense within the framework provided by the coalitional enforcement model.

The coalitional enforcement hypothesis depends on several inclinations and abilities of its agents. Several of these may seem unrealistic at first glance. First, the hypothesis is dependent upon an individual's ability to monitor for defection in cooperative actions. This is expected to be easy in small interactions or interactions in which the benefit is highly visible and quantifiable. If two people hunt together and only one walks away with any meat, then it will not be too long before one becomes suspicious that he drew the short straw. Interactions between people in a society are often repeated, often include large numbers of people, and have benefits that may be enigmatic—such as in the form of the promise of future payoffs, or payoffs that may be deferred to allow an increase in reputation. For the coalitional enforcement hypothesis to be useful as a heuristic device to examine organizational change, it will need to be able to stabilize cooperation in both simple and complex interactions. Thus, understanding how well humans can detect defection within a group is vital to assessing the validity of the hypothesis. The coalitional enforcement hypothesis also assumes that there is a cost in monitoring, and that this cost is scalar (increases with group size). Thus, the cost of cheat detection in humans is also of importance.

The hypothesis also assumes that people will have an inclination to punish, and to also ascertain when punishing will be beneficial to them; that is, which tertiary mutualistic behaviors can become mutualistic by punishing a defector and which remain untenable. As discussed earlier, punishing an individual comes with a risk. Most immediate is the risk of injury or death. However, individuals also may have to fear retaliation from any who felt their punishment unjust or undeserved. Individuals also have to overcome any personal aversions or fears in order to participate in the punishment. Adding all these considerations to the fact that many of us rarely if ever engage in, or even witnesses physical violence or severe punishment, may give the impression that cooperative stability based on a structure of physical responses to defection is unrealistic—although this may not be the case in the societies being examined.

Should individuals be unable to gauge when they will likely prevail in a fight, they run a high risk of misjudging situations in which they should punish from those in which they should defer. Failure to punish in interactions where it is warranted will erode cooperative stability when the benefit following punishment would still have remained positive, and failure to defer in instances when punishment is not beneficial could incur high costs, including death of the punisher(s). If humans do not possess an ability to assess the likely cost of punishment the coalitional enforcement hypothesis would be questionable.

An Evolutionary Psychological View of Behavior

An important assumption of the coalitional enforcement hypothesis is that humans can accurately detect when they are being cheated. Research in evolutionary psychology has examined behavior in humans extensively through examination of psychological architecture, and may provide insight into how well humans can monitor for defection, and at what cost (Gigerenzer and Hug 1992; Sugiyama et al. 2002). Before addressing the results of work that addresses the specific assumptions that the coalitional enforcement hypothesis relies upon, I first provide an overview of the background on which most of the work in behavioral studies builds upon.

Human mental architecture can be understood, at a coarse level, as comprised of domain-general mechanisms and domain-specific mechanisms (Ermer et al. 2007). There is argument about which of these two mechanisms is primary. Most of the social sciences, including human behavioral ecology, assume a mental architecture comprised of domain-general mechanisms. Proponents of domain-general mechanisms argue that human mental architecture is comprised of a few content-free, general purpose, and highly adaptable mechanisms. Social learning, induction, imitation, and culture are among the key inputs that frame how these mechanisms work. Because the mechanisms have no built-in content, they can be understood as highly versatile, although it has been argued that this versatility might lead to inefficiency in quickly solving problems.

Many proponents of evolutionary psychology, on the other hand, argue that our mental architecture is comprised predominantly of domain-specific mechanisms—mechanisms/modules designed to solve problems common in our environment of evolutionary adaptedness (EEA), generally defined as the Pleistocene, hunter-gatherer environment. These modules are felt to have an archaic origin, as the evolution of their specificity would be expected to require a long period of time. They are also felt to be able to quickly and efficiently solve the critical or common problems that they evolved for in the EEA. Ermer et al. (2007) present problems they see with domain-general mechanisms. These include the fact that different problems are unlikely have the same optimal solution. Domain-general mechanisms would not be able to simply apply a singular solution to several tasks, and instead would have to compute which solution is ideal for the task at hand. As a module could conceivably have to run through every option before a workable solution was found, the computational power needed for domain-general mechanisms would be staggering. Finally, the environment does not always provide clues to an optimal solution, as would be needed for efficient functioning in domain-general mechanisms. These decrease the likelihood that just a few modules would be able to handle the breadth of human experiences. Ermer and colleagues (2007) feel that these problems represent non-issues when modules are high in number and highly specific.

Monitoring within Social Contracts

If human cheat detection relies on domain-general mechanisms, it would be quite variable and context-dependent. Conversely, if human cheat detection relies on domain-specific mechanisms, then detection of cheaters should be fairly consistent, accurate, and energetically cheaper to maintain.

To determine which of these positions is the more viable, several authors have applied Wason selection tasks to examine cheat detection. Wason four-card selection tasks provide a subject with four possible violations of a conditional rule -- “If P then Q,” “If P then not Q,” and inverse variations. Depending on how the context for the task is presented, performance varies significantly. Rules that are abstract or descriptive typically result in correct responses only 5-30 percent of the time; rules that express social contracts and the presence/possibility of a cheater result in correct responses 65-80 percent of the time (Stone et al. 2002:11531). In simple terms, people taking the same “If P then Q” test are much more likely to choose the wrong answer unless it is framed in terms of a social contract. Similar results have been found in various studies, and as discussed below, cross-culturally (Sugiyama et al. 2002). The following studies, most of which employ some version of a Wason selection task, help lead to a better understanding of how the human mind monitors for cheaters.

Gigerenzer and Hug (1992) examined under what exact frameworks people could successfully answer the questions in Wason selection tasks. As discussed above, people perform much better on Wason selection tasks when they are in presented terms of a social contract that is being violated. Gigerenzer and Hug simplified this concept through the idea of a “cheat-detection algorithm” that, when activated, increases performance on the selection tasks. To do this they studied the theoretical differences between pragmatic reasoning schema theory (PRS), social contract theory, and availability theory. PRS is a "permission schema," and uses set rules which are often utilized by social contract theory when administering Wason selection tasks. PRS differs from social contract theory in that it does not use the idea of a "cheating option and cheater-detection algorithm," both of which are central in social contract theory, and instead provides the rules but no judgment calls—no one is labeled so as to suggest someone is "cheating" and someone is "being cheated" (Gigerenzer and Hug 1992:6). Availability theory is a suite of hypotheses arguing that, in content-independent task behaviors, previous experience that an individual has with a task helps them queue the right response in subsequent iterations of the task—i.e., it measures how the ability to remember relevant information helps guide decisions associated to the task at hand (Gigerenzer and Hug 1992:6).

Gigerenzer and Hug's work (1992) shows that the presence of a social contract does not necessarily entail activation of a "cheater-detection algorithm." Instead, activation was found to be largely dependent on social context. Two sets of tests were performed to reach this conclusion. First, Gigerenzer and Hug examined the results of presenting subjects with two different versions of a Wason selection task-- a "cheating" version and a "no social contract, no cheating" version. The first task's background is indicative of a social contract, while the second task's background gives no mention of a social contract (Gigerenzer and Hug 1992). Subjects performed much better in the version implying a social contract. The second set of testing separated out social contracts and cheating-detection algorithms, which early work in the field (Cosmides 1989) had neglected to do. Gigerenzer and Hug's tests gave a traditional cheating Wason selection task, as well as a version of the task from the perspective of a third party, who understood the rules, but could not be directly affected by violations. The authors found that background knowledge of the tasks at hand did not increase levels of correct responses as predicted by availability theory. Second they found that, even if a rule is perceived as a social contract, this in itself is not sufficient to activate the cheating-detection algorithm (Gigerenzer and Hug 1992:17). Instead, the crucial issue regarding social contracts is the cheating aspect itself, dependent on the perspective of the individual. Gigerenzer and Hug's work is valuable as it helps to show that humans are not that talented when it comes to monitoring interactions in social contracts except when these social contracts included the threat of defection. The fact that humans are mentally attuned to monitor for defection at a much higher level than they are to monitor general social tasks speaks to the likelihood that humans have evolved the capabilities to accurately monitor for defection, and have been able to do so for a long time.

Early testing of cheat detection using Wason selection tasks was done primarily in the United States and several European countries. To determine whether the efficiency in cheat detection found in these modernized, industrial societies is due to shared cultural values and experiences, or instead represents overarching human consistency, Sugiyama et al. (2002) used a modified Wason selection task to examine if social contract algorithms led to similar cheat detection in a non-Western culture. The authors chose the Shiwiar, of the Ecuadorian Amazon, a non-literate, low-contact indigenous group. Given selection cards that represented the familiar 'if P then Q' Wason selection task, the Shiwiar tested almost identically on the Wason selection tasks as did a group of Harvard students, performing worse only in those tasks that did not deal with cheating detection. The authors suggest that “contrary to the general-purpose acquisition hypothesis, subjects perform just as well on their very first exposure to culturally unfamiliar social contracts as they do on culturally familiar ones, so that there is no evidence for improvement even with a lifetime of exposure” (Sugiyama et al 2002:11538). Sugiyama’s results are in line with those of Gigerenzer and Hug (1992), and in contrast to the predictions of availability theory show the relative unimportance of cultural familiarity, and demonstrate the general consistent performance cross-culturally on the Wason selection task.

Another line of research suggesting that cheat detection may be a universal, domain-specific neurological mechanism, and thus energetically cheap to maintain, has been executed by Stone et al. (2002). These authors attempt to provide neurological evidence “that social exchange reasoning can be dissociated from reasoning about other domains” (2002:11531). To do so, they strive to demonstrate that neurological performance in social contract inference may be impaired without impairment to other domains. If impairment in social contract inference is found to be linked with other sorts of impairment, then, conversely, the results would indicate that social contract inference is more likely part of some domain-general mechanism, and that all conditional evaluations could fall within the confines of expectations of the pragmatic reasoning schema theory. The authors followed a test patient “R.M.” who had had received bilateral damage to his medial orbitofrontal cortex and anterior temporal cortex, with disconnection of both the right and left amygdala. These are key areas for social intelligence, and R.M. had previously been found to have difficulty with social intelligence and social inferences (Stone et al. 2002:11533).

The authors administered Wason selection tasks to a group of normal control subjects and to R.M. While R.M. performed about as well as the control subjects on the selection tasks that dealt with abstract/descriptive rules and on the selection tasks that dealt with precautionary tasks (if you engage in hazardous activity P, then you must take precaution Q), he tested significantly worse on the tasks that dealt with social contracts. Testing was also completed with two other patients that had extensive bilateral damage that overlapped with, but was not identical to, R.M's. These two patients performed equally well on both the precautionary selection tasks and the social contract tasks, and did no worse than the control group (Stone et al. 2002:11533-11534). Given that R.M.'s performance was much worse on the social contract tasks than on the equally difficult precaution tasks, and that he did not have the highest amount of overall tissue damage, the results indicated that specific damage to the brain can cause specific impairments. Because the behavioral impairments seen in the test case did not include all manners of selection tasks, this research provides further evidence that 1) cheat detection is a domain-specific module that has limited but highly specialized functions, and that 2) cheat detection/social contract rules are neurologically specific, thus represent an evolved, universal trait.

The above studies provide evidence that cheat detection in social contracts is an ingrained and highly specialized mechanism. The fact that cheat detection is separate from other social contract tasks indicates that there has long been selective pressure for this ability. The assumptions that the coalitional enforcement hypothesis must make about cheat monitoring appear to be sound. These mechanisms, representing evolved and neurologically instantiated adaptations, are cheaper to maintain and operate than learned traits. As such, it can be expected that monitoring costs (cheat detection) in cooperative actions are relatively low-cost and cross-culturally universal. These findings support Fehr and Fischbacher's speculation that

> the very fact that humans seem to have excellent cheating detection abilities suggests that, despite many repeated interactions, cheating has been a major problem throughout human evolution. Therefore, humans' behavioural rules are likely to be fine-tuned to the variations in cheating opportunities, casting doubt on the assumption that humans systematically overestimate the future benefits from current altruistic behaviours [2003:789].

Monitoring cost is assumed to be scalar: the total cost of monitoring is directly related to the number of individuals being monitored. Monitoring costs are directly applicable to the coalitional-enforcement model. Arguments about the scalar limitations of coalition size are based upon the feasibility of tracking in-group interactions. The above work has shown that while monitoring is expected to be low in cost, it will not allow unimpeded growth. It also conforms to the expectations of the coalitional enforcement hypothesis that humans are capable and likely to monitor for defection in cooperative actions.

Formidability

If humans strive for personally optimal returns, then even a consistent cooperator may defect from a social contract, if in so doing she will accrue additional gains (a strategy known as conditional cooperation). Beyond this, it is functionally important to understand whether a defector will focus solely on the benefits of defection, or, more likely, that perceived net gains depend upon both the benefit and the cost of being punished should they be found out. This segment examines work done regarding monitoring for perceived costs of punishment. This is applicable both to situations in which a potential defector evaluates the risk/benefit ratio of defecting, as well as situations in which a cooperator evaluates the risk/benefit ratio of punishing a defector. The ability to accurately gauge another individual's or coalition's formidability would have been highly adaptive. Formidability here represents the perceived cost of engaging in conflict with an individual or group. A stronger, more powerful individual will likely be energetically more costly to punish (or to be punished by) than a weaker individual. The stronger individual is thus more formidable. Accurate assessment of formidability can help confirm whether an opposing group's signal threats are credible or not. Taken together, visual assessment and signal recognition would allow groups to know when they can (more) safely attack the other group, and when they should submit.

Sell et al. (2008) examined visual assessment of formidability in humans. The authors suggest that conflict was a major selection pressure for humans. In some ethnographically investigated small-scale societies a third of adult males die violent deaths, with up to 59 percent reported for the Achuar, and some paleoanthropological evidence suggests that aggressive conflict in our ancestors was substantial (Sell et al. 2008; Keeley 1996). Aggression would likely increase as vesting in the landscape increases—as when reliance on agriculture and storage increases. Because conflict is costly for all individuals, including the victor, it is advantageous to be able to assess individual formidability prior to the conflict, in order to ascertain if it is better to defer than to engage in the conflict. With this in mind, Sell et al. examine human capability to visually assess strength and fighting ability. To do so, the authors designed four studies to test their hypothesis that "the human neurocognitive architecture includes mechanisms that are well designed to visually assess individual formidability, especially in males, through accurately assessing their upper-body strength from cues present in body and face" (Sell et al. 2008:2). The tests build off of each other and examine whether people can assess strength from visual images; whether perceptions of fighting ability are related to perceptions of strength; and whether people can assess strength cross-culturally. Results indicate that perceptions were more accurate when the subjects were examining men, but that, generally, people can accurately gauge strength and fighting ability given visual cues. Individuals performed best when viewing images of the subject's body, but still performed well when only viewing a subject's face. The results were similar cross-culturally. This work supports Sell and colleagues' claim that, across hominin (and likely pre-hominin) evolution, selection took place for the cognitive ability to accurately perceive conspecifics' strength and fighting ability. In the larger context of cooperation and punishment, this is important as it suggests that defectors and punishers are able to assess the general costs of punishment prior to action. Because these costs can be calculated, should the cost of punishment be high, defectors can be dissuaded from cheating without incurring any actual physical punishment, as long as it is apparent that the capacity for punishment exists and is very costly.

These studies have helped to show that humans have specific mechanisms designed to aid in detection of both cheating and in assessing the formidability of conspecifics. Because these are evolved mechanisms, it can be assumed that their cost is generally low: essentially they are there "for free." A scientific basis for justifying an assumption of low-cost monitoring permits the inclusion of monitoring costs into quantitative examinations of the evolution of cooperation (Boyd et al. 2003; Fehr and Fischbacher 2003; Fehr and Gachter 2002, 2005; Fowler et al. 2005; Hauert and Doebeli 2004; Hauert et al. 2006).

Anger

As with formidability, an examination of the role of anger can help illuminate how individuals and coalitions are able to deal with defectors. "When cheated, people get angry" is a fairly obvious statement, but it is useful to this argument to understand, at a low level, the purpose and value of anger in social contracts. Sell et al. (2009) provide an evolutionary analysis of anger, and its effects in interpersonal interactions. The authors argue that an individual—who in the context here could also represent a coalition—interacts with others based on a welfare tradeoff ratio (WTR), which calculates the weight that one individual places on another's welfare relative to his own (2009:1). Each person or coalition has a target WTR, and will anger if treated at a level below his or her target. The recalibration model (Sell 2006; Tooby et al. 2008), argues that anger has developed to resolve disputes in favor of the angry individual—acted out by either inflicting a cost upon the target, or by withdrawing benefits from the target (Sell et al. 2009:1-2). The recalibration model of anger makes a prediction—confirmed experimentally—that individuals with "enhanced abilities to inflict costs or to confer benefits will anger more easily" (Sell et al. 2009:2). The authors argue that this is due, first, to the fact that anger is more likely to be successful, with a lower cost, for powerful than for weaker individuals. This is similar to the quantitative findings of Grafen (1990) mentioned previously. Second, it is argued that their greater leverage leads these individuals to expect better treatment, as they expect people to place greater emphasis on their welfare. The authors, through two experiments, find that level of individual strength and level of sexual attraction both positively correlate to how prone that individual is to anger.

Findings also indicated that individuals who are more prone to anger are also more likely to endorse the use of violent, military force within coalitions. Sell et al. (2009) considered this result to be an evolutionary anomaly, as an individual's anger in large secondary coalitions does not generally benefit the coalition. The size of the group and the conflict are likely exponentially larger than a single individual can influence. The result would be expected, however, if the use of coalitional force was generated by the same processes that evolved for assessing the success of smaller coalitional (such as a primary coalition) forces, in which individual formidability and signals can be observed, and the overall coalitional strength measured and accounted for (Sell et al. 2009:2, 5). Finally, although not tested, the authors argue that familiarity and access to weaponry is another factor that should contribute to anger-proneness, as it effectively increases strength and likelihood of positive outcome in conflicts (Sell et al. 2009:5).

Coupled with the ability to assess formidability, Sell et al.'s work may have implications regarding group behavior following the introduction of the bow and arrow. When the adoption of the technology has not become widespread, we can expect that: groups that do not have the technology will be able to quickly realize its impact on the formidability of groups that do possess the technology; and that groups that do have the technology will likely develop a higher welfare tradeoff ratio than groups that do not have the technology. Thus we may expect, separate from the impacts on group cooperative stability that the bow may bring, that groups who adopt the bow early may display more aggressive tendencies toward less formidable groups. The impacts of the bow and arrow on warfare will be further discussed in chapter five.

Review

The first two chapters outlined Bingham's (1999, 2000) coalitional enforcement hypothesis. Bingham argues that the ability for humans to punish conspecifics remotely allowed for a reduction in the cost of punishing defectors from a social contract, making punishment of defectors a more plausible behavioral strategy. Projectile weaponry allows and supports a large number of punishers, as increases in the number of punishers exponentially reduce the risks and costs associated with punishing. Bingham argues that, with advances in projectile technologies, cooperation may become stable in larger coalitions, and later, groups of coalitions, can cooperate stably and over the long term, creating complex forms of social organization. In essence, improvement in weaponry makes larger communities more socially stable by reducing punishment costs and making cooperation with punishment of defectors the dominant strategy.

This chapter presented research indicating that the assumptions of this model are reasonable, and indeed can be expected to have evolved. Humans have the ability to accurately and cost-effectively identify situations in which they are being cheated, due to positive selection pressures following early solutions to coalitional enforcement. They also have the ability to recognize when the costs of defection may be too high, and to understand that coalitions and individuals have leverage to seek compensation for having been cheated. Once a coalition has been created, and coalitional punishment is in place, it is expected that the coalition will monitor for defectors, the coalition will assess the cost of punishing the defecting individuals, and should the cost be reasonable, the coalition will enforce a punishment. It is also expected that, with increasing strength and stability of a coalition, the degree to which the coalition is sensitive to being cheated will increase, and it will be more likely to punish non-cooperators. With improvements to projectile technology, it is also possible that while the technology is novel enough to confer an advantage over other groups, that coalitional warfare upon other groups will increase. These behavioral traits and expectations raise the hope that the coalitional enforcement hypothesis is observable in the archaeological record. The next chapter discusses in detail how this might be done.

4| ARCHAEOLOGICAL EXPECTATIONS: EXAMINING THE HYPOTHESIS

If the coalitional enforcement hypothesis is valid, several archaeological expectations should be observable. This chapter will not offer a complete list, but instead focuses on the primary data needed to examine the hypothesis. While these expectations identify what might be left as markers, it should also be noted that the archaeological record is neither complete, nor perfect. Thus, the lack of archaeological evidence of any of the following does not necessarily undermine the model, and in fact may simply indicate a scarcity of currently available archaeological data appropriate for addressing the hypothesis.

The overall expectations of the hypothesis are that 1) prior to the adoption of the bow and arrow, group size was limited by the inability to sustain cooperation in larger groups, and 2) after the adoption of the bow, groups became capable of expanding in size achieving much larger primary and secondary coalitions. I do not, however, suggest that the phenomenon of increased group size is *driven* by the introduction of the bow. Rather, the presence of the bow only speaks to the *solution* to cooperative instability. Thus, archaeologically, I expect that coalition size will be seen to increase after the bow and arrow, but not necessarily immediately. Immediate changes most likely indicate situations where groups had already reached, or were near, their maximum stable group size, and were also below the regional carrying capacity. In these situations, the adoption of the bow would allow for immediate increases in group size and organizational structure (such as in group “A” in Figure 1). Smaller groups (imagined as group “B” in Figure 1) may have been well below their maximum stable group size, and while they would still benefit from the introduction of the bow, in terms of coalitional enforcement, they may not have had any impetus to drastically increase in size to where the bow was a necessity for continued group stability. In sum, while increases in population and group size are indicators of the coalitional enforcement hypothesis, they are also reliant on other factors, such as climate, agriculture, warfare, and wild resource availability.

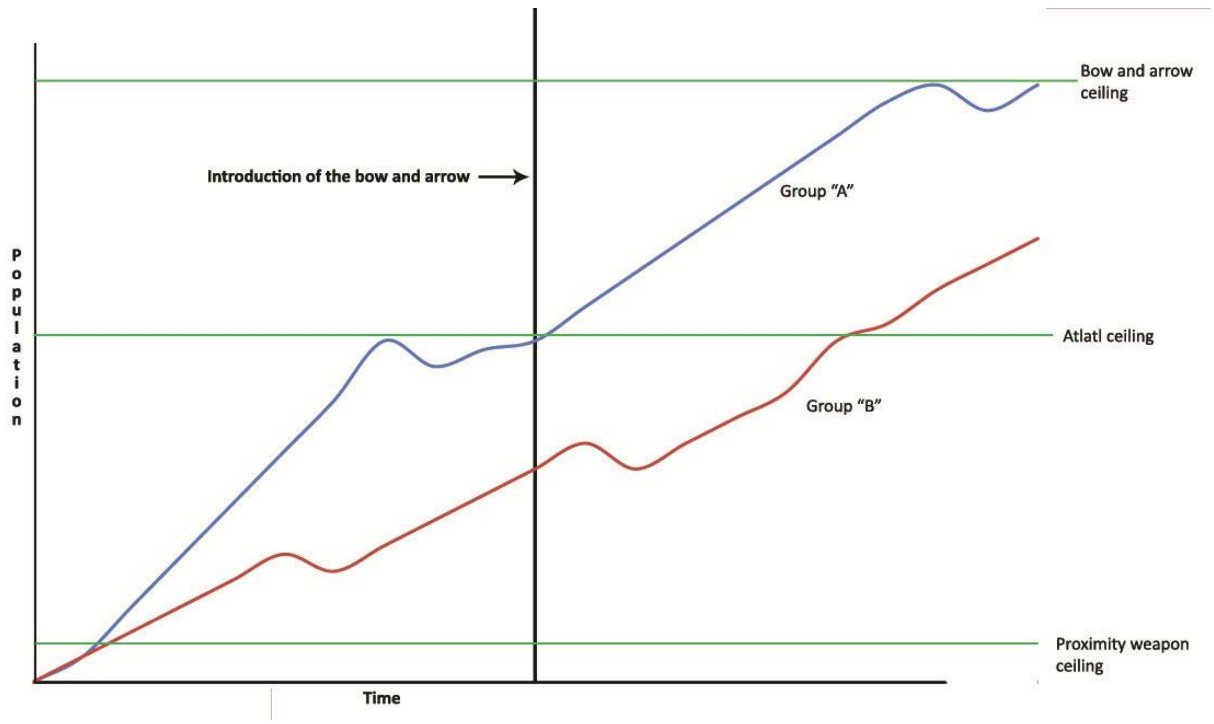

Figure 1: Conceptual impacts of the coalitional enforcement hypothesis

Figure 1 (above) is a conceptual diagram, meant to display how to groups of different sizes—groups "A" and "B"—might respond to the introduction of bow and arrow technology. The coalitional enforcement hypothesis suggest that each weapon technology is associated with a group ceiling—a point beyond which the weapon technology is no longer able to facilitate cooperative stability. In this example, both groups are increasing in size, but only group "A" is constrained by the limits of coalitional enforcement as practiced with atlatl technology. Group "A" is expected to have cycles of fissioning and growth until the bow is adopted, at which point it can increase until it reaches the limit of coalitional enforcement under the bow. Group “B” is smaller, with growth unimpeded by the limits of coalitional enforcement. Group “B” may then continue with simpler forms of organizational structure, and smaller populations well after the introduction of the bow. Given population density in the prehispanic Southwest, I argue that both scenarios are possible.

Of course, the model as I have posed it can only be examined where there is evidence of the introduction of the bow and arrow. In times and places with mixed evidence of both atlatl dart and bow and arrow projectile points, it is my opinion that complete adoption of the bow-and-arrow technology need not have to be reached prior to seeing the realization of some of the benefits to coalitional enforcement—but this is essentially an empirical question that can be examined. For intra-group, small-scale defection, it is likely that in many instances, a few cooperator/punishers could successfully enforce group cooperative behaviors, especially if there was a technological disparity—such as the punishers having easier access to weaponry. Thus, in small-scale intra-group conflict, the presence of only a few bows and arrows, held by the punishers, could reduce risk of punishment and promote cooperation within the group at large. In larger-scale conflicts, while a mixed assemblage of atlatl and bow technology does not reduce the cost of punishment to the degree that an all bow assemblage would, the cost is reduced proportional to the number of bows present. In sum, the presence or absence of bow and arrow technology within a group may well suffice to reduce the cost of punishment enough to be noted in the archaeological record. Simple presence/absence of the bow is also felt to fit into the available data in terms of the breadth of archaeological knowledge. As much of the archaeological data for the Southwest is from survey, sites are often categorized by visible surface materials. The presence or absence of visible surface artifacts does not negate the presence of other buried components. While a site with exposed dart points is unlikely to contain buried arrow points, the reverse is not necessarily true. This, coupled with the almost complete replacement of the atlatl by the bow, illustrates the necessity of a dichotomous classification for present purposes.

To gauge the validity of the coalitional enforcement hypothesis, two coarsely defined phases will need to be examined—the time before, and the time after the introduction of the bow and arrow into a region. Reconstructed population sizes need to be representative of the population at or close to the date of introduction. While regional generalizations will be avoided when possible, I will sometimes need to use population reconstructions from nearby times and areas. Regional population increases may or may not accompany an introduction of this technology into a locality; regionally, populations may be limited by resource availability and some degree of inertia in changes to population size. Community size—here taken to be the size of the cooperating group—is the primary issue of importance. Regional population growth due to the introduction of the bow and arrow is of course possible if for example hunting efficiency is dramatically enhanced, but that is not the main focus of the research here.

Coalition Size

With a few exceptions (such as Ruscavage-Barz 1999) archaeologists have generally not reconstructed community sizes, so site sizes (average or maximum) will in most cases have to suffice. Thus, I will look primarily at maximum observable group size, and secondarily at momentary group size. Bingham (1999) mentions that groups will expand to the point that the primary coalition size cannot be effectively monitored and punishment cannot be effectively enforced. After decreases in the risk of punishment, which prompts more punishment within a group, the coalitional enforcement hypothesis predicts increases in coalition size up past primary coalition capacity, at which the emergence of secondary coalitions is a more stable mechanism for continued growth.

Dunbar (2003) calculates that the maximum potential size of a primary coalition is around 150 individuals, given cognitive constraints. Limits to coalitional enforcement and ecological carrying capacity may often limit maximum coalition size to below this number. An understanding of a group's size will allow understanding of what constraints the group may have faced (cooperative, ecological) or whether they functioned as a primary or secondary coalition (i.e., if the group is above 150 individuals). In the prehispanic Southwest, it is likely that maximum coalition size was well below the cognitive maximum. I do not expect that groups grew alone separate and isolated until the maximum size of a primary coalition had been reached prior to formation of secondary coalitions. Likewise, it would be erroneous to assume that prior to the adoption of the bow and arrow, secondary coalitions were not achievable. The coalitional enforcement hypothesis predicts that coalition size is *limited* by the inability to punish defectors with less-efficient projectile weaponry. I expect that prior to the adoption of the bow and arrow, the maximum size of both primary and secondary coalitions was small, as punishment, especially carried out against other primary coalitions, was costly. I do expect that interaction among secondary coalitions was very important during this time, if for no other reason than small, family based groups generally have to rely on exogamous mating practices.

Anthropologists traditionally classify societies according to general level of organizational complexity. While these typologies can be overly confining, for the present purposes they may serve to qualify what archaeologists should expect for primary and secondary coalitions. *Bands* are the smallest of the usual divisions, representing autonomous groups, often with an informal headman (Keeley 1996:26). These usually represent largely lineage-based structures, and are generally on the size of twenty to fifty individuals. I use the term *macroband* to refer to the larger structure comprised of several bands/microbands. *Tribes* are broader in definition, but incorporate much larger numbers of people. I view Haas' definition of tribe as "a bounded network of communities united by social and political ties and generally sharing the same language, ideology, and material culture. The communities in a tribe are economically autonomous and there is no centralized political hierarchy" (1990:172) as useful. *Chiefdoms* are often larger yet, operating to unite thousands to tens of thousands of individuals under formal political leadership (Keeley 1996:26). The last commonly used organizational class is the *state*, which requires the most rigid and permanent political leadership, and can support the highest populations.

Other classification schemes exist, such as that of Johnson and Earle (1987) who use camps, hamlets, local groups, big man collectivities, chiefdoms, and states as the primary units. Camps are characteristic of low-density foraging societies, having family-controlled groups of 25-50 persons in cases of highly localized resources. Hamlets are representative of slightly higher-density societies, where families cluster into a clustered settlement on a more permanent basis, and are more likely to be found in association with increased use of cultigens and storage. Organizational leadership remains limited, and often contextual. Local groups vary up to a few hundred individuals in the community, generally five to ten times larger than family-level groups. Organization is often along lineage or clan lines. Ceremonialism is seen to increase both to aid in group communication and to define group relationships and bounds. Local groups would be on the “tribe” level. Big man collectivities vary in size up to around 800 individuals, and exist in moderate to high population densities, and in cases where the group organizational strategy allows for power to be held by a few, or single, individuals. Warfare is common, but generally focuses on the exclusion of other groups and protection from them. Chiefdoms can support a range from hundreds of individuals in the community and tens of thousands in the polity to cases such as Cahokia where the community itself contains tens of thousands of people (Milner 1986). Social stratification is increased, and warfare serves to incorporate additional lands and groups, as well as for defense (Johnson and Earle 1987:19-22, 313-314). I will primarily use the band/tribe/chiefdom classifications.

Lightfoot and Feinman (1982) also introduce the concept of village formation as a process linking the relatively egalitarian, family run household and band level society and tribal level of society. They view the change from household to village society as the change from a group with no regulated hierarchical organization to a group with one level of suprahousehold administration (1982:64). Village formation can be understood here as a process of tribalization. Feinman et al. (2000) note that their early work emphasized those sites practicing a network organizational strategy, thus overlooking sites which were developing suprahousehold organization along other paths (2000:458).

Within the Southwest, for the periods defined, the Basketmaker III/Pueblo I transition has been viewed as the transition between band and tribal levels of organization. However, the process of tribalization, including increased village formation, is argued to have occurred throughout the Basketmaker III (Haas 1990), following the adoption of the bow and arrow.

To examine the coalitional enforcement model, maximum or average momentary site (or community) population estimates will be examined for sequences encompassing the introduction of the bow in various regions. These data will be gathered from existing reconstructions for the Southwest, with preference for areas with the highest temporal resolutions and most accurate population estimates.

Population and Group Size

Population and site/group size estimates have been created from a wide variety of archaeological data, such as the number of sites in a region, the number of rooms on a site, the floor area of residential architecture, and quantities of artifacts (Powell 1988). As archaeological techniques for calculating rates of artifact production and use-life of occupations have improved, population reconstructions have become more accurate. The validity of reconstructions which depend on the number of residential structures on a site is, in turn, dependent on calculating the number of contemporaneously occupied structures on the site. This is influenced, in part, by how long these structures were occupied prior to abandonment. Disagreements remain about various aspects of site occupation history, such as structure use-life, which can vary from fairly short pit-structure life-spans, such as Cameron's (1990) estimate of 15 years and Varien and Ortman's (2005:140) estimate of eight years for sites occupied around A.D. 600 within the Village Ecodynamics Project, to long spans such as Blake et al.'s (1986) 75-year estimate.

The use-life of a structure is determined both by the materials employed and by climatically driven deterioration, so use-life is expected to vary regionally and is also subject to cultural and idiosyncratic variation. Structure size and use-life are also tied into residential mobility. As residential mobility of a group decreases—as is expected following increases in group size, agricultural dependency, or social circumscription—investment in construction and maintenance of architecture should increase (Gilman 1987; McGuire and Schiffer 1983). Cross-cultural research has suggested that structures occupied fewer than 121 days per year tend to be constructed of non-durable materials like brush; structures occupied over 121 days and less than 250 days are usually made of wood and earth, while those structures occupied for even more of the year are constructed of more durable materials such as prepared wood, adobe, or stone Diehl (2001c:40).

Population and site size estimates are more difficult to calculate for earlier time periods, including the periods I focus on for this thesis. Basketmaker peoples, for example, still dwelled in pitstructures during the time of interest. Pitstructures are less visible in the archaeological record than later surface structures (especially masonry structures) since they are likely to be covered by sediment accumulation, suffer great integrity loss following any reuse of materials, and can erode away. Moreover, places that were well suited for habitation in earlier time periods were often well suited for occupation in later time periods. Basketmaker sites—lacking masonry architecture and ceramics—are often obscured by later, more visible occupations. As a result, archaeological surveys are less likely to find and record sites that fall within the temporal periods of interest. Variation within the periods can also be lost or consolidated. This can result in erroneous population estimates that are biased downwards, both within sites and within regions. Schacht (1981) is a valuable reference for more on the impacts of differential archaeological preservation and early component underrepresentation on paleodemographic reconstructions.

In terms of the coalitional enforcement hypothesis, I expect that following the adoption of the bow and arrow, along with intensifications in agricultural reliance, groups generally became larger, less residentially mobile and increased investment in the construction and maintenance of their residential structures. This increased the use-life of each structure, and increases the likelihood that more structures were contemporaneously occupied at sites than prior to the adoption of the bow. Because of the various factors mentioned above, which make it difficult to apply one population estimation methodology across the Southwest, I will not modify any reconstruction unless it is explicitly contradictory to another estimate in the same region. Should any modifications be made, I will also present the original and suggest why it may be erroneous.

Other Indicators

Tracking the effects of coalitional enforcement on prehistoric group sizes is most easily and obviously done by focusing on the introduction of the bow and arrow and on changes in momentary and maximum group sizes around the time of the introduction. However, several other archaeological indicators of a change in group organization and group size may be found. Archaeologically, a trend for increased labor specialization and increased importance in trade and prestige goods is commonly seen following gains in population size and the adoption of more complex forms of social organization. Should similar increases in emphasis on labor specialization and prestige goods be seen in the prehispanic Southwest, it is not unreasonable to expect that this increase should be seen archaeologically. There is no question that technological and social developments happened along different dimensions in the New and the Old Worlds. However, in an examination of the origins of projectile point technology in Africa, the Levant and Europe, Shea notes in support of coalitional enforcement, although admittedly not directly indicative of coalitional enforcement, that "it does not escape notice that the first evidence for consistent projectile point production in Europe and the Near East coincides rather closely with evidence for the consistent production of personal adornments in the form of perforated shells, animal teeth, ivory segments and stone beads" (Shea 2006:840). Similar expectations may be made for the prehispanic Southwest.

Powell (1988) provides further arguments for the necessity of trade with high-population densities. Noting the low animal and plant biomass in the Southwest, Powell argues that humans could adopt either a low- or a high-density strategy. Low-density, low-population strategies allowed for small groups to move across large expanses of land and directly exploit resource catchment areas. Larger areas of land were necessary to function as buffers against climatic variation, as this strategy is minimally invasive and minimally productive. High-density, higher population strategies relied on more labor- and production intensive strategies that increase the amount of resources in the area. Higher density population co-varies with circumscription and higher investment in labor and production reduces mobility, thus reducing the ability for a large group to travel to attain resources not immediately available. Powell argues that this necessitates exchange in heterogeneous landscapes (Powell 1988:176-178, 185). If Powell is correct, then not only should we expect an increase in trade goods after the introduction of the bow following Shea's arguments (potentially correlated with increases in population, and structural organizations that are more likely to value prestige), but we should also expect that, increases in population density were, in cases, dependent upon the formation of commodities exchange. If Powell is correct, then the necessary level of cooperative stability prior to the formation of larger groups and village aggregations would be even higher, as not only would intra-group cooperation need to be stable, but the group would depend upon successful cooperation with another coalition.

Some second-order indicators of the coalitional enforcement hypothesis may occur as well, although these will be harder to classify as uniquely dependent upon the hypothesis. For instance, increases in hunting and warfare have previously been posited as explanations for demographic and organizational changes following the introduction of the bow and arrow. It is my assertion, discussed at length in the following chapter, that neither the hunting nor the warfare hypotheses can fully explain the demographic and organizational changes seen after the bow's adoption. This is not to say that they did not have an impact, or that the increases in warfare and hunting are not expected after the introduction of the bow and arrow. Indeed, it is likely that the increase in cooperative stability foreseen by the coalitional enforcement hypothesis can explain some of the changes in warfare and hunting. In short, the coalitional enforcement hypothesis should allow for larger cooperative groups to successfully form and maintain themselves. Increased population heightens competition over resources, and in areas in which resources are scarce and costly to acquire, the benefits of defection increase. The bow allows for reduction in resource stress via hunting, as well as increased efficiency in coalitional enforcement—i.e., increased ability to protect resources for a larger group, which may be evidenced in the archaeological record as indicators of warfare. Archaeological indicators of increased hunting and warfare can thus be used as supplementary data in support of the hypothesis, but given existing hypotheses regarding these and demographic change, these data by themselves are unlikely to win over those skeptical of the coalitional enforcement hypothesis.

Conclusion

In sum, this thesis will look primarily at archaeological evidence for possible linkages between the introduction of the bow and arrow and increases in group maximum and average population. Should the introduction of the bow and arrow be associated with an immediate or somewhat lagged increase in group size, it is of course necessary for the introduction to precede the increase. While exact dates are archaeologically rare, age ranges that do not allow us to determine temporal priority will not allow us to test causation. Other archaeological indicators of the introduction of the bow and arrow, such as physiological markers that display changes in muscle utilization following the adoption of the bow and intensification of agriculture (Bridges et al. 2000), may be present in the archaeological record and data. Most of these are uncommon in the available archaeological data, or may not be as precisely dated as would be necessary to contribute to this discussion. Likewise, other evidence of factors affecting changes in group size may available. Some of these, including changes in agricultural intensification, or the adoption of ceramics, will be noted along with the archaeological data. Improved hunting capabilities, changes in warfare, and an increased reliance on storage, maize, and ceramics all have important paleodemographic impacts, which may muddy the water, making it more difficult to examine the hypothesis.

5| THE BOW AND THE ATLATL

There is very little debate about whether or not the bow was a significant introduction to the Southwest; the bow and arrow confer numerous advantages over the atlatl. Some advantages of the technology are obvious, while some possibly significant advantages, such as the reduction in punishment costs, have scarcely been considered by archaeologists. One indicator of the bow's advantage over the atlatl is the high degree to which it replaced the atlatl.

This chapter provides an overview of the technology and examines some of the impacts caused by the bow's introduction. I will discuss the basic morphology of the atlatl and the bow and arrow; the methods that have been used to distinguish the two in the archaeological record; and the general history of the bow in the New World as it pertains to the Southwest. This descriptive material will lead to a discussion of the advantages that the bow may confer over the atlatl and what I consider to be the most significant implications of the transition for prehistoric groups in the Southwest, emphasizing what these mean for the coalitional enforcement hypothesis.

General History of the Bow and Arrow in North America

There is evidence for the use of projectile weaponry in Old World contexts since roughly 40 kya (Shea 2006). The earliest projectiles were in the form of thrown spears, which have effective ranges of only around 7.8 m (Churchill 1993:18; Shea 2006:824). The first truly effective long-range projectile weapon, the atlatl, followed, and was in use by the time of migration of humans into the New World. Evidence of bow-and-arrow technology is seen first in Africa around 11,000 B.C., in the form of microblades used as barbs on arrows (Blitz 1988:126). In North America the bow and arrow is possibly seen as early as in the Paleoarctic Tradition (9000 to 6000 B.C), with clear evidence, in the form of microblade arrows, occurring only after 3000 B.C (Blitz 1988:126). After 1600 B.C. a transition to chipped stone and antler projectile points is seen in the Arctic, and is associated with seasonal sea-mammal hunting (Blitz 1988:127).

Following its introduction to the Arctic the bow moves southward to mainland North America. Blitz considers its diffusion into the Southwest the result of a movement through the Great Basin—reaching the Great Basin sometime between A.D. 1-500 based on a sharp reduction in size, or around A.D. 200 if the Rosegate tradition is considered as an arrow technology (Blitz 1988:129). Bettinger and Eerkins (1999) suggest a replacement of the atlatl by the bow and arrow around 1350 B.P. (ca. A.D. 600) across the Great Basin, based on a reduction in projectile size. Mesoudi and O'Brien (2008) present A.D. 300-600 as the period of adoption on the Great Basin. The initial appearance of the bow and arrow in the Four Corners region of the Southwest is a topic of debate, and ideas on the date of introduction have changed over time. Generally, the introduction has been dated between A.D. 575 and A.D. 750. Blitz notes Lipe's (1978) assertion that the bow is present by the end Basketmaker III period, ca. 700 A.D.

There are, however, several instances of earlier, Basketmaker II, adoption of the bow and arrow. The Tamarron Site (5LP326) and site 5DL896, both in Southwest Colorado, are dated to the Basketmaker II phase, and display evidence of an early introduction of the bow. Radiocarbon ages from a stratum at 5DL896 that contained eight small projectile points fall between A.D. 130 and 420 (calibrated at 2σ [Reed 1990]). Five projectile points—all morphologically similar to those at 5DL896—were recovered at the Tamarron Site in Southwest Colorado. The Tamarron site is undated, but architectural similarities to the Talus Village site lead to estimates of occupancy between A.D. 250 and 500 (Reed and Kainer 1978; Reed 1990:139-140). Evidence on the northern Colorado Plateau also suggests that the bow began to replace the atlatl by A.D. 300 (Geib and Spurr 2000; Holmer 1986; Reed and Kainer 1978). Geib and Bungart (1989) have recovered arrow points from Glen Canyon contexts radiocarbon dated to the first few centuries A.D., while Richens and Talbot (1989) have recovered arrow points in Southeast Utah at the Sandy Ridge Site (42SA18500) that also date to the first few centuries A.D. (Geib and Bungart 1989; Geib and Spurr 2000). LeBlanc (1999) places the introduction of the bow and arrow to the northern (Pueblo) Southwest at around A.D. 200-300, with diffusion to the southern (Mogollon) Southwest over the next centuries (LeBlanc 1999:101). Although data such as these suggest some use of the bow-and-arrow slightly earlier, the complete adoption of the bow and arrow by ancestral Puebloan peoples by around A.D. 600 is securely dated by many tree-ring samples from structures in the area (Geib and Bungart 1989). Given these data, the traditional distinction between the Basketmaker II and III (ca. A.D. 500) as a distinction between atlatl and bow using populations appear sound—at least for the Basketmaker III.

Morphology

The atlatl, also known as a spear-thrower, is a projectile thrower which predates the bow and arrow. In its simplest form the atlatl consists of a plank which typically has a spur near one end against which the base of a projectile is held prior to launch. Near the other end there are typically either indentations on the sides, some form of strapping, or a combination of both to provide a connection between the atlatl and the hand (Figure 2). Morphological distinctions are seen temporally and regionally, and can include the addition of grooves, weights, or composite atlatls, in which a portion of the atlatl (such as the spur) is of a different material than the body of the atlatl.

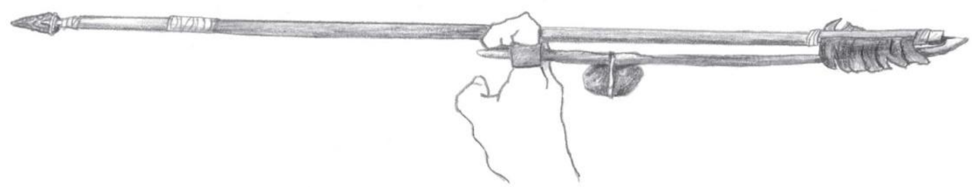

Figure 2: Example of an atlatl (top), after Reed (2009)

Atlatl darts vary in morphology through time, by regional tradition, and according to the prey they were designed for. Typically, however, the dart shaft is wooden with a hafted point made of wood, bone, or stone, and it is generally fletched. Darts are reported as ranging from 118 to 460 cm, but are more typically between 140 and 300 cm in length (Cattelain 1997:218, 229).

Functionally, the atlatl serves to increase the length of the throwing arm, which increases the velocity of the thrown projectile. The force of the throw, extending from the shoulder, through the wrist, and culminating at the end of the atlatl, is much greater than could be generated by throwing a traditional spear by hand. The atlatl thus allows for accurate and forceful impacts of darts at targets over a short distance.

Atlatl-thrown darts have a maximum flight of between 90 and 125 m. Although significantly longer throws have been recorded, it appears that these are atypical. However, the maximum effective and maximum accurate range of the atlatl is much less. Tindale (1928) recorded aboriginal attempts to hit a target from varying distances, finding that throws were accurate up to around 27 m, with only one individual able to hit the target from 31 m. Churchill argues for a slightly longer effective range of 39.6 m (1993:18). Effectively, the atlatl is best used at close ranges, with the successful stalking and approach of prey crucial in hunting success.

Rather than increasing the length of the arm, the bow operates as a spring comprised of elastic limbs held in tension with a string (Figure 3). An arrow is placed on the bow, with the tail end of the arrow resting on the string, and the forward shaft resting against the midpoint of the bow. When the string is pulled back the bow limbs are flexed and energy is accumulated in the bow. On release of the string, the energy is transmitted into the arrow, projecting it forward with a high amount of velocity and force. Bows generally fall into three categories. Self or simple bows are made of one material, usually wood, and represent the simplest and earliest form of bow. Reinforced bows have a wooden core reinforced with a laminate such as sinew. The third category is composite bows, which are formed of multiple components and can be made of different elements.

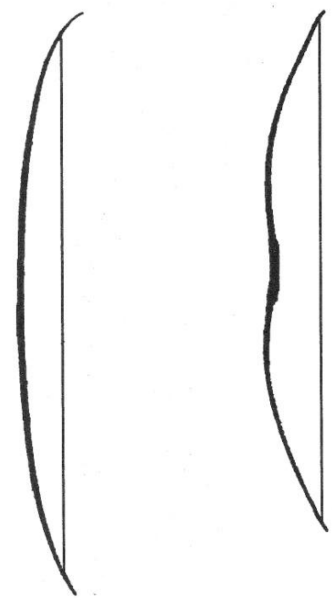

Figure 3: Example of a self-bow (left) and recurved bow (right) (after LeBlanc 1999:100).

Bows can also have different profile forms, such as straight bows, double-curved (recurved), reflex, or asymmetric (Cattelain 1997:219-222). In North America, the most common forms are the straight and the double-curved bow. These generally range between 1.15 and 1.7 m in length, although both shorter and longer forms have been observed in the archaeological record. Like darts, arrows consist of a wooden, wicker, or reed shaft with a fletched base, and a hafted projectile point usually of stone, bone, or wood. In the prehistoric Southwest, both atlatl darts and arrow points are usually stone. Arrows range in length from about 43 to 110 cm in North America (Cattelain 1997:219-223, 229). Self-bows were the first type introduced into the Southwest, and were not replaced by sinew-backed reinforced bows until around A.D. 1300 (LeBlanc 1999:98). In the Southwest, self-bows are almost exclusively straight bows, and reinforced bows are almost always recurved (LeBlanc 1999:99).

Bows typically have a maximum range between 130 and 185 m, with an average of 160 m. However, it appears that the effective, accurate maximum range is about 45 m, with the ideal range reported to be less than 30 m (Cattelain 1997:226-227). Churchill suggests an effective range of around 26 m for the bow and arrow (Churchill 1993:18). Bow type and profile shape also have an effect on released-arrow velocity and distance—LeBlanc (1999:99-100) reports that sinew-backed bows, which are also double-curved, release arrows at a 25 percent faster velocity than self bows.

Distinguishing arrow points from atlatl darts

Due to the rarity of arrow and dart shaft preservation in the archaeological record, as well as the even greater rarity of atlatls and bows themselves, the task of distinguishing their presence and use relies on correctly distinguishing the durable lithic projectile points they employed. Several ways to do this have been suggested. I will present a few of the methods employed over the years, along with some of the primary methods in use today.

Fenenga, examining a collection of 884 projectile points from 22 sites west of the Mississippi (predominately in California) found that the points fell almost exclusively into two different classes—a small projectile point tradition and a large projectile point tradition (1953:313). Almost all (92.3 percent) of the points in the small point classification fell under 3.49 g, while almost all (99.6 percent) the large points weighed more than 4.5 g. Further, the modal size of the two classes is even further apart, with the small point mode at about 1.1 g, and the large point mode around 9.0 g. Coupling his classification with archaeological and ethnographic evidence, Fenenga was able to show that the larger projectile points came either from culture areas that never had the bow and arrow, or from sites that pre-dated its introduction. The small points came from either later in cultural sequences, or in cultures known to prehistorically use the bow and arrow (Fenenga 1953). Thus, Fenenga believed that the small points could be identified as arrow points and the larger points as dart points with a high degree of probability (Fenenga 1953:317).

While Fenenga suggested that weight could accurately separate the two technologies, he also was able to experimentally determine that atlatls can function efficiently with small points—points that, by his scheme, would be classified as arrow points. Similarly, Brown (1938) found that many archaeologists (citing Baker, Kidder, and Campbell specifically) were making assumptions of function based purely on size and weight of recovered projectile points. An avid bowman, Browne gathered dart points from three archaeological sites and experimentally determined that they could be efficiently fired with a bow. Browne also hafted a 6-cm-long projectile point and was able to fire it 165 yards with a bow. Browne used these data to argue a pre-Pueblo I introduction of the bow (Browne 1938:358-359), and to emphasize that simple assumptions of bow-and-arrow presence based exclusively on point size were potentially erroneous.

Thomas (1978) noted that because archaeological projectile point specimens are rarely found attached to a haft, a classification scheme was needed so that archaeologists could make reasonable assumptions when they find only the projectile points (Thomas 1978:466). Thomas gathered a collection of 118 arrow points from archaeological and ethnographic contexts, as well as an additional 14 points found along with a quiver from Pueblo Bonito, and what he described as a “painfully small” sample of dart points (Thomas 1978:467-468). Collecting total length, width, thickness, neck width, and (estimated) weight, discriminant function analysis showed that width was the most important variable, and length the least.

Thomas ultimately created two classification equations which resulted in an 86 percent correct classification rate (Thomas 1978:471), although if he confined his analysis to the small darts in his sample he was only able to classify 70 percent correctly. Thomas also noted that, while there is a correlation between overall point size and overall arrow shaft size, the correlation is not strong. Overall dart size was not found to have much effect on the size of the dart projectile point. However, when comparing the size of arrow and dart points, Thomas was able to fairly successfully separate the two technologies using discriminant function analysis, with shoulder width the most important discriminating variable. Thus, while not finding that Fenenga's bimodality was necessarily wrong, Thomas was able to form an accurate classification method that did not depend upon univariate bimodality.

Shott (1997) expanded on Thomas' work, greatly increasing the dart point sample size. Shott found that though he could increase the possible dart sample to over 75 if he included only specimens that were hafted, could have all attributes measured, were authentic, and were not known to be designed for marine hunting. He ended up with a sample of 32 dart points, most archaeological, a large portion of which originated from SE Utah (Shott 1997:89-90). Shott ran discriminant function analysis on this sample using variables that Thomas had used, determining which of them were the most important by reducing the number of variables until a one-variable solution was reached. He found, as had Thomas, that shoulder width was the single most important factor in distinguishing dart points from arrow points (Shott 1997:95). With a four-variable solution, using shoulder width, neck width, length, and thickness, Shott achieved an 86.5 percent correct classification rate overall, with 76.9 percent of the darts points correctly classified. To study the impact of having a solution with fewer significant variables, a three-variable analysis was performed that omitted length. (Length is the variable most susceptible to reduction through resharpening during point curation.) The three-variable solution was found to have a higher rate of successful classification, and had no outliers among arrow points. Overall, 89.4 percent of the assemblage was correctly classified, and 84.6 percent of the darts were correctly classified. A two-variable solution using only shoulder width and thickness had an overall correct classification rate identical to that of the three-variable solution, but slightly lower correct dart classification. A one-variable solution was also run, using only shoulder width, with similar results. The one-variable solution classified 92.4 percent of arrow points correctly, and 76.9 percent of the darts. Shott considered the one and two variable solutions to be the most promising, with the one-variable solution correctly identifying arrow points at a higher rate than any multivariate solution (Shott 1997:98-99). Shott (1997) critiqued Fenenga's work—while admitting that Fenenga's technique would often work—because it was developed using archaeological specimens of unknown status. Furthermore, in cases of known status—when the dart or arrow is still attached to its haft—weighing the specimen would require removal from the haft, damaging a specimen type that is, itself, uncommon (Shott 1997).

Hughes (1998) suggests tip cross-sectional area (TCSA) as another measure for discriminating dart from arrow points. TCSA is defined as the "tip maximum sectional area," i.e., the portion of the point that cuts the hole that the shaft enters, where "tip" references a projectile point (Hughes 1998:350). Essentially, Hughes argues that projectile penetration is dependent upon four variables: mass, velocity, tip cross-sectional area, and projectile shape. Because arrows are smaller than darts, arrows impart less kinetic energy to a target. If all else were equal, arrows would not penetrate as deeply, and be ineffective. This issue can be overcome if the TCSA of the arrow is smaller, which allows for a smaller penetration hole, thus losing less energy on initial impact and retaining more force for penetrating and injuring (Hughes 1998:351-353). Using an assemblage from Mummy Cave, Wyoming, Hughes found that tip cross-sectional area was able to distinguish between atlatl and bow technology, and was also able to indicate when point size decreased following the adoption of fletching—stabilizing feathers added to the end of the arrow shaft (Hughes 1998:395-398). Shea's (2006) examination of Old World projectile points utilized the tip cross-sectional analysis, comparing them to Thomas's (1978) and Shott's (1997) assemblages. Results employing TCSA seem similar to those obtained with Thomas' method.

Of these methods, that of Thomas's (1978) seems to be the most used, and was employed in much of the archaeological work to be discussed below. While other classification schemes exist, it is not my purpose to represent the full range of methodology that exists, nor is it within the scope of this thesis to reanalyze existing projectile point datasets to confirm classification.

Advantages of the Bow

Functional Differences

Adoption of the bow could occur for a variety of reasons, and likely was chosen for purposes that were obvious and visible to a group. The bow has numerous functional advantages over the atlatl. Groups that were in the position to observe, and potentially adopt, the technology, would not necessarily know the detailed attributes of the technology in comparison to the atlatl. Along with taking into account observable traits of the bow (perhaps when at the receiving end of a demonstration), groups would be adopting the technology based on studying groups that already had the technology. We should expect, then, that groups were able to have some sense for both the obvious and less obvious impacts of the bow prior to the adoption. Blitz suggests that the apparent large-scale pattern of dispersal and adoption is not directly attributable to regional environmental circumstances, but that the bow spread rapidly across major ecological boundaries as a result of offering a "contagious competitive advantage in intergroup conflict" (1988:124). Hughes (1998) agrees with this position, noting that the complete replacement of the atlatl by the bow implies that the bow both duplicated and improved upon the functions of the atlatl. Selective pressures also likely played a role in prompting the adoption of the bow and arrow—benefits conferred by the bow and arrow likely increased group fitness, thus increasing the group size relative to groups that did not adopt the bow (Shott 1997).

One of the primary advantages of the bow is its increased effective range over the atlatl. As discussed above, the atlatl is most effective at distances less than 27 m, while the bow is effective at distances less than 45 m. Churchill (1993) does argue a longer effective range for the atlatl than for the bow, although his general conclusions are in line with my general argument. I will discuss this further in my examination of hunting. Bingham argues that an increase in effective range may not be important in hunting—though I would disagree—but that it is important in coalitional enforcement, where even a small increase in the probability-per-shot of inflicting injury or death can create a significant increase of risk associated with being punished (Bingham 1999:157). Hughes' (1998) work shows that the bow imparts greater velocity to a projectile, allowing increases in both effective and maximum distance. The bow is also a much more versatile weapon than the atlatl, effectively increasing possible distance between prey and hunter. Increases in distance between prey and hunter increase the chance of successfully stalking the prey, and also decrease the risk of a hunter being injured by the animal. The bow also produces less noise and motion during firing, and is easier to transport (Hughes 1998:394). The bow has a faster volley rate, averaging around five to ten aimed shots per minute (Keeley 1996:51). The bow is also advantageous in terms of position of the individual. Atlatls achieve maximum energy imparted several steps into the launch, and thus require firing from a standing position, whereas the bow can be shot from a variety of positions. This in turn decreases the visibility of the archer, which confers numerous advantages in hunting and warfare. Due to their smaller size, arrow points have a lower manufacturing cost than dart points. While large points require bifacial reduction, the smaller arrow points can be pressure flaked expediently, saving both time and lithic material (Hughes 1998:394-396). Another advantage of the bow and arrow pertains to projectile velocity. Fending sticks—short, often slightly curved sticks, equipped with a thong for a wrist strap—are first seen in Archaic assemblages, and were used until the adoption of the bow (Figure 4). Fending sticks have also been recognized in Mesoamerican contexts (see Morris and Burgh 1931). Given the fairly slow speed of a thrown atlatl dart, a fending stick would be held in one hand, while the atlatl was held in the other, and could be used to bat away incoming projectiles (LeBlanc 1999:96, 106). This further reduces the effectiveness of the atlatl when engaging in conflict, and makes the bow, which has projectiles that are too fast to be blocked effectively with a fending stick, a much more dangerous weapon.

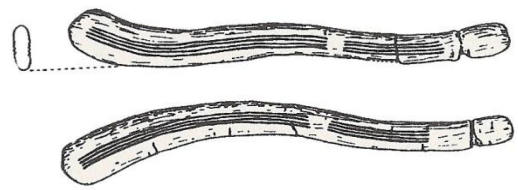

Figure 4: Example of a fending stick, after LeBlanc (1999:97).

In sum, the bow offers numerous advantages over earlier technologies. It is true that the heavier darts can deliver more force than a typical arrow. The lighter-weight bolts of the bow are more affected by resistance during flight, which reduces the maximum and effective range, and increases the likelihood of deflection in forests. However, considering the many disadvantages of the atlatl compared to the bow, its few advantages are likely not significant.

The advantages of the bow—increased maximum effective range, increased velocity, flatter flight path, advantages in individual positioning—are all important in terms of coalitional enforcement. Atlatl darts were slow, accurate over a shorter effective distance, and had to be thrown from a standing position (and after several steps). This resulted in a projectile that was easy to block or sidestep, and left the thrower in a prone position. Rather than trade volley after volley of slow moving darts, individuals may have been better served by closing in combat with melee weaponry. This exponentially elevates the risk, as the benefits of projectile weaponry are lost. Arrows are capable of being fired from a variety of safer positions, had a longer effective range, and a faster flight path, resulting in a projectile which was harder to block and an archer who is better hidden from retaliation. These differences may not make much difference in activities like hunting, but in situations in which a potential defector is evaluating the potential risk of defecting, the bow is markedly more dangerous than the atlatl. More importantly, to those engaging in punishment, the bow offers a clear and high level of risk reduction over the atlatl.

Hunting

Among the advantages of the bow, that which is most often cited is ability of hunters so armed to bring down larger prey more reliably and in larger numbers than earlier weaponry would have allowed. This in turn is argued to have increased an environment's carrying capacity, allowing the formation and stability of larger groups.

While the bow indisputably confers advantages over the atlatl for hunting, several researchers, including Shott (1997:86), argue that these conventional assumptions of bow superiority for hunting are doubtful. One basis for Shott's argument is his examination of ethnographic hunting return rates. For the groups he included, average prey body mass was significantly larger where prey was killed by atlatl. As hunting return rates were higher with the bow and arrow, Shott argues that this serves to cast doubt on arguments of superior efficiency of the bow, and that it may instead argue only functional differences (1993:437-438). Similar arguments have been made by Churchill (1993), who also finds a smaller average prey size with the bow and arrow than the atlatl. Shea, albeit for Old World contexts, also notes a smaller median prey size following the introduction of the bow and arrow, and notes that:

> While there is a longstanding hypothesis linking projectile point origins to big game hunting, evidence for effective big-game hunting long precedes the widespread use of projectile weaponry. Indeed, plausible stone projectile points are conspicuously absent in precisely those contexts, the [Middle Paleolithic] of Europe, where one ought to expect big-game hunting to have been a significant part of hominin subsistence [2006:842].

For those who would argue that the atlatl has a longer effective range (Churchill 1993), and even admitting that there are situations where increased kinetic impact is more important than velocity, the advantages that the bow confers to hunting are worth noting. Churchill notes that the bow is a versatile technology, conducive to any hunting technique. Despite the superior versatility of the bow compared to the atlatl, he argues that the bow, having in his opinion a reduced effective range, requires either a very accurate shot to a vital area of a larger animal, or it requires that the animal is hit multiple times (Churchill 1993:18). Given the relatively quick re-fire rate of the bow, this is not necessarily impossible for a single hunter to accomplish, but it does highlight the advantages that group hunting would bring. This, outside of kin groups, of course underscores the need for cooperative stability and coalitional enforcement.

Even assuming that the bow brought considerable improvements to hunting, these are not expected to be very important in affecting group size and complexity. Increases in hunting returns due to the introduction of the bow and arrow may allow temporary increases in carrying capacity for a region, but this is not enough to prompt significant changes in social organization. In any case such increases in returns might be transient if game populations were depressed. Practices such as meat-sharing—which is a commonly seen ethnographic practice, and would be expected to intensify following given hunting driven changes in social organization—are dependent on reciprocity in some form (Hawkes et al. 2001; Kaplan and Hill 1992). If we expect group size to increase due to increased hunting returns, we would also expect the incidence of defection to increase, as the only thing that has changed about the group is the level of food available for sharing/not-sharing. When there are the means to punish those who do not cooperate, then practices such as meat sharing can exist, and can help to stabilize cooperation. However, these are dependent upon the fundamental issue of cooperation having been stabilized prior to their success.

Overall, I argue that the bow and arrow did not bring about important changes to groups because of advantages specifically for hunting. While various aspects of efficiency and advantage of the technologies are debated, there is a consensus that the bow is a superior weapon. If the bow provides an increase in a group's hunting efficiency, then we should expect that to only heighten the selective value of solving the coalitional enforcement problem. For example, if group hunting of larger mammals increases, effective monitoring of division of returns is necessary for its continued success. If instead, the bow allowed smaller prey to be killed easily and at greater numbers, we should expect one of two trends. Small game is not traditionally shared as widely within a group as is larger game. If this remains the case, then the introduction of the bow and arrow might allow more protein intake at the household level, possibly removing one of the primary advantages of larger coalitions. Conversely, if there is an increase in the quantity of small game shared within the community, cooperative levels must be stable and at high levels. Indeed, it is likely much more difficult to hide the killing and preparation of a large mammal from a group, than to hide the killing and preparation of small game. If small game hunting is kept as an individual action, then the hunting hypothesis cannot explain the driving forces behind larger group size.

Warfare

This section examines arguments about the relationship of warfare to weaponry that do not directly relate to the coalitional enforcement hypothesis. Such unpacking can be difficult to do. For example, Chavaillon writes:

> During the Paleolithic, man sought food on a daily basis; he had only his prey to defend. Neolithic man, by contrast, stored and amassed food supplies… The sturdy dwellings and defended villages also ensured a relatively secure lifestyle. However, man soon became prey himself, his material wealth motivating the deprived and dishonest to seize these possessions [1996:189-190].

From the perspective of the coalitional enforcement hypothesis, this demonstrates the fuzzy line dividing raiding from within-community defection. Many of the models for warfare that I review below oversimplify the processes at hand by ignoring the possibility of explanations based on coalitional enforcement. I define warfare following LeBlanc (1999) and Meggitt (1977); as a "period of armed hostility… between politically autonomous communities, which at such times regard the actions (violent or otherwise) of their members against the opponents as legitimate expressions of the sovereign policy of the community" (LeBlanc 1999:7). This definition does not restrict itself to formalized warfare between groups of a certain level of organizational complexity, and thus can include situations such as raiding and ambushing. This is in line with the Guilaine and Zammit's (2005) definition, which also includes raiding, ambush, and the murder of individuals. Some of the sources cited below use a significantly different definition of warfare, and when that is the case I will provide their usage.

The introduction of the bow and arrow impacted the conduct of warfare. Indeed, many researchers see changes in the practice of warfare, and its intensification, as the most significant impacts of the bow and arrow. Increasingly common defensive settlements, and aggregation itself, are commonly cited as social impacts of bow-and-arrow technology. For example, LeBlanc suggests that the later (ca. Pueblo IV) pueblos of the Acoma, Zuni, and Hopi were fundamentally designed for defense, both in their topographic placement and in their architecture (1999:2). LeBlanc identifies two overarching reasons for war –competition for scarce resources, and nonmaterialist causes, which include revenge, colonial expansion, ritual, etc. However, as Keeley discusses, warfare is a complex phenomenon, and like all complex microcosmic phenomena, usually does not have a single cause (1996:17). On a mircrocosmic scale, the causes for the start of violence between two groups are many, and not of primary importance to this thesis. There is a wealth of primary literature (including Boehm 1984; Guilaine and Zammit 2005; Keeley 1996; and LeBlanc 1999) treating warfare, and the reader is directed towards those for more details. More important here are any effects warfare may have on group size and complexity, and determining whether it is more likely that warfare is directly responsible for the large transitions we see around the time of the introduction of the bow and arrow, or if other processes such as those identified in the coalitional enforcement hypothesis are responsible.

War and Scale: Distinctions have been made between state-level warfare and primitive warfare, which further illustrate the utility of the coalitional enforcement hypothesis. Wright (1942) and Turney-High (1949) report that groups with simpler forms of organizational strategies were disadvantaged relative to state-level organizations as they suffer poor mobilization and military training of manpower due to reliance on completely voluntary participation; poor command, tactics, and discipline; and inadequate supply and logistics to conduct protracted campaigns (as reported in Keeley 1996:11). Along these lines, Turney-High "conceded that social pressure alone was sufficient to raise large war parties in some tribes, [but] also believed the system of physical compulsion used by the Zulu, Dahomean, Celtic, and modern states was superior" (Keeley 1996:12, citing Turney-High 1949). Both the list of "deficiencies" and the argument against a lack of forceful motivation do not signify organizational or strategic weakness of simpler groups. Instead, these groups, which include the societies of the prehispanic Southwest, are only "deficient" in their ability to maintain the organizational and cooperative complexity required to develop the ability to train warrior-specialists, supply long campaigns, or to be able, with low risk, to coerce participation in a war from individuals and groups who do not want to participate. Only after solving the problem of cooperation, and having reduced risks of both partaking in a war and coercing participation for a war, can groups develop an efficient body of warriors. As a reminder, war is defined here as any sort of violent skirmish between politically autonomous coalitions, and for the time in question, war will more often consist of raiding and ambush than of prolonged battles. The above, besides illustrating the impact of the coalitional enforcement hypothesis on how war may be gauged, also illustrates a further element of risk reduction with increasing levels of cooperation. For an individual, partaking in a violent activity versus a rival group always is risky. Following the adoption of the bow, I argue that the risk is less than when the atlatl and fending stick were the primary long-distance weapon. Larger groups may be able to devote more effort to training and specialization, which may further reduce the risk for the individual, especially if the group has a strategic or technological edge over other groups.

Archaeological Implications: Ignoring such extremes as group annihilation, common outcomes to a climate in which there is at least a believable threat of war include group aggregation or dissolution, group movement to more defensible locations, and the creation of defensive architecture. Some of these warrant examination. If a warfare hypothesis is a valid replacement for the coalitional enforcement hypothesis as an explanation for increases in group size, then these examples of the influences of war on group organization should be able to stand independently from the model. LeBlanc (1999) mentions three types of evidence of warfare: settlement patterns, burning of structures, and deaths from violent causes. Burning in the course of warfare and evidence of violent deaths are more immediate impacts of warfare, and while these have an impact on groups, are felt to serve well as evidence of warfare only. Changes in settlement patterns, however, can be both an indicator of warfare and of changing organizational strategies. Within his discussion of changes in settlement patterns, LeBlanc mentions changes in: 1) site configurations, which include evidence of defensive planning and layout, evidence for site size increasing over time, evidence for smaller sites being abandoned prior to large site abandonment, and evidence for rapid construction of sites; 2) site placement, with sites on defensible land forms, and a tendency for larger sites to be located on less defensible land than are small sites, and evidence of sites located to provide access and defense of water supplies; 3) Site distribution, in which LeBlanc includes evidence for site clustering with empty zones around site clusters, and sequence of abandonments; and finally 4) Sites located for line-of-sight communication (LeBlanc 1999:56).

In the Southwest, walls were the primary defensive feature, taking the form of palisades or stockades made out of logs, or freestanding walls constructed out of adobe or stone. Other defensive forms included towers, dry moats, safeguarded entryways, tunnels, and keep-style architecture (LeBlanc 1999: 57-62). Large settlements have inherent defensive advantages since a larger community has both more defenders and potential attackers than any smaller group that may attack it. Indeed, LeBlanc argues that once a portion of the population of the Southwest began to reside in large defensible settlements:

> It would have been almost impossible for small, homestead-like sites to be viable. Once the size of the attacking group grew large, compared with the number of defenders, the small sites had to be abandoned and the inhabitants had also to move into larger settlements… However, once one group aggregated into a large site, it gained a military advantage over dispersed small sites, and the residents of the small sites would have been forced to either follow suit and join forces or flee [1999:63].

LeBlanc argues that sites on defensible landforms, such as hilltops, are advantageous as they are harder to access, allow line-of-sight communication with allies, and confer tactical advantages against other groups, as it is harder to throw and shoot uphill accurately with force than to shoot or throw downhill. Smaller sites should be more common on defensible landforms whereas larger sites could defend themselves adequately without topographic advantage (LeBlanc 1999:66). Finally, site clusters and empty zones are claimed by LeBlanc to be among the clearest signatures of warfare, as dense concentrations of people cause overexploitation of the resources close to the cluster and underutilization of resources further away from the settlement. Further, site clustering would decrease the breadth of available resources, making clusters more prone to catastrophic failures of drought, flooding, freezing etc. Instead, had defensive measures not been necessary, LeBlanc suggests that, in the

Southwest, the optimum strategy would be one of well dispersed populations that could ensure adequate risk buffering (LeBlanc 1999:70).

Conclusion

This chapter has covered a wide range of topics that relate to the atlatl and the bow and arrow. The data presented indicate that the bow is a much more efficient and dangerous weapon than the atlatl, and is thus more likely to precipitate the causal sequences expected in the coalitional enforcement hypothesis than is the atlatl. Although variation exists in the time that the bow was introduced into different regions of the Southwest, and the dates that researchers have argued for the adoption, should specific dates not be available for a region, A.D. 600 seems empirically grounded as a fairly conservative estimate for the introduction and adoption of the bow into the region. Finally, it has been argued that, although the bow confers advantages that are important to both hunting and warfare, neither of these alone can explain the organizational changes seen in the mid-first millennium A.D. The hunting hypothesis does not explain how or why the bow and arrow caused population and organizational complexity to increase, or how the problem of cooperation was overcome. Warfare hypotheses help us understand why groups would aggregate and increase in size, but do not provide an account for how these groups could maintain successful cooperation. Shea reaches a similar conclusion based on his consideration of data on the origins of projectile technology in Africa, the Levant, and Europe. He suggests that coalitional enforcement acts as a good explanation for the intensification and diversification of projectile point technology, and that increased coalitional killing between 30-50 kya cannot be accounted for through warfare or big-game hunting (Shea 2006:840). This is not to argue that the bow and arrow's impact on hunting and warfare is unimportant. As discussed in Chapter 2, it may be expected that groups possessing the bow earlier than other groups may have quickly become much more formidable than other regional groups, had a higher group wealth tradeoff ratio score, and ultimately become more likely to engage in aggressive conflicts. Increased aptitude in practicing warfare and hunting are important, but do not explain the demographic and organizational changes seen in the mid-first-millennium A.D.

6| Archaeological Data Relevant to the Model

This chapter discusses archaeological data from selected areas in the prehispanic Southwest—especially dates for the introduction of the bow and arrow, changes in group maximum, and momentary population size—to investigate the hypothesis that the introduction of the bow and arrow was linked to demographic and organizational change in the ways proposed by the coalitional enforcement hypothesis.

General Regional Prehistory and Trends

Three primary prehistoric cultural traditions are recognized within the Southwest during the time periods being discussed: the Anasazi (or prehispanic Pueblo), the Hohokam, and the Mogollon. Figure 5 displays the general location of each. These traditions, and the subcultures within them, have diverse cultural practices and materials which Martin (1979:61) argued are largely accounted for by the adaptation of each group to their ecological niches.

Maize was introduced into the prehispanic Southwest ca. 2000 B.C., although the adoption was not temporally uniform, as it reached northeastern Arizona by 1940 B.C., but not the northern reaches of the Colorado Plateau until ca. A.D. 600 (Kohler et al. 2008:647-648). Squash appears to have been introduced at the same time with corn, but beans did not arrive into the Southwest until 300-500 B.C. (Cordell 1997:131). While maize was thus introduced very early in the Southwest, its use does not seem to have significantly increased rates of population growth until the first millennium A.D. Population in each of the three cultural tradition areas was low and dispersed at the beginning of the first millennium A.D., but experienced significant growth throughout the millennium, especially in the latter half (Kohler et al. 2008). Cordell has (1997) contended that, based on variability in the degree of dependence on crops, continued seasonal movements, and small settlement size, demographically and socially viable villages did not appear in the U.S. Southwest until around A.D. 850 (Cordell 1997:222).

LeBlanc argues that, between A.D. 1 and 900, the region displayed more warfare than would be expected given the general demographic and regional stresses. LeBlanc attributes this to increases in the differences of value in resources being utilized, conflict over resource ownership, and general population pressure (LeBlanc 1999:36).

The Mogollon and the Anasazi share more common cultural traits and timelines than either do with the Hohokam, so this thesis focuses exclusively on these two culture traditions. The archaeological sequences in these two areas also tend to be better dated, because of tree-ring chronologies. Neither area is homogeneous, nor is either intended to be represented as such. This thesis will examine both general traits of each culture group, as well as the regional variation indicated by the archaeological data. In what follows I emphasize data that can help examine the coalitional enforcement hypothesis.

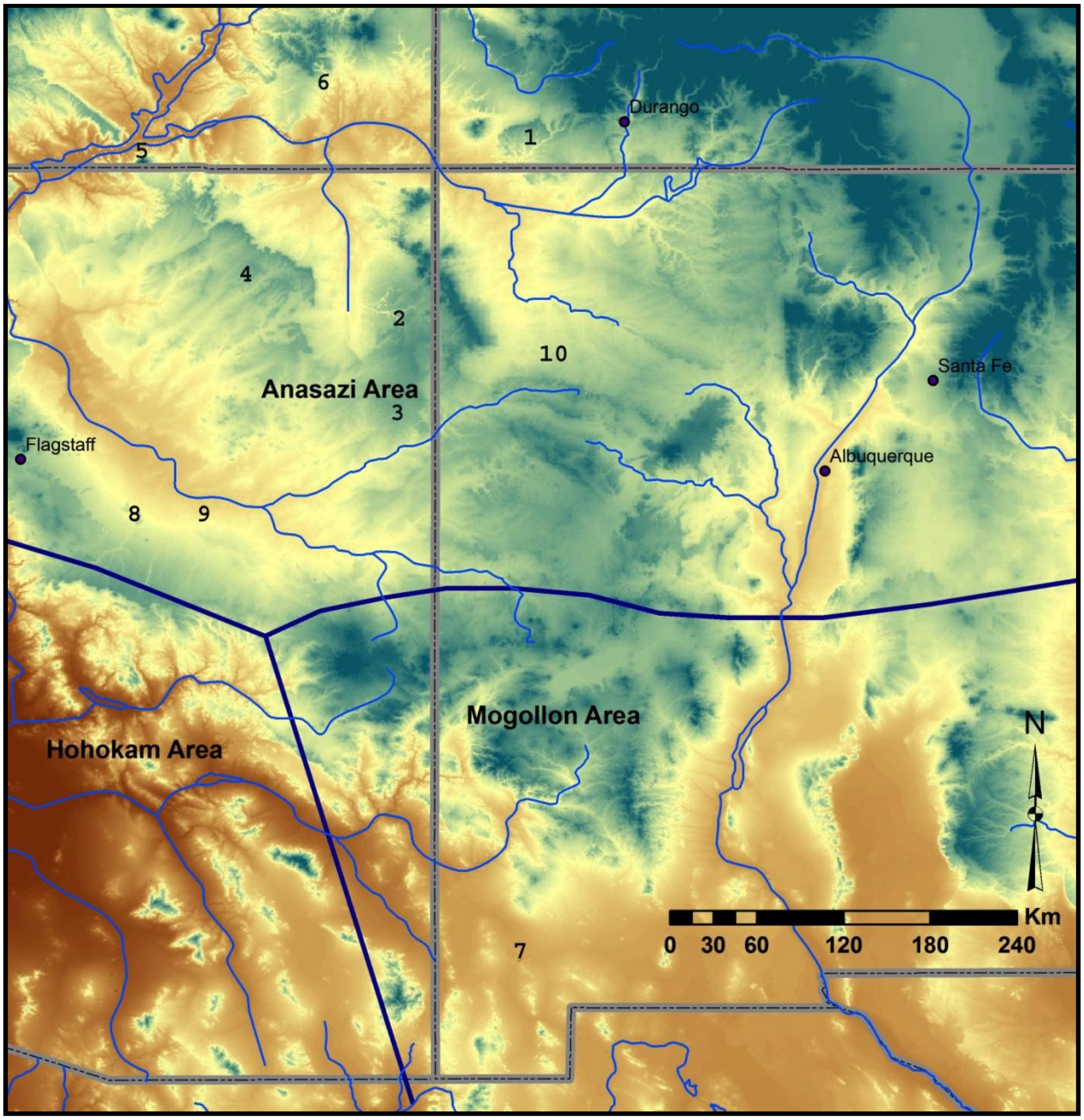

Figure 5: General area of study (modified from Diehl and LeBlanc 2001 Fig 2.1b).

Approximate locations of 1) Mesa Verde; 2) Canyon de Chelly; 3) Defiance Plateau; 4) Black Mesa; 5) Rainbow Plateau; 6) Cedar Mesa; and 7) Mimbres Valley, 8) Chevelon Creek, 9) Hay Hollow Valley, and 10) Chaco. The image represents the focal area for this thesis and not the precise boundaries of the areas in which the cultural traditions developed.

Culture Groups of Focus

Anasazi

The Anasazi, also referred to as the Ancestral Pueblo, occupied the Four Corners area, and extended east to the Rio Grande area in New Mexico and west through northern and central Arizona and into southern Nevada. As the periods bracketing the introduction of the bow and arrow, the Basketmaker II and the Basketmaker III periods are of primary interest.

The Basketmaker II of Southwestern Colorado. While the Basketmaker II time period generally extends from 1000 B.C. until around A.D. 400-500, within the Four Corners region it is usually confined to the years from A.D. 1 to 500 (Lipe 1999:133). Although the Basketmaker II period has been defined in various ways, in general, definitions have been fairly close to A.V. Kidder's, who considered Basketmaker II to represent "the agricultural, atlatl-using, non-pottery-making stage" of the Anasazi (Kidder 1927:490). Kidder also used the presence of cranial deformation as a marker between the two stages, although this is not widely used any more. Definitions based largely on absence or presence of cultural traits can be problematic. As archaeological knowledge has increased, so has the understanding that cultural transitions are rarely quick and complete. Early definitions of Basketmaker II, such as Kidder's, confined Basketmaker II to aceramic, atlatl-using people. However, crude ceramics were introduced within the Basketmaker II (Reed 2000) and the bow was introduced at varying times in the Southwest, with some evidence from Basketmaker II times. Most of the changes in definition of cultural phases have been largely due to data availability. The early periods in the region, especially the Basketmaker II, have not been as intensively studied and dated as have later periods. This is due, in part, to the lower populations of the period; to the fact that pithouse habitation sites are more prone to weathering than later sites which use masonry and adobe; and finally to the difficulty in distinguishing Basketmaker II cultural material from earlier and later occupations—especially in cases where later occupations built upon early components.

While these aspects of the Basketmaker II archaeological record can make it difficult to distinguish from other early sites, especially aceramic Archaic sites, several distinctive characteristics of Basketmaker II are widespread enough to serve as general markers of the phase. In southwestern Colorado trough and oval metates, and shallow, relatively small, circular pithouses with coursed or cribbed log walls and mud mortar, are indicative of the Basketmaker II period (Lipe 1999:137). Shallow grinding slabs and cradleboard burials are also used as phase markers (Reed 2000:6). Projectile points are somewhat variable within the region, but commonly include corner-notched, expanding stem dart points, which often display prominent tangs. Also found are points such as those of the Marsh Pass Basketmaker II sites which contain side-notched San Juan dart points (Lipe 1999:140, 156). Presence and reliance on maize is a primary distinction between earlier Archaic populations and Basketmaker II populations (Reed 2000:6).

The Basketmaker III of Southwestern Colorado. The Basketmaker III (A.D. 750-1000) period is generally characterized by residential sites; the widespread cultivation of crops such as maize, beans and squash; the widespread presence of plain pottery and the bow and arrow; and the cessation of cranial deformation (Lipe 1999; Wilshusen 1999:166).

Residential sites are quite variable throughout the Basketmaker III period. Generally ranging from small structures, to hamlets of up to nine pithouses (such as at Step House in Mesa Verde National Park), the majority of the residential sites are one or two household habitations. The main residential structures are pithouses and lack masonry. Pithouse architecture during the Basketmaker III changes enough through time that it has been argued that a 50-year chronology could be created by fully examining all aspects of dated pithouse structures, including structure layout, depth, roof construction and features. Common architectural features of pit structures include storage cists, domed storage structures, hearths, formal central hearths, deflectors, wingwalls, and slab-lined storage bins (Wilshusen 1999:174). In general, pithouses are larger and more elaborate than in the Basketmaker II, with more upright-slab storage cists and rooms (Reed 2000:7) generally to the north of the pithouse.

The earliest ceramics in the Basketmaker III period are typically brown wares. Gray and white wares come into use later on in the sequence, with gray wares comprising about 90 percent of the total ceramic assemblage at many of the Basketmaker III sites in the Four Corners area (Wilshusen 1999:172-173). Paul Reed views A.D. 550 to 750 as the heart of the Basketmaker III period, as the use and production of gray, red, and white ware ceramics became refined and entrenched; pithouse complexity and the construction of storage cists increased, with the transition to surface rooms by late in the period; a full dependence on domestic cultigens; evidence of increased levels of trade in shells and lithics; and the materialization of economic and sociopolitical differentiation (2000:8).

Southwest Colorado Basketmaker Agriculture. The fertile upland dry-farming soils in the Four Corners area were generally not fully utilized during the Basketmaker II period, though they supported very large populations during the Pueblo II and Pueblo III periods (Lipe 1999:155-156). Likewise areas such within the Mesa Verde-Mancos and Monument-McElmo drainage units were not utilized agriculturally until Basketmaker III. The lower reliance on maize and storage, a higher reliance on foraging, and a lower population than seen later periods also play a part in the underutilization of the region (Lipe 1999:161).

Over the entire Basketmaker II period dependence on agriculture increased, showing that by the end of the Basketmaker II period, especially in the northern part of the Four Corners region, groups depended heavily on maize, cultivated squash and continued to collect wild plants. Beans do not preserve well in the archaeological record, but lithic assemblages contain a higher percentage of projectile points in Basketmaker II sites than in many of the later periods, suggesting that hunting remained an important source of protein even in late Basketmaker II, suggesting that beans, if present, were not a major protein source (Lipe 1999:160).

Subsistence from the Basketmaker II to the Basketmaker III became increasingly reliant on agricultural crops, with earlier research suggesting that up to 50 percent of the Basketmaker II diet was supplied from maize, beans, and squash. Recent methods, such as human coprolite analysis (Stiger 1979; Wilshusen 1999) and isotopic bone analysis (Decker and Tieszen 1989) now suggest that maize may have contributed between 50 and 80 percent of the annual dietary intake (Wilshusen 1999:185-186). The Basketmaker III period saw an increase in dependence on food storage, and the distribution of sites in agriculturally rich areas with “thick Pleistocene loess-derived soils, nearby permanent water, and pinyon-juniper woodlands” (Wilshusen 1999:186) which, along with the decreased evidence of meat as a dietary staple, reaffirm the importance of agriculture in the Basketmaker III period (Wilshusen 1999:186). Matson and Chisholm’s (1991) isotopic bone analysis shows heavy reliance (over

80 percent) on plants that utilize a ^{4}C metabolic pathway (such as maize, chenopodium, and pigweed) from Basketmaker II individuals at Cedar Mesa—data supported through coprolite and bulk soil analysis (1991:450-452, 454).

Southwestern Colorado Basketmaker Populations. Several different population constructions have been made for southwestern Colorado. Basketmaker II population in Southwest Colorado appears to dramatically decline in size towards the end of the Basketmaker II occupation of the region, from around A.D. 375 until around A.D. 575 (Wilshusen 1999:167). This decline in population, which is backed by chronometric evidence as well as a general scarcity of recorded sites dating between A.D. 375 and 575, appears to have been at least partly the result of cooler climates in the fourth and fifth centuries A.D., which would have made agriculture increasingly difficult, prompting migration from the region, or the adoption of a more nomadic hunting and gathering lifestyle which left fewer habitation sites for the period in the archaeological record (Wilshusen 1999:193).

Wilshusen calculated population estimates for the region, noting that it is unlikely that population changed significantly between A.D. 620 and 680. Population either decreased heavily between A.D. 720 and 750, or archaeological sites within that time period have failed to be identified. It is apparent that population in the region was increasing by A.D. 760 (Wilshusen 1999:188).

Within the central Mesa Verde region of Southwest Colorado there is considerable variability in population depending on the drainage unit of focus. Several drainage units, such as the Upper San Juan-Piedra, supported fewer than 250 people during the entire BM III period, while many of the other drainage units contained much higher populations (Wilshusen

1999:188). Within the Dolores River valley occupancy started ca. A.D. 650 and terminated around A.D. 1150. Several population estimates came out of the work involved with the Dolores Archaeological Project (such as Kane et al. 1982; Orcutt 1981). The Dolores River valley appears to have experienced a peak population late in the ninth century, and then a decline to abandonment in the twelfth century. Orcutt (1981) estimates a Dolores River valley population of roughly 1500 people between A.D. 650 and 850, 2300 people between A.D. 850 and 975, and a decline to 250 between 1050 and 1150. Overall, the region sees its first real population boom and population consolidation, as the population of the Four Corners region exceeded well over one thousand people for the first time (Wilshusen 1999:191).

Within the Village Ecodynamics Project (VEP) study area in southwestern Colorado (Kohler et al. 2007), utilizing Bayesian methods for analyzing archaeological survey and excavation data Ortman et al. (2007), and Varien and colleagues assessed occupational histories from more than 3000 sites, provide a new maize paleoproductivity reconstruction, and use these to analyze the settlement dynamics of the VEP archaeological site database (Varien et al. 2007:274).

The VEP encompasses an area located in southwest Colorado, slightly northwest of Mesa Verde National Park (location 1 on Figure 5) including the eastern portion of the Canyons of the Ancients National Monument. The site database is comprised of sites largely recorded during cultural resource management survey work. At the time of the Varien et al.'s work, around 15 percent of the project area had been surveyed. The authors defined a settlement as a year-round residence if it exhibited a midden and one or more pit structures.

A total of 3,176 sites in the database were qualified as either single habitation, multiple habitations, or community centers; the latter are defined as settlements "with nine or more pit structures, 50 or more total structures, or sites with public architecture" (Varien et al. 2007:275-276). Community centers have longer use histories than do other habitation sites, and are assumed to represent locations of social, economical, and political actions that did not occur at the smaller habitations. Work was done to gather data on all community centers within the project area for which high-quality maps and ceramic tallies were not already available (Varien et al. 2007:276).

The authors create maize productivity calculations, modifying Van West's approach to include a more explicit role for temperature variability, and extending the reconstruction back to A.D. 600. The paleoproductivity reconstruction is used to help understand the population history of the area from A.D. 600 to 1300. The total number of households for the sites in the project area was calculated using a Bayesian framework developed by Ortman et al. (2007).This framework takes into account different use-lives for households in small sites and in community centers. Household use-life estimates were calculated in part by examining the accumulation of cooking pottery on the site, further developing methods pioneered in the Dolores Archaeological Project. These methods are obviously of use only for reconstructions of ceramic sites, and so are of somewhat limited use to this thesis.

Varien et al. present three methods for gathering population estimates, but focus on a method that they felt was most reasonable. Their results indicate a population peak during the A.D. 1225-1260 period of approximately 19,500 persons and, more relevant, a population of approximately 1,826 people from A.D. 600 to A.D. 725, occupying roughly 300 sites. The following modeled period, A.D. 725 to 800, was based off of 325 sites, supporting an estimated 1,955 persons (Varien et al. 2007:283-284). The authors note immigration into their study area between A.D. 600 and 725.

Overall, population in Southwest Colorado appears to follow a few general trends. Some areas within the region appear to have been sparsely populated up until the end of the fourth century A.D., after which the area underwent near-abandonment until the end of the sixth century/early seventh century A.D., at which point the region sees several hundred years of continual occupation and population growth. The similarity of some of the Basketmaker III brown ware ceramics with contemporary Mogollon ceramics has led some researchers to suggest that much of the population in the Basketmaker III is the result of immigration from the Mogollon region. Immigration poses a slight problem to evaluating the model—testing of the hypothesis is ideally done on the same group before and after the adoption of the bow. However, I argue that the hypothesis is still testable in these situations as both the immigrants and the migrants were subject to the same limitations in coalitional stability, and received the same coalitional enforcement advantages conferred by the bow.

Cedar Mesa Basketmaker. Cedar Mesa in southeastern Utah (location 6 on Figure 5), has had a series of occupations that precede and follow the introduction of the bow and arrow. Cedar Mesa is within the Basketmaker/Puebloan cultural sphere.

Within the Cedar Mesa area, Basketmaker II occupation coincides with the Grand Gulch phase (A.D. 200-400). Matson et al. (1988) estimated total population for the Basketmaker II period within their study area as between 440 and 880 individuals. Population was estimated from the 130 sites with Basketmaker II components within their study area, of which 52 were classified as habitations, 28 as limited activity sites, 36 as campsites, and 4 as lithic reduction loci (Matson et al. 1988:248). Residential sites typically only had one visible pithouse, although the authors estimate that at least 80 percent of the habitation sites occur within 200-400 m of another habitation. Following the Basketmaker II occupation of Cedar Mesa, there is a suggested occupational hiatus, with the Basketmaker III reoccupation coinciding with the Mossbacks phase (A.D. 650-725). In both periods people relied heavily on maize. This has been supported through isotope analysis, coprolite analysis which from the turkey pen ruin of which 25 of 28 early first millennium coprolites contained maize, bulk soil analysis (Matson and Chisholm 1991). During the Basketmaker III occupation (by populations using the bow and arrow), Cedar Mesa supported a total momentary population of between 600 and 1200 individuals, calculated from 49 Mossback component sites (31 habitations, 15 limited activity sites, and 2 indeterminate sites). The Basketmaker III occupation was more spatially aggregated than the Basketmaker II occupation, and each habitation site had at least one dwelling (Matson et al. 1988:251).

Similar to the occupational pattern seen in Southwestern Colorado, then, Cedar Mesa was abandoned between the late fourth century/early fifth century A.D. until the mid-to late seventh century A.D. Demographic growth and increases in organizational complexity following reoccupation are suggested by the archaeological data.

Rainbow Plateau Basketmaker. The Rainbow Plateau (location 5 on Figure 5) encompasses a broad north-sloping tableland in northeastern Arizona and southwestern Utah, south of the confluence of the Colorado and San Juan Rivers (Geib and Spurr 2000:175). Rainbow Plateau is worth mentioning for several reasons, including that it represents a continuous occupational sequence between the Basketmaker II and Basketmaker III. Further, as of Geib and Spurr's (2000) discussion, 68 radiocarbon dates were available for the time around the Basketmaker II/III transition. Most of the radiocarbon ages are from maize or other materials that have a clear cultural origin and do not overestimate age as wood charcoal can (Geib and Spurr 2000:179). The radiocarbon dates indicate continuous occupation on the Rainbow Plateau from around 400 B.C. to at least A.D. 700, with no indications of any gaps. The quantity of samples that date between A.D. 200 and A.D. 300 is higher than other dates in the time range represented—indicating either a population increase or biased sampling. Likewise, Geib and Spurr are unsure if the lack of dates after A.D. 700 is representative of a population decline, or if it is an artifact of their use of 1300 B.P. as an upper limit of inclusion in their analyses (2000:181-182). Euler (1988:203) does mark the time period between A.D. 700 and A.D. 800 as a temporary abandonment, with a sparse occupation in the following two centuries after reoccupation.

Population. A continuous occupation (at least until A.D. 700) on the Rainbow Plateau is argued to provide evidence against Berry's (1982) distinct and separate temporal scheme, in which he argued that chronometric data for the Colorado Plateau suggested three separate and discrete occupational periods, each separated by a marked hiatus (Berry 1982:87). In Berry's interpretation of the archaeological record, he argued that each of these occupational periods could be taken to represent Basketmaker II, Basketmaker III and Pueblo I periods respectively, and that with the argued hiatuses, no arbitrary distinction between the stages was necessary (Berry 1982:116-117). In addition to finding that Berry's tripartite scheme does not fit their analyses of Rainbow Plateau, Geib and Spurr also do not find support for

Glassow's (1972) arguments of a transition between Basketmaker II and Basketmaker III induced by scalar stress resulting from a steady population increase. Unfortunately, Geib and Spurr do not provide numeric estimates along with their general population trend estimates. The Rainbow Plateau therefore can only speak in a limited manner as to the validity of the coalitional enforcement hypothesis. Table 4 reports site data from Table 9.2 in Geib and Spurr 2000 (183).

Table 4: Reported sites from the Rainbow Plateau, after Geib and Spurr (2000:Table 9.2)

Site Name/ Number	Date Range	Residential Structures	Bow and Arrow	Site Name/ Number	Date Range	Residential Structures	Bow and Arrow
Kin Kahuna	390 B.C- A.D. 435	7+	+	Ditch House	165 B.C. to A.D. 20	2	
The Pits	400 B.C. to A.D. 230	1+		Mountainview	A.D. 145-375	1	+
Big Bend	unknown	2+		Panorama House	A.D. 240-420	1+	
AZ-J-14-54 (NN)	Unknown	5+	+	Polly's Place	A.D. 145-650	2	
AZ-D-2-174 (NAU)	Unknown	2+		Sin Sombra	A.D. 130-325	1	
AZ-D-2-200 (NAU)	Unknown	1?		Tres Campos	105 B.C. to A.D. 140	1	
AZ-D-2-355 (NAU)	Unknown	1	+	Sand Dune Cave	Unknown	+	
Blake's Abode	unknown	1		Atlatl Rock Cave	A.D. 20-660	2+	+
Ch' iidii Cave	unknown	+					

<u>Subsistence.</u> There is plentiful evidence on the Rainbow Plateau for early maize dependence. Maize was fairly ubiquitous throughout the entire Basketmaker occupation,

including at sites such as Kin Kahuna with dates ranging from 400 B.C. to A.D. 400, where kernels, cupules and cobs were found (Geib and Spurr 2000:189). Maize was found to be the second most common food recovered in floatation samples at every site, following goosefoot seeds. Habitation sites with storage had maize remains that often equaled or surpassed goosefoot in quantity. The authors found that overall, there was not much difference in maize ubiquity between habitation sites with storage and those without, and that there was not much difference in maize ubiquity across the Basketmaker chronology for the Rainbow Plateau. Geib and Spurr argue that the representation of Basketmaker maize is, in fact, on levels equal to that in the Pueblo II and III periods (Geib and Spurr 2000:196). Overall, the authors echo Matson and Chisholm's (1991) argument that the similarities of Basketmaker settlement patterns to later Anasazi occupations indicate similar dependence on maize agriculture (Geib and Spurr 2000:189).

Although the data do point to equal ubiquity of maize across the Basketmaker chronology on the Rainbow Plateau, there are temporal differences in subsistence. Variance of maize kernel morphology is seen, and there may be important dietary implications of newer varieties. Likewise, the adoption of beans during this time is noted as potentially influencing settlement patterns, as beans require more constant attention than maize, and thus necessitate lower mobility. Finally of note, Geib and Spurr argue that their recovery of a turkey coprolite with a maize date of A.D. 425 to 660 is consistent with an adoption of turkey husbandry circa A.D. 500 (2000:197-198).

Material Culture. Plateau-wide, it appears that as early as the second century, but more concretely by the fourth century A.D., some occupants on the Rainbow Plateau had adopted pottery (Geib and Spurr 2000:193). The adoption of pottery is apparently not universal and rapid, either on the Rainbow Plateau or on the Colorado Plateau. The authors note that distinguishing between Basketmaker II and III by the introduction of gray ware, not the introduction of ceramics, would provide more accurate separation between the phases (Geib and Spurr 2000:198).

Rainbow Plateau has data points indicating an adoption of the bow and arrow earlier than the traditional A.D. 500-600 date. A single arrow point was recovered at the Atlatl Rock Cave site with an associated maize date of A.D. 425-660. The Mountainview site has multiple points that have been dated with three statistically contemporaneous maize dates to fall within an A.D. 145-375 range. The earliest data for the adoption of the bow however comes from The Pits site, in which one stemmed point, classified by Geib and Spurr as an arrow point, has a maize dates of 105 B.C. to A.D. 110. The authors find that, similarly to Obelisk Utility Pottery, the bow was adopted by the fourth century A.D., and perhaps as early as the beginning of the millennium, but more confidently by the second century. The authors also argue that, based on their data, the bow was in use prior to the adoption of pottery (Geib and Spurr 2000:194-195).

The archaeological record on Rainbow Plateau lacks any distinct boundary between Basketmaker II and III. Instead, it appears that adoption of new traits and technologies occurred at varying rates, with evidence that most of the classic traits used to distinguish between Basketmaker II and III—ceramics and the adoption of the bow and arrow first appear in Basketmaker II. While Glassow (1972) argued that population growth was a cause for adoption of new traits, Geib and Spurr argue that the adoption of these traits and technologies were the impetus for the population growth seen during Basketmaker III, and that this growth "would have precipitated experimentation with new social forms evidence by multifamily settlements and integrative structures…laying the foundation for future developments" (2000:1999). This thesis, of course, not only believes that it was the adoption of traits (namely the bow and arrow) that gave rise to population growth and experimentation with new forms of social organization, but that the adoption of the bow and arrow allowed new forms of larger and more complex social organization to develop.

Other Anasazi Groups. The following section mentions briefly data from other sub-cultures within the Anasazi cultural sphere. Due to data constraints, these receive less attention than was given above, but will receive brief mention to general demographic and technological trends. Much of the data below owes to Euler's (1988) construction of general demographic trends across the Colorado Plateaus, and unfortunately, most of the data is limited to population trends, rather than site and group size.

<u>Kayenta/Virgin Anasazi.</u> The Kayenta Anasazi sub-tradition, in which I include the Virgin tradition, occupied an area around the Virgin River and the Muddy River drainages of southern Nevada (Larson 1996). They are further west than the focus of this thesis, but are within the Anasazi culture area, and have some paleodemographic data, so are briefly mentioned. Euler places the first Anasazi occupation here as early as A.D. 200, around the

time that maize was introduced to the area. The lowland Virgin River drainage was occupied slightly later, by around A.D. 500. Euler notes that the area is argued to have fairly low population density, occupying pithouse settlements until approximately A.D. 900 (Euler 1988:195-196). Population is thought to increase between A.D. 700 and A.D. 1150 and expanded into higher elevations (Aikens 1966; Euler 1988:196). Exchange is noted as important throughout the phase. Larson (1996) examined the correlation between agricultural intensification and population within the Virgin Anasazi between A.D. 100 and A.D. 1150, utilizing detailed survey data. For the early periods (A.D. 100 to 850) Larson identifies a settlement strategy based on dispersed family groups who supplemented hunting and gathering with some cultigen use and minimal water control. From A.D. 850 to 1150, by contrast, sites were highly aggregated and populations were higher, with heavy reliance on storage and cultigens, and a larger tool kit (Larson 1996:68-70). Larson attributes the demographic change and increases in organizational complexity to a cycle of increasing population necessitating increases in resource procurement and processing intensification. Larson makes no mention of bow and arrow technology, although the bow would have been introduced in his earlier phase (prior to A.D. 850).

Upper Little Colorado. The Upper Little Colorado area underwent a mix of Chacoan Anasazi and Mogollon occupations. The area was occupied early on by the Concho Complex, which lasted from 1500 B.C. to A.D. 300. Longacre (1964:203-211 cited in Euler 1988:207) argues that the population was low between A.D. 300 and A.D. 500, with evidence of a reliance on horticulture and the use of storage pits and occupation of shallow pithouses. Population remained low until large increases between A.D. 700 and A.D. 900, at which point villages of twelve to fifteen pithouses became common (Euler 1988:207). It has since been argued that at some point between A.D. 200-600 the settlement pattern in the Upper Little Colorado area shifted becoming increasingly sedentary. A slow population growth, increased level of food production, and evidence of regional exchange is also seen with this transition (Lightfoot and Feinman 1982:65).

Hay Hollow Valley. (Location 9 on Figure 5). Hay Hollow is roughly 10 miles east of the town of Snowflake, Arizona, supported a low population beginning in approximately 1500 B.C. Population remained low and dispersed across the valley floor, employing hunting and gathering primarily, until around A.D. 300. Between A.D. 300 and 500 settlements were constructed on the mesa tops. Population increased from A.D. 200 to 400, reaching a Basketmaker peak at A.D. 400, due to the internal growth of just a few sites (Plog 1974:94-95). Population decreased between A.D. 500 to 800, although site density increased drastically. Although the largest sites decreased in size, a larger number of moderate size sites rose. Population increased rapidly after A.D. 800 (Plog 1974:95). Table 5 combines data from Plog's Tables 9.1, 9.2 and 11.1 for Hay Hollow Valley (1974:96,120). Early evidence of the bow is evident around A.D. 200, but widespread adoption is not complete until around A.D. 500 (Plog 1974:136).

Plog suggests that the collapse and abandonment of villages circa A.D. 500 was the result of social organization not being able to keep up with environmental and social stresses following the increase in group size and population following reduced mobility (1974:157-159). Essentially, Plog describes what the coalitional enforcement hypothesis predicts will happen as group size grows too large—monitoring and punishing costs become too costly, and defection cannot be halted. As a result, groups dispersed, increasing again only after increases in agriculture had progressed to the point to reduce the risks inherent in larger groups.

Table 5: Hay Hollow Site Data, after Plog (1974: Tables 9.1, 9.2 and 11.1)

Time Period (A.D.)	Sites/mi^2, (total number of habitation sites)	Percentage of Habitation rooms for sites with X rooms				Time Period (A.D.)	Sites/mi^2, (total number of habitation sites)	Percentage of Habitation rooms for sites X rooms			
		1	**2-12**	**13-20**	**Over 21**			**1**	**2-12**	**13-20**	**Over 21**
200-250	0.15, (**6**)	17	83	0	0	500-550	0.55, (**73**)	5	36	27	32
250-300	0.20, (**11**)	0	100	0	0	550-600	0.60, (**65**)	1	54	45	0
300-350	0.20, (**28**)	0	100	0	0	600-650	0.95,(**65**)	11	44	45	0
350-400	0.20, (**54**)	0	20	37	43	650-700	1.0, (**64**)	12	88	0	0
400-450	0.25, (**115**)	0	10	0	90	700-750	1.05, (**66**)	8	73	19	0
450-500	0.25, (**115**)	0	10	0	90	750-800	1.0, (**64**)	10	90	0	0

Chevelon Creek. The Chevelon Creek drainage (location 8 on Figure 5) runs approximately 50 miles west of the Hay Hollow Valley. The valley contained a small and dispersed population until around A.D. 700-800 except for several pithouse villages which were initially settled between A.D. 200 and A.D. 300, and were continuously occupied, growing in size between A.D. 500 and A.D. 700 (Euler 1988:209).

Canyon de Chelly. Initial structures at Canyon de Chelly (location 2 on Figure 5) appear to be occupied from around 200 B.C. to A.D. 400. Some of these contain evidence for violent deaths of the occupants. After A.D. 500 the population moved up-canyon, as well to the

Defiance Plateau. Population increased from A.D. 700 to 900, during which the plateau, which had seen intensive occupation earlier appears to have been little used (Euler 1988:209-210).

Chaco Canyon region. (Location 10 on Figure 5). Site frequency in the San Juan Basin, is reported as doubling in the A.D. 500 to 750 time period, tripling in the A.D. 900 to 1100 period, and then dropping by approximately 32 percent between A.D. 1100 and 1300 (Euler 1988:217). Survey of Chaco Canyon suggests that pithouses (n=135) were in use by roughly A.D. 450 to 500, and were utilized until A.D. 700-750. Following this period, site occupation stabilized between A.D. 750 to 900 (site n=373) (Euler 1988:218).

Within Chaco Canyon, the Shabik'eschee Village has received considerable attention. The site contains around 70 pithouse structures, over 50 exterior storage pits, and a large communal structure, often referred to as a great kiva (Cordell 1997:240, 246). The site is larger than other Basketmaker III sites within the Chaco area, and was constructed ca. A.D. 550-600 and occupied until A.D. 700-750 (Cordell 1997:240; Wills and Windes 1989:355). Average pithouse size is roughly 17.8 square meters, and is similar across the occupation of the site (Wills and Windes 1989:354). Lightfoot and Feinman (1982) argue that the site reflects the development of suprahousehold decision making. Wills and Windes (1989), however, suggest that Shabik'eschee was occupied by a relatively small core group of families, occasionally augmented by more households when climatic conditions could support the larger group, and that the achieved size of the site thus does not reflect increases in organizational complexity, sedentism and site size. They do note the development of private storage, which they attribute to the difficulties of typical hunter-gather reciprocity in a situation of episodic aggregation (Wills and Windes 1989:358-359). Wills and Windes report a projected maximum population of 76.5 individuals based on an estimate of 42 of the 68 pithouses being occupied at a given time. This is much larger than the reported modal Basketmaker III site size of roughly one to three pithouses occupied by 5 to 15 people (Wills and Windes 1989:363). The size of the site and the population supported is felt to indicate the need for some level of increased social organization. Wills and Windes (1989) argue against Lightfoot and Feinman's (1982) site history conclusions about the presence of a permanent suprahousehold organization, and instead feel that any leadership role was episodic and situational (1989:365).

Sites like the Shabik'eschee Village, following the adoption of the bow and arrow, likely are good indicators of increased coalitional stability.

The Navajo Reservoir District. The Navajo Reservoir district lies northeast of the Chaco Canyon and southeast of the central Mesa Verde area. This area is reported as having a small population prior to A.D. 750, followed by a rapid increase in the quantity and size of settlements between A.D. 800 and 900 (Eddy 1974:79). Eddy argues an increase in site density from an average of 1.4 sites/square km to 1.5 sites/square km for the centuries of A.D. 750-850 and 850-950, respectively (Eddy 1974:79-80). He does not posit density prior to A.D. 750.

Anasazi Review. It is obvious from the above that regional differences led to quite different timelines within the Anasazi area. Places like Cedar Mesa and Southwest Colorado have archaeological records that indicate regional abandonment during the time of the adoption of the bow and arrow. This increases the difficulty in examining the hypothesis, as reoccupying populations do not necessarily represent the same group that abandoned the region, although given the higher-mobility patterning associated with lower dependence on agriculture, it is possible that the reoccupying group was the same. The Virgin Anasazi and those occupying the Upper Little Colorado River Valley, Chevelon, the Navajo Reservoir District, and Canyon de Chelly, saw increased group sizes after A.D. 700, which is in-line with the model's expected population increase, following traditional arguments regarding the timing of the bow and arrow. Other groups, such as those occupying Rainbow Plateau, and Hay Hollow Valley and the Chacoan area see earlier spikes in group size and in regional population. Some of these areas, such as the Rainbow Plateau, have indications of earlier adoption of the bow and arrow technology.

Mogollon

The Mogollon is a macro-tradition, whose range is south of that of the Anasazi. They are believed to have developed from the Cochise culture from southern Arizona. The basis for this argument is some continuity in form in mortars, pestles, manos, metates, and choppers from the Ciracahua and San Pedro stages of the Cochise culture. These tools, along with the presence of maize and squash as early as 2000 B.C. point to a very early introduction of cultigens to the Mogollon culture (Martin 1979:63). In the heavily studied Mimbres Valley, the Mogollon tradition has been divided into four primary periods: the Early Pithouse Period (A.D. 200-550), the Georgetown Phase (A.D. 550-700), the San Francisco Phase (A.D. 700-825/850), and the Three Circle Phase (A.D. 825/850-1000) (Diehl 2001a:26). In a study of the Mogollon of Pine Lawn Valley, Bluhm uses the latter three phases, but uses the Pine Lawn Phase to represent the time period between 200 B.C. and A.D. 500 (Bluhm 1960). More generally, the

Mogollon can be broken into the Early Pithouse Period, running from around A.D. 200 to around A.D. 600; the Late Pithouse Period, which runs from around A.D. 600 up to the Classic Mimbres Phase, which starts around A.D. 1000 (Diehl and LeBlanc 2001:4). The Mogollon is divided spatially into several different regions including the Mimbres (location 7 on Figure 5), Cibola, Forestdale, San Simon, Black River, and Jornada (Martin 1979:62).

<u>Residence.</u> Some argument exists as to the form and level of residential mobility practiced by the Mogollon during the pithouse phases. Models propose either a largely sedentary population that practiced seasonal abandonment; a population that practiced varying degrees and periodicities of movements; and a wholly mobile population that only settled into winter habitations for a few months (Diehl 2001:26). Gilman (1987), suggesting a biseasonal, bilocational subsistence strategy, argues that the pithouse-occupying Mogollon were less residentially mobile than in the Archaic, but more so than the classic Mimbres, and that the pithouse-to-pueblo transition represented a significant shift in organization and subsistence. Researchers such as Hunter-Anderson (1986) have argued the middle ground, between the mobility extremes, while researchers such as Minnis (1985) and Shafer and Taylor (1986) have argued that cultigens were a substantial component of the diet by A.D. 200 and a primary component after A.D. 800, with a correspondingly sedentary residence pattern (Diehl 2001a:27). Diehl's work on Mogollon pithouse architecture (2001c) provides evidence that throughout the Pithouse periods, overall investment in the construction and maintenance of dwellings increased. The finding that Mogollon investment in residence investment increased over time, rather than suddenly at the pithouse-pueblo transition as

argued by Gilman, provides further evidence that the Mogollon were agriculturally dependent in the Early Pithouse Period.

Sites during the Early Pithouse period tend to be on hilltops. This may be explained by avoiding cold-air sinks (such as in Haury and Sayles 1947), maximizing resource availability (Rice 1975), or for ceremonial (Hogg 1977) or defensive purposes (LeBlanc and Whalen 1980). Hilltop locations confer tactical advantages, especially for the atlatl. The transition from hilltop locations to valley locations around the time of the introduction of the bow may suggest that defense was of primary importance in the decision to place earlier sites on hilltops (LeBlanc 1999; LeBlanc and Whalen 1990). Diehl acknowledges that the level of population and population density in the region is similar to ethnographic cases which show a high level of warfare, but argues against a defensive hypothesis for the earlier hilltop locations, using the lack of fortification and the general inaccuracy and slow speed of the atlatl as evidence that these sites were not defensive in nature since the projectile technology was not sufficient to warrant defensive measures (Diehl 2001c:31-32). Instead Diehl argues that given the low population density of the Early Pithouse Period, demographic pressure would have necessitated the visible placement of sites to help spread goods, information, and genes (Diehl 2001c:33). Only once population density was high enough that groups could have a self-sufficient resource base and practice endogamy would the disadvantages of visible hilltop site location outweigh the advantages of living lower in the valley.

Agriculture. Maize and other cultigens are generally agreed to be important in the diets of early Mogollon Pithouse villagers. Based upon type and frequencies of charred seed remains, Diehl and Minnis argue that cultigens such as maize, beans and squash were important in the Early Pithouse Period, along with wild plants such as amaranth, goosefoot, and piñon (2001:57). Analysis of ceramics at the McAnally and Thompson Early Pithouse period sites indicate functional design that would have allowed processing of starchy foods, such as maize, amaranth or goosefoot (Arthur 2001:75-76). Reliance on domesticates increased throughout the Late Pithouse period at the expense of the wild plants (Diehl and Minnis 2001:57). Martin suggests a slightly different chronology for other parts of the Mogollon territory, where he argues an increase in reliance on maize use up until approximately A.D. 500 at which point it decreased drastically in prevalence, relative to wild foods. After A.D. 700, agriculture again became more prevalent (Martin 1979:64). This overall increase to almost exclusively sedentary horticulture is also evidenced by changes in ground stone technology and prevalence, which point to a shift from mixed strategy horticulture and foraging to classically sedentary agriculture between A.D. 650 and 700. An increase in the reliance on maize may have been due to a proposed fourfold increase in population in the Mimbres and Gila valleys from the Early Pithouse period through the end of the Late Pithouse Period, or from the introduction of the potentially more advantageous strain of maize, maiz de ocho (Diehl 2001b:68).

Projectile Points. LeBlanc's (2001) census of projectile points in the Mogollon region resulted in only 11 points from the Early Pithouse Period that could be analyzed. Based on the measurements of these, they were all classed as atlatl dart points.

Mogollon Population and Group Size Reconstructions. Using a basal population growth rate of between 0.3 to 0.4 percent, LeBlanc calculated population estimates for the McAnally and Thompson sites, and a regional estimate for the Upland Mogollon region

(LeBlanc 2001b:116). Along with a population growth rate, LeBlanc used estimates of site occupation along with the calculated average use-life of a pit-house. Based upon earlier work at the Galaz site (Anyon and LeBlanc 1984) which compared use-life estimates and estimates based on mortuary data, LeBlanc suggests a use-life of between 25 to 40 years. This differs from estimates by Cameron (1990) whom argues for a 15-year use-life based on the length of time that a pit-house could survive without significant degradation. LeBlanc (2001b:116) believes Cameron's use-life estimates to be in error as they do not take into account increases in use-life due to maintenance or refurbishing. This argument is supplemented with site data which shows regional site remodeling episodes averaging every 22 years. Thus, a site that was remodeled after 22 years, and then lived in for an equivalent amount of time would have an expected use-life of 44 years. Using this logic, LeBlanc suggests an average use-life of around 40 years. LeBlanc uses these data to estimate population for the McAnally site, in which he estimates an initial four-household occupation, and an overall occupation of around 300 years. By LeBlanc’s estimate, an initial population of around 16 to 20 occupants would have grown to 48 to 60 occupants at the end of the 300-year occupation. Using the same methods LeBlanc (2001b:117-118) arrived at a maximum population of around 200 people for the Thompson site.

Valley wide, LeBlanc suggests that, given an incomplete sampling, with 500 known sites, 30 of which have been assigned to the Early Pithouse Period, that the total number of pithouse sites in the valley can be estimated at around 86. Likewise, within the 30 known pithouse sites, 221 pithouse depressions were identified, from which LeBlanc extrapolates an estimate of 646 pithouses in the area. This is less than six-times smaller than the number of habitation rooms present during the Mimbres Classic period (2001b:118).

Blake et al. (1986) estimates population for the same region in a four-step process. Initially taking unadjusted numbers of sites, rooms, and room areas for each period and stratum, they adjusted these based on the length of the period. This was then standardized to the length of the shortest period. Next, they calculated the room areas, based on different approximations of structure use-lives and annual growth rates, which allows an approximation of changes in total occupied room area during each period's span. These are finally converted to population estimates (Blake et al. 1986:449). The authors calculated structure use-life utilizing a 0.3 percent population growth rate and structure use-life at both 40-year use-life and 75 years, although for the time periods they suggest that this latter use-life was more correct. Based on previous archaeological and ethnographic research, the author's use a four square meters per person estimate for the Pithouse period, and a six square meters per person estimate for the Mimbres Classic period, resulting in an initial valley population estimate of 290 individuals and a peak population of 5,133 (Blake et al. 1986:454). For the pithouse periods, which are of more interest here, they estimate, using a 75-year structure use-life and 4 people per square meter area, an initial population of 290 in the Early Pithouse Period, a mid-period population of 491, and a final population of 830. Estimates for the Late Pithouse period place the midpoint population at 1630 and a final population at 3200 (Blake et al. 1986:455). Blake et al. do warn that Late Pithouse period sites may be underrepresented due to the shift from largely hilltop and ridge site locations in the Early Pithouse period to terraces and valley bottoms. These lower and later sites continued to be used throughout the

Late Pithouse Period and into the Classic Mimbres, which may obscure the Late Pithouse Period sites (1986:469). LeBlanc (2001b) argues the use of the more conservative 40-year use-life, which places his initial valley population in the Early Pithouse Period at around 155, with a final population around 442. He argues that this range of individuals, especially on the upper end of the range, was similar to many observed villages observed around the world, and large enough to have practiced endogamy (2001b:118). He argues this is important as it is suggestive of group size large enough to no longer need to look outside the confines of its own coalition for continued growth—in terms of this thesis, this likely suggests that the group was large enough to be classified as a secondary coalition.

Both of these are much larger estimates than those of Lekson (1993), who argues for an initial Pithouse Population Period of 58 and an ending population of 166 people, using Cameron's structure use-life estimates of 15 years. LeBlanc argues against the validity of this estimation, in part due to the aforementioned critiques of Cameron's use-life estimate, but also that he does not feel that such a small populating group would have occupied and built the approximately 86 sites over a 400-year time period, and that further, Lekson's population estimate is inconsistent with the widely accepted estimates used for the Classic Mimbres period (LeBlanc 2001b:119).

In her population reconstruction of the Pine Lawn Valley, Bluhm notes that the earliest occupations, in the Pine Lawn Phase (prior to A.D. 500) were located on defensible mesa and ridge tops. Interestingly, Bluhm's data included 15 more sites from the Pine Lawn Phase (n=21, 200 B.C. to A.D. 500) than the later Georgetown Phase (n=6, A.D. 500/550 to 700), although this can largely be accounted for by the comparative shortness of the Georgetown

Phase (Bluhm 1960:542). Bluhm argues for family-based organization until the Reserve Phase (A.D. 1000-1100). In terms of population, Bluhm argues that there is no indication of population increase between the Lawn Pine Phase and the Georgetown Phase, which she attributes to climatic stress. A population spike is seen after A.D. 700, during the San Francisco Phase, and continues through the Three Circle Phase. At this time, the number of houses occupied in the valley is argued to rise from 17 in the preceding two phases up to around 50 for the latter phases (Bluhm 1960:543).

Lekson (1990), in a synthesis of the archaeological data recovered from three surveys of the Upper Gila Mimbres, reports the documented room counts by chronological period. Chronological period was determined by ceramic assemblage composition (Lekson 1990:85). Of 997 rooms documented for the Upper Gila Water Supply Study Class II (UGWSSII; reference to Chapman and others 1985), 6.7 percent of the rooms were assigned to the Early Pit House period (A.D. 200-550), and 3.5 percent were assigned to the San Francisco Phase (A.D. 650-750). The Upper Gila survey (reference to Fitting 1972) documented 3744 rooms, assigning 4.3 percent to the Early Pithouse Phase, and 3 percent to the Three Circle Phase (A.D. 750-1000). Finally, the Redrock survey (reference to Lekson 1974) documented 865 rooms, assigning 9 percent to the Early Pit House Phase and 8.8 percent to the Three Circle Phase The ceramic assemblage spanning the Pit House period and Mimbres phase, was expressed very high in all three surveys, representing 27.9, 43, and 34.7 percents, respectively (Lekson 1990:86). Site size across the Mogollon region did not surpass 200 individuals, except in rare cases, until the mid-700s A.D. (LeBlanc 1999:136).

Finally, of brief note, are some of the Mogollon sites detailed in Lightfoot and Feinman (1982). The authors, attempting to study suprahousehold organization, chose eight large Mogollon sites to examine. Seven of them are within the general periods around the introduction of the bow. These are the Flattop site (occupied A.D. 300-500, ~25 pithouses), the Bluff Ruin (A.D. 200-400, ~35 pithouses), the Crooked Ridge site (A.D. 1-900, primarily within 300-500, 100+ pithouses), the Promontory site (A.D. 300-500, 25-30 pithouses), the S.U. site (A.D. 300-500, 28 pithouses), and the Turkey Foot site (A.D. 700-800, 15 pithouses) (Lightfoot and Feinman 1982:70). As is evidenced by the data, large sites exist both before and after the introduction of the bow. Further, of the above, only the S.U. site and the Crooked Ridge site met the authors expectations of having increased nonlocal goods associated with the largest structures at the site—as expected in organizational structures based on prestige and exchange (Network strategies as later defined by Feinman et al. 2000), and as expected if growth and organization is thought to increase unilineally (Lightfoot and Feinman 1982:78-79).

This discussion of the Mogollon represents a small proportion of the work done in the area, but is felt to be representative of at least the Mimbres area. In sum, if we assume that the traditional timing of the introduction of the bow and arrow is correct, both the Mimbres area of the Mogollon and the Lawn Pine Valley area appear to fit the expectations of the coalitional enforcement hypothesis. The population seen in the Late Pithouse Period (starting around A.D. 600) is significantly greater than the population growth in the Early Pithouse Period. Likewise, the population increase after circa 700 A.D., in the Lawn Pine Valley postdates the introduction of the bow, and is a marked change from the preceding two centuries of little population change.

Review

The data presented above represents some of the available archaeological data regarding the cultural groups in the prehispanic Southwest around the time of the adoption of the bow and arrow. As is apparent, general trends are seen regionally. Over the course of the first millennium A.D., especially in the last half, group and regional populations increase, as does investment in architecture, agriculture, technology and organizational structure. These changes are not uniform, even within small sub-regions. Figure 6 provides a visual approximation of the data presented in this chapter. A large amount of the primary literature only referenced population trends, or population ranges—which confuse a graphical representation quickly. In cases in which only general trends were given (those marked with *), I have assigned values in series of 250 individuals. When ranges were given, I used the midpoint. Further, dates were skewed to fit into 50-year blocks—thus Wilshusen's estimation of population at A.D. 680 is placed in the "A.D. 650-699" column.

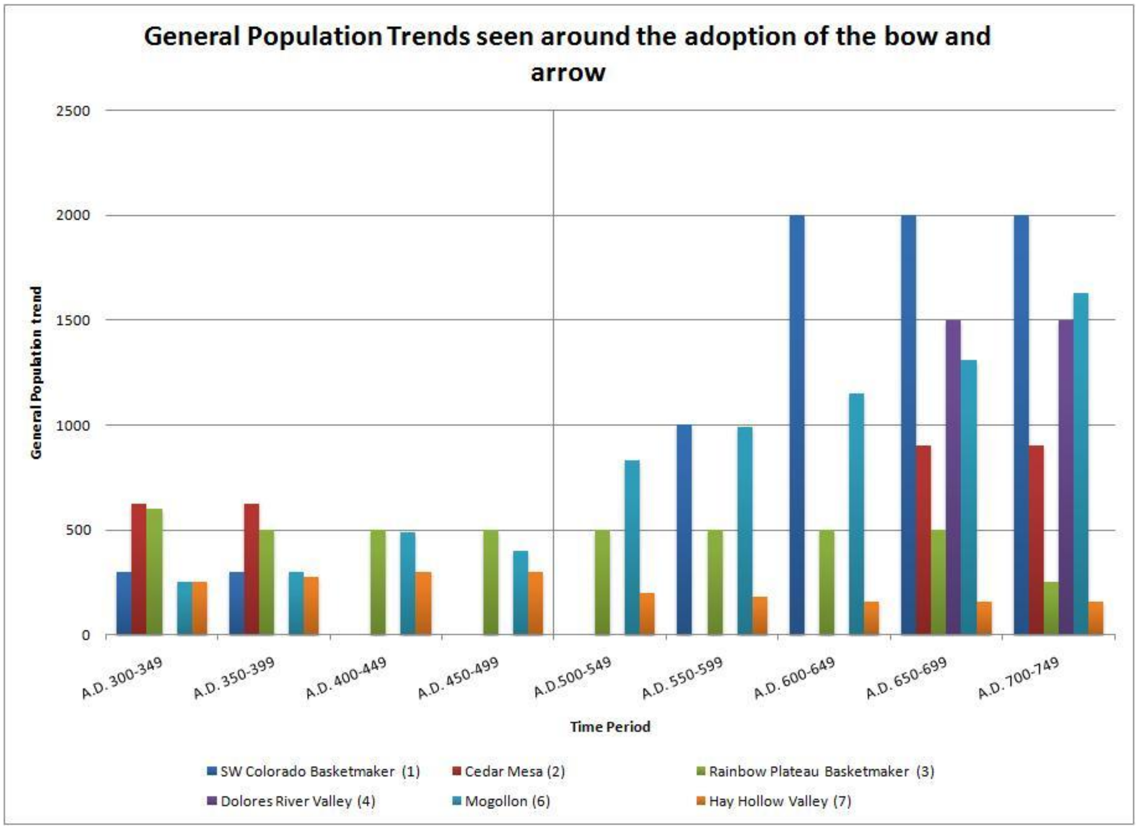

Figure 6: Selected Population Trends seen around the time of the adoption of the bow and arrow.

*** Primary literature referenced population trends only. These data do not reflect real population values.**
References: (1) Wilshusen 1999; Varien et al. 2007; (2) Matson et al. 1988; Euler 1988, (3) Geib and Spurr 2000; (4) Euler 1988; Orcutt 1981; (6)Blake et al. 1986; (7) Euler 1988.

7| Discussion and Conclusion

This thesis has covered a variety of topics pertaining to Bingham's (1999,2000) coalitional enforcement hypothesis. Studies from behavioral and archaeological realms have been enlisted to help assess the plausibility of the Bingham's model in the prehispanic U.S. Southwest. This chapter reviews the arguments behind the coalitional enforcement hypothesis, and discusses its plausibility within the prehispanic Southwest. Overall, I argue that the hypothesis presents a plausible causal chain—groups could have formed and stabilized throughout history in the manner it claims. This is backed by experimental and observational data from behavioral and economic sciences, as well as the archaeological record of the prehispanic Southwest.

Studies of the dynamics of cooperation have established that humans attempt rational behavior in their actions (in terms of seeking out profitable actions), and will strive for protection of earned resources, in whatever form those may occur. Human interactions are complex, and the promised good of a completed social contract may not be in terms of a material resource, but instead may confer gains in reputation or indirect fitness. The complexity of these interactions does not limit the applicability of the coalitional enforcement hypothesis to instances of one-time interactions regarding a material good that are likely to erupt in violence if defection is present. Instead, the coalitional enforcement hypothesis is expected to work alongside other cooperative solutions, such as indirect reciprocity and reciprocal altruism. Reputation and standing can function to maintain cooperative interactions because humans have, now and in the past, evolved methods of punishing defectors in a cost-efficient manner. Coalitional enforcement provides one way in which cooperative stability may be achieved in large groups. Other behaviors and institutions that further stabilize cooperative behavior may follow, but these act in addition to coalitional enforcement, and cannot achieve stability by themselves.

Defection, too, is a problem that must be solved by multiple co-acting means. While each of the possible defection-deterrent mechanisms discussed in this thesis have some merit, working alone, none can explain the sorts and levels of interactions seen among human populations. Arguments of human reliance on other cooperative mechanisms, to the exclusion of punishment, need to but cannot easily account for the patterning in the archaeological record. Humans have long had the mental capacity to engage in reciprocal altruism and monitoring of reputation/standing. If these were viable methods for sustaining cooperation at high levels, then what was the trigger in the mid-first millennium A.D. that caused a fundamental shift from lower-density, lower size groups to larger groups and more complex forms of social organization? Arguments pertaining only to resource buffering are weak, as agriculture was already heavily relied upon. Advantages of defensive aggregation (larger work pool, increased safety from other groups, etc.) existed before the introduction of the bow and arrow—thus, arguments about defensive aggregation following the introduction of the bow and arrow need to explain what the catalyst for change was. The coalitional enforcement hypothesis provides a plausible explanation for the changes seen in the prehispanic Southwestern archaeological record.

The coalitional enforcement hypothesis is also supported by research on human behavior and its history. As the amount of tertiary mutualistic actions increases in a group, that group will have advantages over other groups that have lower frequencies of group-beneficial behaviors. Individuals in such groups who are more willing to act according to the tenets of coalitional enforcement will thus perform better and have fitness advantages over those who do not engage in such behavior in less-cooperative groups. Over the course of hominin history, we should expect that this positive selection should further improve cooperative behaviors, behaviors that lead to improved cooperation, or both. Recent findings in evolutionary psychology do help confirm that humans have evolved traits that directly aid in coalitional enforcement. Humans have evolved specific capabilities to detect defection in social contract situations (Gigerenzer and Hug 1992; Stone et al. 2002; Sugiyama et al. 2002), and monitoring for defection is expected to be common and efficient. Humans also have the capability to detect physical formidability in humans—a trait that is of less immediate benefit today, as the outcome of a conflict is not nearly as determined by physical prowess as in the past (Sell et al. 2008). Additionally, individuals who would operate at a fitness advantage, either because they are stronger (more formidable) or are more sexually attractive, are found to anger more quickly when they think that they, or their coalition, are being cheated (Sell et al. 2009). These findings also fit within the framework of the coalitional enforcement hypothesis. Having monitored and caught an instance of defection, those groups that could accurately gauge the cost/benefit ratio of punishment, would perform, on average, better than those that either punish, or defer, blindly. Thus, stronger groups or individuals that would anger and punish quickly would achieve higher payoffs than groups that anger less, and thus are less likely to allow defection in situations that warrant punishment. Although gauging the physical strength of a group as a means of measuring their formidability represents somewhat of a mismatch in contemporary society, this was probably not so in groups utilizing the atlatl or bow and arrow. These behavioral traits help to reinforce the use and maintenance of coalitional enforcement within groups. However, without the ability to cost-effectively punish defectors, these traits are less advantageous, and thus would confer less selective advantage. I argue, then, that the evolution of the human capability to launch projectiles accurately and with force allowed a cyclical pattern of reinforcement between evolved psychological mechanisms and enacted coalitional enforcement.

Given the argument that projectile weaponry functioned importantly as a tool of defector punishment, it was important to compare the technological advantages provided by the atlatl and bow and arrow. While researchers argue over many of the possible advantages of the bow and arrow, it is commonly accepted that the speed by which the bow and arrow replaced the atlatl in almost all contexts indicates that it was functionally superior to the atlatl. The bow is more accurate, has a decreased reload time, employs points that are energetically and materially cheaper to construct and maintain, and has the ability to be fired from a greater range of positions than the atlatl (Hughes 1998). Debates exist about which technology has a greater effective range, although these appear to mostly hinge upon the estimates of the range of the atlatl's accuracy. Despite some disagreements among researchers, this thesis has established that the bow *does* confer advantages over the atlatl, and that these advantages help underwrite the coalitional enforcement argument. Because the bow allows the archer to fire from a safer position than the atlatl, and because arrows travel faster, flatter, and more accurately than an atlatl dart, arrows are harder to avoid or block, as evidenced by the fending stick's fall into disuse. These advantages increase the danger of the bow to the defector, and equally importantly, highly reduce the risk to a punisher as ambushing and hiding from return fire are much more effective. Because of this two way street—advantages against a target and advantages in self protection—the bow likely conferred greater impacts on coalitional enforcement and warfare than on hunting.

The two other commonly mentioned functions of the bow and arrow—hunting and warfare—cannot by themselves explain lasting increases in group size and stability. While the hunting hypothesis often hinges upon imagined efficiency increases in large-game hunting using the bow, researchers have found in both New and Old World contexts that such an increase is not seen. In fact, the opposite is observed, with larger quantities of *small* game remains found in association with arrow points. Moreover, the hunting hypothesis still cannot account for increased group complexity and cooperative stability. Increases in amount of hunted meat outside the confines of immediate family amplify the need for formalized meat sharing. At no point in the prehispanic Southwest do we expect game to be so plentiful that hunters can indiscriminately share among the entire community with no concern for defection. Meat sharing is dependent upon reciprocity, either in the form of hunting assistance or in terms of future payoffs in the currency of resources or prestige. Even when prestige may be a hunter's goal, he cannot bankroll an entire community of grateful and worshipping individuals; at some point, for sharing to continue, there must be a cooperative structure in place, and the hunting hypothesis cannot account for the emergence and stability of high levels of cooperation between unrelated conspecifics.

The warfare hypothesis argues that groups had to aggregate for defense, especially following the introduction of the bow and arrow. While this is a supported driving force for the creation of aggregated communities, as with the hunting hypothesis, this explanation also ignores how cooperative structures came into place. While there is no doubt that aggregation allows groups to be more defensible than isolated hamlets, the formation of durable large groups comprised of multiple lineages needs to be explained. While small hamlets can operate well, sustained by the logic of inclusive kinship, a larger aggregate cannot. Fear of an outside group is not enough to maintain long-term stability, so while it is possible that groups may come together for immediate defensive purposes, such groups cannot sustain themselves over the long-term without having a solution to cooperative instability.

Thus, while I view LeBlanc's ideas presented in chapter 5 as generally correct, I suggest that he may oversimplify potential causes for the changes in settlement patterns seen around the time of the adoption of the bow. Besides identifying the risk of resource depletion, LeBlanc does not consider the disadvantages or and difficulties of maintaining large defensive aggregations, and even his explanation of the risk of and solution for overexploitation of resources ignores the complexity in achieving and maintaining cooperation within a group. Consider for example site architecture. In the mid-first millennium A.D., habitations were still primarily pit-structures, with masonry rare or absent. The archaeological record shows the common practice of timber reuse in the Southwest, as large amounts of timber were energetically expensive to acquire. Large non-residential projects, such as palisades or stockades, would have been very difficult for a small group to build. Indeed, Keeley argues that fortifications were the costliest preindustrial military technology, and that some complex aspects of social organization would be required for their construction—something that small groups and bands would have been unlikely to muster, or find worth the vast resource and time expenditure (1996:55-56). Some of the defensive measures listed by LeBlanc as indicators of warfare could have been installed for completely different purposes. Stockades, for example, could be used for many things other than defense, such as to provide protection from wild animals, keep stock enclosed, keep children safe, block wind, keep resources out of view, or define the living space (Chenault and Motsinger 2000:64).

While it is correct that larger settlements can defend themselves better than smaller settlements, hypotheses that suggest aggregation was a defensive measure must take into account potential issues of cooperation. For the warfare hypothesis to be taken as a valid and unique hypothesis for the formation of larger groups, it needs to explain how small groups and individuals—who likely only had limited levels of interaction, with no guarantee that all previous interactions had been positive—could sustain living in close proximity to each other, and solving the inherent problems of cooperation this necessitates. I argue that without having already overcome these issues, any aggregation of groups beyond that of a primary coalition—which is at this time most likely not much above the level of a large band—could function and not disband in the face of internal strife and defection (as discussed in Bandy 2004; Carneiro 1988). Moreover, LeBlanc's assertion that groups without defensive needs will disperse across the landscape to optimize access to resources, rather than aggregate into clusters, also needs to consider a community's needs for coalitional monitoring and cooperation. Unless all such groups in a region are part of a unified organization, it cannot be assumed that they would be willing to trade with those who have suffered a year of bad productivity. Considering the advantages of being in an aggregated settlement, beyond those defensive advantages mentioned by LeBlanc, a focus on group organization and cooperation suggest that there may be significant advantages in task distribution and specialization, which become more important as reliance on agriculture increases. For example, it may be more productive (and provide advantages for monitoring) to send a group from a centralized area to work towards production of a public good, rather than to either work independently or to have manage a dispersed set of workers.

While the introduction of the bow and arrow is often argued as the catalyst for the aggregation of communities and construction of the defensive measures that are seen in the archaeological record, most of the larger defensive structures seen in the Southwest post-date the introduction of the bow and arrow in the Southwest by several hundred years—less immediately than would be expected for a defensive response. Most of the fortifications mentioned by LeBlanc do not occur until Pueblo I, ca. A.D. 800. Sites located in defensive locations, such as hilltops, overhangs, caves or trincheras are however seen throughout the earlier Basketmaker periods, with the southernmost Anasazi and Mogollon areas displaying clear tendencies toward earlier Basketmaker sites on hilltop locations (LeBlanc 1999:129). Some of these sites pre-date the introduction of the bow and arrow. Euler has also found that defensive features are relatively late in appearance across the Colorado Plateaus. Despite some early indicators of violent death at Canyon de Chelly in the late fourth century A.D., Euler finds that defensive structures are most common around A.D. 875 and 1175 (Euler 1988:226). I view that a more immediate effect of the introduction of the bow and arrow was on coalition size and cooperative stability, rather than creating a need for defensive aggregation. Haas (1990) discusses two models of tribalization—warfare driven and cooperative driven. The first views warfare as the force behind consolidation, with cooperation and the formation of discrete political units following. The second views tribal consolidation as a response to any of a number of social/environmental risks (including warfare). Although the response to these risks may be conflict, more likely it is felt to also include intensification of cooperative between different communities. This second method of tribalization can also take place in the absence of discretely bounded groups (Haas 1990:173-174). The latter method of tribalization is in line with the coalitional enforcement hypothesis and details secondary coalition formation, and can account for coalition growth even when population is mobile and sparse across a landscape.

I suggest that the archaeological patterning of changes in group size and site architecture follows the trend predicted by the coalitional enforcement hypothesis (Figure 7). Following the adoption of the bow and arrow (Bubble 1 on Figure 7), the individual risk associated with engaging in punishment of defectors is reduced (2), this in turn promotes more individuals to engage in punishment (3), further reducing the risk associated with cooperative punishing and allowing cooperation to be mutually beneficial at higher levels than previously possible (4). Robust cooperative stability allows increases in group population and in organizational complexity (5). Larger groups need more resources (6), leading groups to respond by investing heavily in the land (increases in agriculture and/or wild resource collection), and increasing their utilized territory, as possible (7). These, coupled with the dynamics of a larger group, reduce the mobility of a group (8). Conflict with neighboring groups would increase as territories became concrete and regional carrying capacity was strained supporting the higher populations. Conflict with other groups to acquire new territory, or to defend it from other groups, would prompt the defensive settlements seen (9). It is felt that this series of events better fits the gap between the introduction of the bow and intensification of defensive settlements seen in the archaeological record as it allows time for population to grow (as is necessary prior to the construction of costly defensive features), and for social organization to solidify in a more complex form before large defensive aggregations.

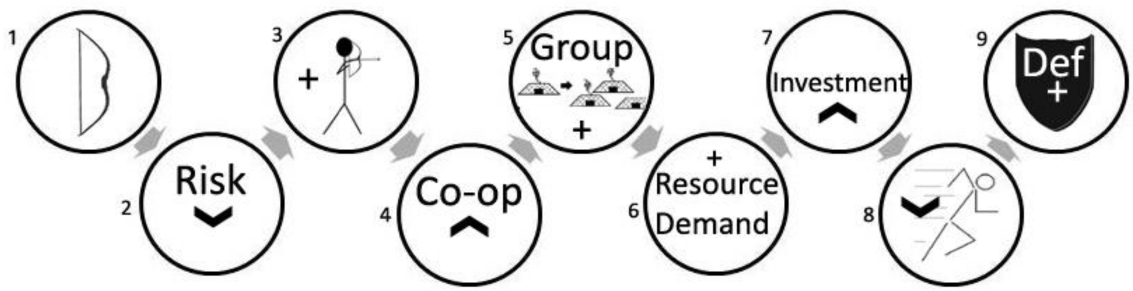

Figure 7: Causal diagram of expected order of events following adoption of bow and arrow

We can see then, that while warfare may have been a factor for village formation and aggregation, the successful long-term existence of these aggregations was due to the fact that coalitional enforcement was already in place and could stabilize interactions between multiple primary coalitions. Warfare and hunting may provide a proximal method for increases in group size and organizational complexity, but they are not the ultimate reason for these changes.

As with warfare and hunting, it does not appear that either increased reliance on cultigens, storage, or the adoption of ceramics can account for the sustained demographic expansion in the second half of the first millennium A.D. The archaeological data presented almost uniformly speak to an existing reliance on agriculture prior to population expansion, and often prior to the adoption of the bow and arrow. Similarly, ceramics, at least in a crude form, predate the demographic increases seen mid-first millennium A.D. Reliance on storage represents an important risk-buffering device, but also increases the chance of theft. Storage of goods in large populations in which defectors cannot be efficiently punished leaves these goods liable to theft. Thus, effective storage is dependent upon effective cooperation and coalitional punishment.

This thesis does not argue that increases in agricultural dependence, introduction of more efficient strains of maize, and nutritional benefits from the ability to cook in ceramic vessels did not impact paleodemography. These mechanisms are important means by which groups were able to support larger populations in marginal environments. They cannot, however, account for the ability to successfully operate within larger coalitional aggregations. I reiterate that this thesis differentiates between what the driving forces behind population and group expansion were, and what allowed these larger populations to be stable and avoid the common prehistoric cycle of frequent fissioning. This distinction is seen archaeologically—throughout the Southwest, maize was a very important dietary contributor prior to the adoption of the bow and arrow. Other cultigens were already in use and played important roles in diet as well. The observed increases in reliance following the observed increases in organizational complexity and sedentism speak to the more likely scenario that maximum coalition size increased following the adoption of the bow and arrow. Cordell also posits that the consistency in early maize varieties across the Southwest was due to the difficulty in maintaining isolated varieties when residential mobility was high (1997:132). Should this be the case, it would only make sense that increases in group stability, per the coalitional enforcement hypothesis, would allow larger, less mobile groups to form and develop more efficient varieties of maize than was possible prior to the adoption of the bow and arrow.

Again, this mid-first-millennium paleodemographic expansion is felt to be better explainable by the coalitional enforcement hypothesis for two main reasons. Primarily, and most discussed in this thesis, are the direct impacts on cooperative stability within and between coalitions. The cost-effective punishment provided by the bow allows an increased amount of previously maladaptive behaviors to become tertiarily mutualistic, and allows for larger, durable coalitions. Secondly, the coalitional enforcement hypothesis it does not preclude the advantages of the bow and arrow. Thus, alongside the coalitional enforcement hypothesis, the bow and arrow is felt to prompt and sustain regional population growth. Increases in the efficiency of hunting and intensification of agriculture will allow increased ecological carrying capacity—which help sustain population growth, and are both dependent upon the solution to the problem of cooperation. Increases in the number of unrelated individuals in a group allow endogamy and likely eases the ability to find a mate, which could prompt faster population growth. A variety of other individual and group-level benefits of the bow and arrow are felt to sustain and drive the population increase that is seen mid-first-millennium A.D. within the Southwest. Kohler and Reed (2010) discuss in greater detail the causes for and nature of the organizational shifts in the northern Pueblo I Southwest.

The work and ideas mentioned above make a case for the necessity and existence of the use of coalitional enforcement among human populations. What remains is a further look at the data presented on the prehispanic Anasazi and Mogollon populations to determine if evidence for the model may be seen in the archaeological record. From the data presented, it is clear that not every region contains the archaeological data necessary to examine the hypothesis, and not every region for which I have data supports the model. Regions such as southwestern Colorado and Cedar Mesa experienced occupational hiatuses around the time of the introduction of the bow and arrow. Thus, while these regions' large-scale demographic patterns fit the expectations of the hypothesis—low, dispersed population prior to the adoption of the bow and higher, more aggregated populations following the introduction—it is difficult to argue that these demographic changes are not more tied to subsistence changes or attributes of the reoccupying group.

Other areas, such as Rainbow Plateau, appear to be more promising. Continuous occupation during the time of the adoption of the bow and arrow makes any demographic changes more immediately relevant to addressing the coalitional enforcement hypothesis. The region displayed demographic change during the first millennium A.D., with Geib and Spurr (2000) suggesting a likely spike in population between A.D. 200 and 300, and a probable decline in population around A.D. 700. Rainbow Plateau appears to have seen an early adoption of the bow and arrow—as early as the second century A.D.—with more evidence pointing to a fourth-century-A.D. adoption. Given the ubiquity of maize early on, it does not appear that cultigen use prompted these demographic changes, and that instead, it may be likely that adoption of new technology such as the bow and arrow may have provided the impetus for population growth, a thought echoed by Geib and Spurr. Other groups, such as those occupying the Chacoan area and Hay Hollow Valley area see earlier spikes in population, so further work on determining a precise date of the adoption of the bow would be warranted.

The Virgin Anasazi and those occupying the Upper Little Colorado River Valley, Chevelon, the Navajo Reservoir District, and Canyon de Chelly, saw increases in group sizes after A.D. 700, is in-line with a population increase following the adoption of the bow and arrow

The Mogollon area also increases in site size and in population in the centuries following the introduction of the bow and arrow. Population in the Mimbres Valley expanded several times larger than the size of the Early Pithouse Period, pre-bow occupation. Other areas within the Mogollon cultural sphere followed this trend as well. Site size remains relatively low for the centuries following the adoption of the bow. The data from Lekson (1990), suggests that although single component sites were represented less in the Late Pithouse Period of the Upper Gila area than in the Early Pit House Period, the number of Late Pit House Period sites that have a Classic Mimbres period component was very high. This suggests that the group and social structure set in place in the Late Pit House period was stable, as these groups were able to grow and mature, in situ, to much larger than had previously been able. Large sites, as reported by Lightfoot and Feinman (1982), can be settled prior to the adoption of the bow and arrow, although, as Wills and Windes argue regarding Shabik'eschee's population dynamics, these occupations are often episodic.

Finally the fact that Basketmaker III site size often remained small, estimated by Will and Windes (1989) at roughly three pitstructures on average, indicates that population and group size growth in the prehispanic Southwest did not happen immediately following the adoption of the bow and arrow. Rather, it appears that the adoption of the bow and arrow set the processes in motion that would increase population and group size for decades to come.

Further Work and Potential Issues

Experimentally, it can be easy to predict the cause and effect of different behaviors. Quantitatively, there are ideal solutions and highest potential payoffs. Structured experiments can demonstrate cooperative stability within a structured environment. As mentioned at the start of this thesis, I consider these simplifications to be useful. They do, however, remain simplifications. Real-world interactions are vastly more complex, and it can be very difficult to see the underlying causes behind outcomes. This section addresses a few issues that make applying the coalitional enforcement hypothesis to the archaeological record difficult, and highlights areas in which future work would be desirable.

The issue of lag in the demographic response between the adoption of the bow and arrow and the expected group population increase remains an unknown in this thesis, and an issue in addressing the hypothesis. The adoption of the bow and arrow provides the ability to cost-effectively engage in coalitional enforcement, increasing the cost of defecting and stabilizing cooperation in larger coalitions than was previously possible. This in itself does not necessitate a demographic expansion, however. There is reason to believe that the resource structure within the Southwest—an environment marked by limitations of water and temporally and spatially variable agricultural production—would have prompted groups to intensify agricultural production and resource management. Intensification in production is often dependent upon the support of the social structure. Thus, heavy investment and intensification of agriculture would have been tied to group size and organization, which is limited by a group's ability to promote successful cooperation. Groups whose size was previously limited by the inability to cooperate at high levels may have been "waiting" for an opportunity to expand, and begun expansion as soon as increases in coalitional enforcement allowed them to do so. Increased dispute over resources as regional population increased may have lead to increased conflict between groups, which also would prompt increased aggregation up to new primary coalition size limit. Quick explosions of population following the bow and arrow's adoption cannot be assumed to be universal. Prior to the adoption of the bow and arrow some regions may have supported dispersed populations that were below the carrying capacity, especially given the general reliance on cultigens that existed prior to the adoption of the bow (which would have increased the carrying capacity). In cases like these, the adoption of the bow would have allowed the formation of larger coalitions, but not demanded it. Thus, a time lag following the introduction of the bow and arrow and increased population and coalition size would not necessarily be unexpected, nor would it necessarily speak against the coalitional enforcement hypothesis.

In his discussion of the coalitional enforcement hypothesis Bingham stresses Lanchester's Square Law (Bingham 1999; 2000). Lanchester's Square Law argues that the risk of engaging in punishment drops exponentially for each increased punisher of a single defector. This asymmetry may be expected in intra-group conflict, and in conflicts between different coalitions where multiple coalitions oppose a single defecting coalition. We cannot always assume asymmetric conflicts, and it is probable that groups will catch up technologically to opposing groups as quickly as possible. The scales of conflict are likely not reliably unequal. In cases of full-on war, Lanchester's Square Law does illustrate the usefulness of surprise attacks—in which case the scale can be effectively tipped in the attacker's favor.

In cases in which two different coalitions of roughly equivalent scale have adopted bow and arrow technology, there is a question of whether any advantage of the technology remains. Indeed, it could be argued that the cost of punishing a group similar in size and in technology may be more dangerous to an individual than when both groups had the atlatl, given the higher accuracy and speed of the arrow. In cases such as this, what effect does the coalitional enforcement hypothesis have?

I argue that when groups cannot take advantage of the asymmetry inherent in utilizing Lanchester's Square Law, they still would benefit from the introduction of the bow and arrow in terms of the hypothesis. The adoption of the bow and arrow reduces the risk of punishing defectors, both intra and extra-coalition. Immediately following the introduction, the maximum potential coalition size increases to the new point at which the group cannot monitor and punish defectors efficiently (new primary coalition maximum size). After this, and after other coalitions increase in size as well, no group has as much of an advantage as when discrepancies in size or technology existed. They have however, reached a new, larger stable coalition size, and in fact have selection pressures not to disband into smaller groups. To do so would put them at a disadvantage to any hostile coalition, as that coalition would be able to derive the benefits from Lanchester's Square Law. This is similar to the tendency toward warfare caused aggregation mentioned by LeBlanc (1999). Archaeologically, the coalitional enforcement hypothesis speaks to the ability for groups to aggregate successfully, rather than the impetus to do so—it is not expected that groups maintain themselves at the size limit imposed by the coalitional enforcement model, rather they likely maintain a size based on a wide suite of variables including coalitional enforcement, ecological and political needs. Following widespread access to the bow and arrow violent enforcement of cooperation would have remained a credible threat, and likely less practiced than when asymmetries in access to the technology existed (as cost of punishment would rise for a same sized group). Instead, groups would depend on other social institutions and cooperative stabilizers, when possible, to avoid the need to physically punish. When refusal to cooperate with a defector is sufficient punishment to defer cheating, but not undermine the collective action, refusal is likely to always be cheaper than engaging in physical punishment.

Conclusion

This thesis has made a case for the coalitional enforcement hypothesis in the prehispanic Southwest. Coalitional enforcement is an important stabilizer in human cooperation, and one that was especially important at the time of the introduction of the bow and arrow. It is not the only force acting to stabilize cooperation; other forces, such as reciprocal altruism and indirect reciprocity also played important roles in maintaining group stability. It is not my intention to argue that the coalitional enforcement hypothesis is the ultimate and only impetus towards complex organizational systems, although I do argue that the coalitional enforcement hypothesis can operate at larger scales than can reciprocity.

The archaeological data available in the prehispanic Southwest is insufficient to support or deny the plausibility of the coalitional enforcement hypothesis relative to the introduction of the bow and arrow. However, non-archaeological research, specifically of human behavioral tendencies, speaks strongly in support of the hypothesis. Given this supplemental research, and the available archaeological data, I conclude that: 1) a case can be made that the increases in group size in the mid- to late-first millennium A.D. can be explained through the coalitional enforcement hypothesis, and that 2) many existing hypotheses that discuss these group population size and organizational changes—such as those based on increased reliance on cultigens, storage, the introduction of ceramics, and the intensification of hunting and/or warfare—cannot accurately account for the timing of changes in group size and organization in this archaeological record.

This thesis also illustrates that archaeological research in the prehispanic Southwest has largely ignored the cooperative frameworks necessary for the groups that we study. A large portion of work in the region assumes that groups can fairly easily increase in size, kept in check only by environmental carrying capacity. Environmental concerns, while relevant, ignore the wealth of existing knowledge on human behavioral evolution and the limits to human cooperation that exist. Arguments about increases in group size and regional population, and increases in organizational complexity and reach need to be able to address how these changes are possible, and how these groups are able to avoid fission. Existing hypotheses largely account for the pressures to aggregate and increase population, but cannot account for how these changes can be sustained. The adoption of the bow and arrow, and its impact on coalitional enforcement can, with some degree of certainty, account for the timing and nature of many of the changes seen in the prehispanic Southwest.

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