Group Formation and Economy in Ancient Societies Using Multi Agent Based Simulation

Lokesh Patil
University of Windsor

Group Formation among primates began with the quest of skills, resources and other goods, which led to the evolution of whole civilizations. This phenomenon led to the beginning of trade and social networks among small societies in primates, which gave rise to the socio-politics thereby leading to wars among these societies. These wars, as mentioned by many researchers, is the prime reason for the evolution of new civilizations. This survey reviews research done in this field

Categories and Subject Descriptors: A.1 [**Introductory and Survey**]: ; I.2.11 [**Computing Methodologies**]: Distributed Artificial Intelligence—*Multi Agent Systems*; J.4 [**Social and behavioral sciences**]: sociology

General Terms: Group Formation, Ancient Societies

Additional Key Words and Phrases: ancient economy , migration and wars

Contents

1. INTRODUCTION

Formation of small groups including some customs evolved to form a whole society. Then from these small societies to the creation of very large societies with complex hierarchies and till to the present civilization human has travelled through a long development phase. This process of evolution of mankind in helping each other to co-evolve is incorporated very clearly in the study by Kohler [2000], who presented in his book a whole civilization, from its origin to the origin of customs and culture within this civilization. His study included all the notions of human social life, picking diligently all those systems such as politics, ecology, health care and others. Where Edmonds [2006] and Janseen [2009] followed Kohler in his study of ancient societies and concentrated their work on the diversities present in the societies on the name of resources, skills, land area and other. They showed in their study how this diversity helped people to interact with each other and come to a decision of forming a group utilizing skills of each and everyone and managing proper availability of goods and resources to each member for the far betterment of life style. Indicating in their study the origin of a social structure.

Evolution of civilization began with the formation of groups and individuals who decided themselves to fall into a group for some purpose, Casterfranchi [1998] in his study presents the same process and states a need for providing self learning technique to agents. He presented the same work to explain the present structure of society. Further Hales [1998] in his research states about the necessity to incorporate a methodology in the simulation so that agents can choose their group depending on their behavior and some other parameters. Hales [1988] also states about observing the behavior of each agent under some circumstances and those behaviors are kept as a information about that agent available to other agents. Where Malsch et al [2007] mentions about restricting the agents over some customs and rules. And mentions about a requirement to put some negative factors in simulation. All of these suggestion by above author gives a way to produce a outcome that can portray near to exact schema of social hierarchy during primates.

Further in the last section of survey the paper deals with the relation between migration of people and transition from one place to other and those major warfare which are also said to be the reason for out burst of civilization .

The research papers for this survey were found using Google Scholar, ACM,

IEEE, MIT publications and Springer.

This survey includes 20 research papers with 4 journals from ACSM, 1 journal from EIC and 1 from Economics behavior and Org. other 14 papers include some conference such as ACM and Springer and 3 are book based. The paper include about 7 experimental papers on agent based modeling and group dynamics and others are theoretical presenting a hypothesis.

The first set of research papers includes a study of life style of ancient societies including 1 book and 2 papers which gives a clear picture of dynamics of social life of ancients. The next group presents group formation and beginning of volunteeristic style of societies includes 5 papers, 1 of which is a journal of Artificial Societies and Social simulation. and 2 are conferences. the last part include the discussion given by authors on the relation between wars, migration and evolution of civilization.

2. SURVEY OF RESEARCH

2.1 Ancient societies and their economic and biological life style.

The book in this section by Kohler [2000] presents a study to explain the social life and the dynamics in the life of ancient people. It sheds light on the social, economic and biological activities of the people living there. It presents the way adaptation and reliably developing properties began among individuals. The time when they started to plan big hunts and big gatherings with the support of each other. Edmonds [2006] describes the very beginning of social life to the whole setup. The study also determine how this diversities helped people in forming groups and how the used to share their resources and skills with each other. The study further defines the way how various groups and categories in the society began.

2.1.1 *Dynamics in life of ancient people and their social life.* Kohler [2000] states the problem of understanding the life style of complex societies, their way of interacting with their biological environment as a social group. To understand the problems of small societies and problems related to their economy and biological life using a agent based simulation. By knowing this we can predict the way the ancient people developed their skills for solving their routine problems. To study the changes that occurred in the cultural network of those people and even the factors that contributed in this changes.

The author refers to previous work by Cowan et al [1994] and Gummerman et al [1994] which is related to the same topic and is extended by author in his work.

According to the author, Cowan et al [1994] in his paper he focused on the social behavior of small scale societies and the same work is extended by the author in his work. According to the author Gummerman et al [1994] discussed about the complexities in the social life of the people on the basis of some archeological parameters and tried to determine their some of the day to day problems and how they use to solve them.

In the future the author expects the computational model to includes a large group of agents and also to implements conditions which are decision based, followed by the members of primate societies. The author speaks of the large hunting games,

and large places for storage of food and water and the way its distribution among families and in inter households. He expects to get a more realistic view to the life of those people through the simulation. The author speaks of applying methods to en light the reaction of peoples during natural calamities and also the weather condition that affects their food production. The author wants to develop a self learning agent who can devise its own methods and can contribute with the other agents for the proliferation of society.

According to the author he conducted 30 experiments, with about 15 different locations in the model design of a village with two productivity levels and two sets of locations which are random by nature with about 1219 cells for a location named PII and about 1067 cells for a location named PIII.

According to author when they applied various conditions like availability of water, land, food he received different results on three major aspects of life of people. The first is maize production, According to author if people prefer to live near water source they can produce good maize and will result in increase in population but if he chooses to live near a temporary source of water so at some time lack of water may cause decrease in maize production and then he would need to migrate in search for some better land area. And with this result he comes out with one more result that finding a place near a permanent water source is much more difficult than finding a place near temporary sources of water.

The author concludes that simulation is a process which enables sociologists to study how interaction between people started for the purpose of resources and skills sharing. The author states that simulation allow us in analyzing some of the conditions which can not be predicted from sociological study.

2.1.2 *Differentiation in society on the basis of skills and resources.* According to the Edmonds [2006] the problem he focuses on is how societies obtain its present structure besides the presence of such diversities where each individual is master of some different skill, where the society is divided into different tags (group by culture), this differentiation could be the major reason for inter skill and inter tag cooperation and also for the spread of population and the growth of civilization to till present.

The idea given by John et al [1993, 1995] was developed by Rialto [1997, 2001 etc.] and Hales [2001, 2009] and finally by Edmond et al [2003].

The author claims in Edmond and Hales [2003] that the resources distribution is unable to provide a clear picture of resource sharing. The main focus is kept on the type of resource, but not on the individual participating in sharing.

The author claims to have given new direction to the researches made in same area by defining the type of resources, products, skills and tags, under which the whole society is to be devided such as each individual would master a skill and will have one product to share with other. Now by doing so the author wants to observe

the cooperation between individuals and their strategy of sharing and transferring their skills either under the same tag or among other tags.

The author claims to have performed a simulation on the discrete time with some random parameters as resource and agent. Each individual is provided with different resources and they are made to share the resources.

The author claims, in his results that, each individual has a requirement for a product and on that basis he takes his decision for choosing resources, While in the case of skills the sharing can be done in two ways. First is when the skill is shared by a father with his offspring and secondly when it is transferred from a individual to an individual from other tag but to someone who is socially compatible.

The author claims that by his study on this area can say that, sharing of skills and resources on requirement has been developed among tags and these societies have developed a symbiotic way of sharing within society. The author also gives an indication about next possibilities in this model as this model does not speak of the working of societies and other things such as, how donation is developed in societies.

2.1.3 *Understanding the ancient social setup of ancient societies.* Janseen [2009] states that no previous model is able to present a proper schema of the Anasazi society, where it is hard to predict the interaction of inhabitants with their ecological system. According to the author the model is even not able to define the structure of society in case of big population. He states that by solving these problem we can able to get a proper schema of the present civilization.

The author refers to previous work by Dean et al [2000], Axtell et al [2002] and Gumerman et al [2003].

The author states that in Dean et al [2000] and Axtell et al [2002] the variance of the population and their interaction with their environment is defined as a simple aggregation to their simple needs for farming and other needs. In their work they were using simple systems but were not dealing with the complex systems which would have prevented them from obtaining exact results in the simulation for the anasazi life style

The author claims the calculation for carrying capacity on the grounds of parameter like harvest adjustment and potential plot area for food production is one way we could exactly measure the carrying capacity of the land area. He looks forward with some more factors that could be included and will come out as major aspects which can drive the solution with more plausibility and more exactness. He expects some future changes in the model.

The author claims to have performed a computational experiment on the model using some parameters, So that he can support his theory that Carrying Capacity of village was proportional to the food production divided by number of households.

The author claims that he observed in his results in the computational model that the variance in population size is proportional to the amount of plot area which has the potential of producing enough food and is inversely proportional to the number of household which feeds from that production. In the results from the experiments conducted by author he claims that whenever there is a drop in production of maize there is always a drop in the increase in population but it is not instantaneous drop, this drop is reflected in the later results and is proportionate .he claims that by using this results one can figure out the actual carrying capacity of the land area there in the village.

The author concludes that in the American Southwest region only environmental factors are unable to explain the sudden disestablishment of the region and in the light of some archeological records, the simulation model developed by authors provide approximately same results which proves the accuracy of model in explaining dynamics of American southwest region. The authors state that as we have a data of number of household present and of average reproduction rate of this households, this model is able to calculate the carrying capacity of the region.

2.1.4 *Summary.*

Year	Author	Title of Paper	Major Contribution
2000	Kohler	Dynamics in human and primate societies	sheds light on the economic, social, and biological life style of ancient people .
2006	Edmonds	The Emergence of symbiotic groups resulting from skill differentiation	Presents a strategy for sharing of resources and skills under same tags or among other tags.
2009	Janseen	Understanding artificial Anasazi	Presented a model to calculate the carrrying capacity of american southwest region.

Table I. Major Contribution in Understanding Life Style of Primates

2.2 Group formation and co-evolution of leadership using multi agent system

The research papers in this section present the process of evolution of artificial societies using agent based simulation. The papers discuss stereotyping and cultural evolution using an artificial society. The papers describe when the agents started recognizing the cultural orientation within the society and for this the authors of this paper performed various experimenting with artificial agents. The authors this papers shown the need of including various norms and rules of societies on the artificial model so that the results obtained from the study of this model can be verified with the statistical data collected by anthropologists and sociologists working in the same area. This authors also advocated for providing intelligence and self learning capabilities to each agent.

2.2.1 *Evolution of artificial society using agent based simulation.* Casterfranchi [1998] states that cognitive emergence has never been given high importance in agent based modeling before, he states that cognitive emergence is a theory based on socio-dynamic emergence of cultures. According to the author C.E. is an effective factor that can describe easily the process of growth of civilizations, if implemented using agent based simulation. He strongly believes that C.E. till now is been underestimated and by taking C.E. in consideration we can explain various social phenomenon and social norms.

The author refers to previous work by Brooks [1991], Castelfranchi et al [1992], Mataric [1992], Steels [1990] and Conte et al [1995].

The author criticizes work by Brooks [1991], Mataric [1992] and Steels [1990], that in artificial intelligence the view of cognitive emergence is very different from pre decided behavior as cooperation and collective intelligence are modeled only for agents those are active but are not cognitive in nature. the authors claims as his opinion is just opposite to this of having a agent with ability to reason for his actions.

The author claims to have introduced a new terminology called "Cognitive Emergence", in his words cognitive emergence is a phenomenon when an agent become aware through a given set of concepts of an objective or a predefined phenomenon that is going to affect their results and outcomes. Than he tries to implement this term in an artificial society using simulation with new agents naming them as cognitive agents. This agent keeps a record of their expectations, goals, implementation and behaviors of other agents. The author then used Cognitive Emergence to explain the relation between subjective and objective way to define social structure.
The author does not describe any experiments conducted.

The author states that when a self-learning environment is created and when the agent starts following some assumption based on his skills this environment is termed as cognitive emergence. The authors strongly believe that in future cognitive emergence can help in providing exact results for simulation. This term cognitive emergence include some rules which can be very crucial factors in understanding various social processes. Cognitive emergence can explain socio-dynamics and has a good influence on the process of evolution.

2.2.2 *Evolution of cultures and groups with stereotype thoughts.* The problem Hales [1998] states is for a requirement of a self-learning tool which can explain the relationship between origin, spread and acceptance of social categories. According to author various divisions in the world are the results of divisions of big societies. The author wants to investigate some possible causes for the formation of more or less distinguishable groupings. The author presents a problem in automating the process of development of civilization, the way of communication and dynamics of social categories. So that he can present a kind of coherence between the belongings of the categories.

The author refers to previous work by Axelrod [1995], Palmer et al [1995], and Skvoretz [1996].

The author claims that in the work done by Axelrod [1995] the identification of categories and the origin of societies, but agent in the model cannot learn things by himself. In the model by Skvoretz [1996] agents are grouped in some categorize but they have no ability to think and learn by them self. agent is not provided with proper functionality to develop his own idea for choosing a group . And in the work done by Palmer et al [1995] they failed to show stereotyping process among agents in case of group selection.

The author claims to have provided the agent with some kind of memory and some protocols are defined. These protocols are the rule extracted from social norms. The author claims to have implemented interaction between agents in two different ways, First is when the agents are made to play a game of Prisoners dilemma and the movements of agents are been observed. The second way is that when they are made to work under different cultural groups. He also implemented some sort of parameter like confidence value and satisfaction test to observe individual behavior.

The author claims to have conducted a implementation of some social rules in the simulation to analyze the behaviors of agent linked to this values. This is used to check sensitivity and the way this agent communicates with each other and how can they be categorized.

The author claims as in his results he observed some possibility which are very opposite to his hypothesis. In his results he found that only 20 percent of the total run there is a possibility for a group to run under single objective.

The author concludes that his method involves the parametrization of some hypothetical conditions and some conditions very specific to the working structure of society. These parameters are the basis from which we can locate the conditions responsible for their behavior and can able to link those behavior with the assumption behind them.

2.2.3 *Social norms and the Origin of leadership in artificial societies.* Malsch et al [2007] claim that sociologists were concerned with the effect of computation using parametrical analysis. They want to apply sociological concepts into simulation to obtain proper results. They mentioned that earlier Artificial Intelligence technique in social simulation were lacking in social concepts and hence they were unable to produce the exact human behavior and his way of interaction with the environment.

The authors refer the previous work by Doran and Gillbert [1994], Hewitt [1977], and Davis and Smith [1983].

The authors claim that in the work done by Doran et al [1994] they are not concerned about individual agents, but they are concentrating on the whole society. Which in result arises the problem of logical indeterminacy.

The authors claim that in multi-agent simulation model there could be a problem of redundancy of actions among agents and for that he suggests to put some very strict regulations with some security checks, They also claim that this idea of

putting some negative factors in the implementation of social rules in the simulation could make an agent to think exactly as a human do. The authors also concerned about the number of agents interacting with each other if the quantity is larger, than this could be some time unmanageable and for this he suggests to use concepts of self-organization and emergence by which agent himself can maintain his states. They claim as this collective behaviors of the simulation is a result of behaviors of its individual agents it is necessary to put some self -learning and self-manageable rules on agent itself.

The authors do not describe any experiments conducted.

According to authors in history of evolution, competition between groups is the reason behind war fares which resulted in the extinction of some communities even, and the author claims that migration is also a result of warfare and this migration is responsible for three various divergence present in the world. He claims that the competition among individuals to get higher positions in the complex hierarchy of large scale societies was one of the major reason behind war fares.

2.2.4 *Transitions in human life from small scale to large scale complex societies.* Turchin et al [2009] claim that it remains a puzzle, that why civilizations switched from small scale societies to large scale societies. Why they felt a need to change their society structure from very simpler ones to the very complex ones as at present. These societies are getting more complex from top to bottom in their hierarchy levels. The authors claim that it is even very hard to predict the correlation between formation of these large scale societies with complex hierarchy and the wars between small societies. They also doubt it that personnel competition between individuals is the reason behind the fall of small societies.

The author in his study includes work by Jaspers [1953], Richerson et al [1958], Boehm [1993], Boehm [1997] and Earle[1991].

The authors present a study of this papers and states no short comings. he starts with the work by Jasper [1953], who in his early drafts with the same topic explains the problem in very narrow manner. Than author talks about work by Richerson [1958] as he was unable to distinguish small scale societies and large scale societies on proper factors.

The authors state that this paper presents a review of same work done by anthropologists and sociologists. And here they present a discussion in a very broad view. The authors claim to have approached this topic in three ways, First they presented a discussion on the transition of small-scale societies into large-scale societies and the effect of this transition on the evolution of civilization. Secondly they defined the various changes in the hierarchy levels of the society and some major changes on the top level of hierarchy. Thirdly they claim to have devised a modeling approach through agent based simulation to answer various questions about the rise of large scale societies. Lastly they studied some pattern and tried to produce the same verified results to explain the transition.

The authors do not describe any experiments conducted.

The authors conclude that large-scale society arose as a result of huge pressure followed by warfare. They argue that theory of evolution itself can explain the territorial dynamics in societies. He concludes that till now the only thing which is responsible for evolution of increased social scale is competition, fights in against with some other groups. He furthers states as till humanity will not experience a major breakthrough that will give a different picture for large scale cooperation, there is a doubt in getting a stable unified humanity.

2.2.5 *The evolution of leadership and inter group hierarchy.* Kohler et al [2012] state that there is always a difficulty in predicting the formation of complex hierarchical structure of society. They further state that its was hard enough to establish a relation between inter group cooperation between the members of the society on the grounds of socio-political movements in the group.

The authors refer the work by Hooper et al [2010].

The authors state that the model given by Hooper et al [2010] is not defined for a big population and the members of the household were not certain. For example even no knowledge of the number of free riders in the society were given. It was restricted to short gaming and does not say anything about intra and inter group violence.

The authors describe the work which they did on the model to get a clear picture of anasazi inhabitants. How the groups in the societies began. The factors which the authors included in the model are violence among member of societies regarding sharing of food and other matters. The model does not focus on big gaming and hunting for the survival and the other next steps is interaction by the people among different groups that each group which is been lead by one leader comes under the other group supervised by some other leader and inter group communication and interaction.

The authors claim to have performed an experiment with individual agents by dividing them into groups and then studying their interaction under leadership and not under leadership.

The authors claim to obtain results that suggest that the inhabitants found it better to be supervised under a leader, which resulted in the development of societies and even the mutual cooperation among members bringing benefits to the survival of societies. They also describe how the group developed strategies for monitoring and punishment by the experiments they performed with an artificial population of agents. They claim as this model is able to explain that why even if the leader is given a free ride ,the members are still want to be under leadership.

The authors conclude that, they have sufficient proofs which demonstrate the advantages of living in groups and with in a complex hierarchical structure based society. It is more beneficial for the growth of society as compare to other non-hierarchical groups. The author further concludes that their goal was simple to

devise a possible way for the beginning of leadership in small scale societies and their study includes to know that, why having a leader is a surety for making successful relationship with other groups. Their model also includes dynamics of inter-group relations and the beginning of hierarchy among those groups to support their relationship.

2.2.6 *Summary.*

Year	Author	Title of Paper	Major Contribution
1998	Casterfranchi	Simulating with cognitive agents: The importance of cognitive emergence	Presented a new term Cognitive Emergence and advocates to develop self learning agents and self learning environment.
1998	Hales	Stereotyping, groups and cultural evolution: A case of second order emergence	Incorporated parameters like confidence value and satisfaction test to observe agent behavior.
2007	Malsch and Schulz Schaeffer	Socionics:sociological concepts for social systems of artificial agents.	Present a idea to include social customs and rules on agents in simulation.
2009	Turchin	Evolution of complex hierarchical societies.	Discussed Transition of small scale societies into large scale complex societies.
2012	Kohler, Cockburn, Hooper, Bocinsk and Kobti	The coevolution of group size and leadership.	Presented a skeptical view beginning of leadership in ancient societies and compared eglitarian life style and volunteeristic set up using agent based model.

Table II. Major Contribution in Understanding Evolution of Complex Societies

2.3 Small Ancient societies and Warfare's.

The research papers in this section describe the term migration and transition and their effect on the evolution of civilization. The authors of [Fix 1999] and [Gavrilets et al 2010] state that migration is one of the major reason for presence of diversities in this world. The authors present some study and statistics to show that this migration are outcomes of wars between small societies. This wars are also the reason behind formation of large-scale societies with very complex structures.

2.3.1 *Migration in ancient societies and cause to wars..* According to Fix [1999] since the beginning of civilization it has always been hard to predict the role of individuals during migration from a society. The co-evolution of society and the factors responsible are one of the major factors for dynamics in social life of ancient people. The changes in cultural, social and geopolitical life of an agent in a society are complex enough to predict, author in his paper studies about gene distribution

which he considers as to be a cause of migration and other variance in present civilization can be explained on this terms.

The author claims as his work is the extension of work done by Boyce [1984] , Crawford and Mieke [1982], and Mascie et al [1988].

According to the author he has just extend the work done by previous researchers and given a suitable hierarchy to distinguish the problem using some patterns which were not given by other authors. The previous author were rendered unable to exemplify there work under the factors of gene distribution and colonization which is explained much better by the author.

The author claims to have introduced some new ideas and some new patterns. He talks about the relation between the emergence of diverged culture and the demo-graphical changes based on the data provided by anthropologists working in same area. According to the author there is a common factor which resulted in such a diverse distribution of genes, cultures and populations.
The authors do not describe any experiments conducted.
The authors presented no results.

The author claims as that, the study incorporates various domain like anthropology and sociology to explain the effect of migration and colonization on the demography of the present civilization, which started from the ancient society. The author in the paper draws attention towards the next step in the same research area. According to him this is the phase form where the division of society into various cast, tags, and culture started.

2.3.2 *Warfare as a cause of complexity in early societies.* The main problem discussed by Gavrilets et al [2010] is about civilizations after major wars in history. It is been estimated that wars are events that gave birth to major civilizations and to prove this using an agent based model is major focus, The authors are concerned about exact estimation of the changes in political and geo-social structures of the societies are yet to be determined and how to obtain the exact figures is still a question for the researchers yet.

According to authors in his paper he has extended the work of Carneiro [1970] which is an agent based model about the ancient societies their beginning the causes that led to warfare.

The authors in this paper did not mention any shortcomings of the previous work.

The authors claim to have given a computational model which produces graphical results showing the formation of societies that can be predicted only when certain factors like specific cultural demographic and ecological condition are taken in consideration. It shows the dynamic behavior in the size of the population, and a growth driven by warfare which, at a certain instance collapses to very less as a

result of defeat in war, the author in his mode signifies characteristics of polities like (size, complexity, power and centrality that are governed by six major factors.

The authors claim to have run various simulations with lots of numerical possibilities using permutation for six major parameters

The authors claim, in the results he obtained, that there were abrupt changes in the societies after wars, like people were coming under a big organization and then the civilization started taking its shape. He also observed in his study that a defeat in a battle results in the fall of a whole society, whereas a win results in the growth of resources and population. The results also show that the victory in a war does not depends on the wealth of society but there are various other factors that plays big role in deciding it.

The authors claim that his model signifies the data observed by anthropologists about the American southwest region. The model can be extended further more for many possibilities .one of those is the participation of members in small societies which led to the formation of very stable societies.

2.3.3 *Summary.*

Year	Author	Title of Paper	Major Contribution
2009	Fix	Migration and Colonization in human microevolution	Presented a view about migration as a reason for diversions in present culture.
2010	Gavrilets	Cycling in the complexity of early societies.	Presented a way in establishing relation between wars and evolution of civilization.

Table III. Major Contribution in Understanding the reason for Social Division

3. CONCLUDING COMMENTS

Kohler [2000] describes the process of civilization taking into account the ancient societies of the mesa verde region. In his research he describes the social and biological life style of the inhabitants. He concludes in his study that simulation is a requirement to figure out life style of ancients near to exact by implementing some conditions. He was the first to create a social simulation which can be seen as a distinct approach to the study of human society. Edmonds [2006], through his research, concludes that skill and resource sharing has began between groups and they started coming under cooperation and these processes led to the evolution of the civilization. Janseen [2009] presents a clear picture of the american southwest region and concludes that the abandonment of this region cannot be explained only by the environmental factors. He further, in his research, concludes as his findings are able to prove his hypothesis and can explain the carrying capacity of american southwest region. Further Casterfranchi [1998] concludes with the term Cognitive Emergence, which he believes is can explain all those anomolies and all those reasons

which makes a human to choose his objectives. He encourages the implementation of the concept of cognitive emergence in multi using simulation for better knowing of the factors responsible for the behavior of individuals in a group. Working under the same direction Hales [1998] introduces some concepts, rules specific to social norms in simulation using some paramertical values and claims to have obtained better results from the work done before. He concludes that for a more accurate outcome we need to inject more social rules in the simulation.

Futher Malsch et al [2007], Turchin [2009] and Kohler et al [2012] tried to present a new phase of human life, when humans begin to migrate from one group to other and from one landscape to other. They studied this phenomenon and tried to reproduce it using multi agent simulation. In their work they conclude to have found some results on to their expectation. These finding are enough to explain atleast the beginning and results of migration in human society. In future this findings can be used as a base study to present some more hypothesis and for the better understanding of evolution of divergent culture as at present we have today. Fix [1999] and Gavrilets et al [2010] continued the work by developing a new computational model and presented a hypothesis over the evolution of complex societies from warfare and migration as a major cause. They presented their views with enough evidence to explain a better way to estabish relation between warfare, transition and emergence of lage scale and complex hierarchical societies.

4. ANNOTATIONS

4.1 Casterfranchi 1998.

Citation.Castelfranchi,C. 1998. Simulating with cognitive agents: The importance of cognitive emergence. In Multi-agent systems and agent-based simulation. Vol. 1534. Springer Berlin, Heidel-berg, 26-44.

Problem. The author states that cognitive emergence has never been given that importance in agent based modeling before, he appeals as that cognitive emergence is a theory based on socio-dynamic emergence of cultures. According to the author C.E. is an effective factor that can describes easily the process of growth of civilization, if implemented using agent based simulation. He strongly believe that C.E. till now is been underestimated and by taking C.E. in consideration we can explain various social phenomenon and social norms.

Previous Work. The author referred majorly to previous work by Brooks [1991], Castelfranchi et al [1992], Mataric [1992] , Steels [1990] and Conte et al [1995].

Shortcomings of Previous Work. The author criticizes work by Brooks [1991], Mataric [1992] and Steels [1990], that in artificial intelligence the view of cognitive emergence is very different from pre decided behavior as cooperation and collective intelligence are modeled only for agents those are active but are not cognitive in nature. the authors claims as his opinion is just opposite to this of having a agent with ability to reason for his actions.

New Idea/Algorithm/Architecture. The author claims to have introduced a new terminology called Cognitive Emergence, in his words cognitive emergence is a phenomenon when an agent become aware through a given set of concepts of an objective or a predefined phenomenon that is going to affect their results and outcomes. Than he tries to implement this term in an artificial society using simulation with new agents naming them as cognitive agents. This agent keeps a record of their expectations, goals, implementation and behaviors of other agents. The author then used Cognitive Emergence to explain the relation between subjective and objective way to define social structure.

Experiments Conducted. The author does not describe any experiments conducted.

Results. The author presented no results.

Conclusions. The author states that when a self-learning environment is created and when the agent starts following some assumption based on his skills this environment is termed as cognitive emergence. The authors strongly believe that in future cognitive emergence can help in providing exact results for simulation. This term cognitive emergence include some rules which can be very crucial factors in understanding various social processes. Cognitive emergence can explain socio-dynamics and has a good influence on the process of evolution.

Citations By Others. There are no specific references to this paper by othere researchers in this survey.

4.2 Edmonds 2006

Citation.EDMONDS,B. 2006. The emergence of symbiotic groups resulting from skill-differentiation and tags. *Journal of Artificial Societies and Social Simulation* 9,1:,10.

Problem. According to the author the problem he focuses on is how societies obtain its present structure besides the presence of such diversities where each individual is master of some different skill, where the society is divided into different tags [group by culture], this differentiation could be the major reason for inter skill and inter tag cooperation and also for the spread of population and the growth of civilization to till present.

Previous work. The idea was given by John et al [1993, 1995] was developed by Rialto [1997, 2001 etc.] and Hales [2001, 2009] and Edmond et al [2003].

Shortcomings of Previous work. The author claims in Edmond and Hales [2003] the resources distribution is unable to provide a clear picture of resource sharing. The main focus is kept on the type of resource, but not on the individual participating in sharing.

New Idea/Algorithm/Architecture. The author claims to have given new direction to the researches made in same area by defining the type of resources, products

,skills and tags, under which the whole society is to be decided such as each individual would master a skill and will have one product to share with other. Now by doing so the author wants to observe the cooperation between individuals and their strategy of sharing and transferring their skills either under the same tag or among other tags.

Experiments Conducted. The author claims to have performed a simulation on the discrete time with some random parameters as resource and agent. Each individual is provided with different resources and they are made to share the resources.

Results. The author claims, in his results that, each individual has a requirement for a product and on that basis he takes his decision for choosing resources, While in the case of skills the sharing can be done in two ways. First is when the skill is shared by a father with his offspring and secondly when it is transferred from a individual to an individual from other tag but to someone who is socially compatible.

Conclusions. The author claims that by his study on this area can say that, sharing of skills and resources on requirement has been developed among tags and these societies have developed a symbiotic way of sharing within society. The author also gives an indication about next possibilities in this model as this model does not speak of the working of societies and other things such as, how donation is developed in societies.

Citations By Others. There are no specific references to this paper by othere researchers in this survey.

4.3 Fix 1999

Citation. textscFix,A. 1999 . Migration and colonization in human microevolution, vol. 24. Cambridge Univ Pr,1999.

Problem. According to author since the beginning of civilization it has always been hard to predict the role of individuals during migration from a society. The coevolution of society and the factors responsible are one of the major factors for dynamics in social life of ancient people. the changes in cultural, social and geopolitical life of an agent in a society are complex enough to predict, author in his paper studies about gene distribution which he considers as to be a cause of migration and other variance in present civilization can be explained on this terms.

Previous work. The author claims as his work is the extension of work done by Boyce [1984] , Crawford and Mieke [1982], and Mascie et al [1988].

Shortcomings of Previous work. According to the author he has just extend the work done by previous researchers and given a suitable hierarchy to distinguish the problem using some patterns which were not given by other authors. The previous author were rendered unable to exemplify there work under the factors of gene distribution and colonization which is explained much better by the author.

New Idea/Algorithm/Architecture. The author claims to have introduced some new ideas and some new patterns. He talks about the relation between the emergence of diverged culture and the demographical changes based on the data provided by anthropologists working in same area. According to the author there is a common factor which resulted in such a diverse distribution of genes, cultures and populations.

Experiments Conducted. The authors do not describe any experiments conducted.

Results.The authors presented no results.

Conclusion. The author claims as that, the study incorporates various domain like anthropology and sociology to explain the effect of migration and colonization on the demography of the present civilization, which started from the ancient society. The author in the paper draws attention towards the next step in the same research area. According to him this is the phase form where the division of society into various cast, tags, and culture started.

Citations By Others. There are no specific references to this paper by othere researchers in this survey.

4.4 Gavrilets et al. 2010

Citation.Gaverilets,S.,Anderson,D., and Turchin,P. 2010. Cycling in the Complexity of Early Societies. Cliodynamics, 1(1), *The Journals of Theoretical and Mathematical History.*

Problem. The main problem discussed by the author is about the civilization after major wars in history. It is bean estimated as wars are events that gave birth to major civilization and to prove this using an agent based model is major focus, The author is concerned about exact estimation of the changes in political and geo-social structures of the societies are yet to be determined and how to obtain the exact figures is still a question for the researchers yet.

Previous work. According to authors in his paper he has extended the work of Carneiro [1970] which is an agent based model about the ancient societies their beginning the causes that led to warfare.

Shortcomings of previous work. The author in his paper did not mention any shortcomings of the previous work.

New Idea/Algorithm/Architecture. The author claims to have given a computational model which produces graphical results showing the formation of societies that can be predicted only when certain factors like specific cultural demographic and ecological condition are taken in consideration. It shows the dynamic behavior in the size of the population, and a growth driven by warfare which, at a certain instance collapses to very less as a result of defeat in war, the author in his mode

signifies characteristics of polities like (size, complexity, power and centrality that are governed by six major factors.

Experiment Conducted. The author claims to have run various simulations with lots of numerical possibilities using permutation for six major parameters

Results. The author claims, in the results he obtained, that there were abrupt changes in the societies after wars, like people were coming under a big organization and then the civilization started taking its shape. He also observed in his study that a defeat in a battle results in the fall of a whole society, whereas a win results in the growth of resources and population. The results also show that the victory in a war does not depends on the wealth of society but there are various other factors that plays big role in deciding it.

Conclusion. The author claims that his model signifies the data observed by anthropologists about the American southwest region. The model can be extended further more for many possibilities .one of those is the participation of members in small societies which led to the formation of very stable societies.

Citations By Others. There are no specific references to this paper by othere researchers in this survey.

4.5 Hales 1998 .

Citation.Hales, D. 1998. Stereotyping, groups and cultural evolution: A case of 'second order emergence'? In Multi-Agent Systems and Agent-Based Simulation (1998), vol. 1534, Springer Berlin, Heidelberg, pp. 141145.

Problem. The problem author states is for a requirement of a self-learning tool which can explain the relationship between origin, spread and acceptance of social categories. According to author the various diversions in the world are the results of divisions of big societies. The author wants to implement some possible cause for the formation of more or less distinguishable groupings. The author presents a problem in automating the process of development of civilization, the way of communication and dynamics of social categories. So that he can present a kind of coherence between the belongings of the categories.

Previous Work. The author refers to previous work by Axelrod [1995], Palmer et al [1995], and Skvoretz [1996].

Shortcomings of Previous Work. Author claims that in the work done by Axelrod [1995] the identification of categories and the origin of societies, but agent in the model cannot learn things by himself. In the model by Skvoretz [1996] agents are grouped in some categorize but they have no ability to think and learn by them self. agent is not provided with proper functionality to develop his own idea for choosing a group . And in the work done by Palmer et al [1995] they failed to show stereotyping process among agents in case of group selection.

New Idea/Algorithm/Architecture. The author claims to have provided the agent with some kind of memory and some protocols are defined. These protocols are the rule extracted from social norms. The author claims to have implemented interaction between agents in two different ways, First is when the agents are made to play a game of Prisoners dilemma and the movements of agents are been observed. The second way is that when they are made to work under different cultural groups. He also implemented some sort of parameter like confidence value and satisfaction test to observe individual behavior.

Experiments Conducted. The author claims to have conducted a implementation of some social rules in the simulation to analyze the behaviors of agent linked to this values. This is used to check sensitivity and the way this agent communicates with each other and how can they be categorized.

Results. The author claims as in his results he observed some possibility which are very opposite to his hypothesis. In his results he found that only 20 percent of the total run there is a possibility for a group to run under single objective.

Conclusions. The author concludes that his method involves the parametrization of some hypothetical conditions and some conditions very specific to the working structure of society. These parameters are the basis from which we can locate the conditions responsible for their behavior and can able to link those behavior with the assumption behind them.

Citations By Others. There are no specific references to this paper by othere researchers in this survey.

4.6 Janssen 2009

Citation. Janseen, M. 2009. Understanding articial anasazi. Journal of Articial Societies and Social Simulation 12, 4 (2009), 13.

Problem. The author states that no previous model is able to present a proper schema of the anasazi model ,where it is hard to predict the interaction of inhabitants with their ecological system.According to the author the model is even not able to define the structure of society in case of big population.He states that by soling these problem we can able to get a proper schema of the present civilization.

Previous work. The author refers to previous work by Dean et al [2000], Axtell et al [2002] and Gumerman et al [2003].

Shortcomings of the previous work. The author states that in Dean et al [2000] and Axtell et al [2002] the variance of the population and their interaction with their environment is defined as a simple aggregation to their simple needs for farming and other needs. In their work they were using simple systems but were not dealing with the complex systems which would have prevented them from obtaining exact results in the simulation for the anasazi life style

New Idea/Algorithm/Architecture. The author claims the calculation for carrying capacity on the grounds of parameter like harvest adjustment and potential plot area for food production is one way we could exactly measure the carrying capacity of the land area . He looks forward with some more factors that could be included and will come out as major aspects which can drive the solution with more plausibility and more exactness. He expects some future changes in the model.

Experiments Conducted. The author claims to have performed a Computational experiment on the model using some parameters, So that he can support his theory that Carrying Capacity of village was proportional to the food production divided by number of households.

Results. The author claims that he observed in his results in the computational model that the variance in population size is proportional to the amount of plot area which has the potential of producing enough food and is inversely proportional to the number of household which feeds from that production. In the results from the experiments conducted by author he claims that whenever there is a drop in production of maize there is always a drop in the increase in population but it is not instantaneous drop, this drop is reflected in the later results and is proportionate .he claims that by using this results one can figure out the actual carrying capacity of the land area there in the village.

Conclusions. The author concludes that in the American Southwest region only environmental factors are unable to explain the sudden disestablishment of the region and in the light of some archeological records, The simulation model developed by authors provide approximately same results which proves the accuracy of model in explaining dynamics of American southwest region . The authors state that as we have a data of number of household present and of average reproduction rate of this households, this model is able to calculate the carrying capacity of the region.

Citations By Others: There are no specific references to this paper by othere researchers in this survey.

4.7 Kohler 2000

Citation:Kohler, T. 2000 . Dynamics in human and primate societies: Agent-based modeling of social and spatial processes. Oxford University Press, USA, 2000.

*Problem.*The author address the problem of understanding the life style of complex societies , their way of interacting with their biological environment as a social group. To understand the problems of small societies and problems related to their economy and biological life using a agent based simulation . By knowing this we can predict the way the ancient people developed their skills for solving their routine problems . To study the changes that occurred in the cultural network of those people and even the factors that contributed in this changes .

Previous work. The author refers to previous work by Cowan et al [1994] and Gummerman et al [1994] which is related to the same topic and is extended by author in his work.

ShortComings of Previous work. According to the author Cowan et al [1994] in his paper he focused on the social behavior of small scale societies and the same work is extended by the author in his work. According to author Gummerman et al [1994] discussed about the complexities in the social life of the people on the basis of some archeological parameters and tried to determine their some of the day to day problems and how they use to solve them.

New Idea/Algorithm/Architecture. In the future the author expects the computational model to includes a large group of agents and also to implements conditions which are decision based ,followed by the members of primate societies . The author speaks of the large hunting games , and large places for storage of food and water and the way its distribution among families and in inter households. He expects to get a more realistic view to the life of those people through the simulation. The author speaks of applying methods to en-light the reaction of peoples during natural calamities and also the weather condition that affects their food production. The author wants to develop a self learning agent who can devise its own methods and can contribute with the other agents for the proliferation of society.

Experiments Conducted . According to the author he conducted 30 experiments , with about 15 different locations in the model design of a village with two productivity levels and two sets of locations which are random by nature with about 1219 cells for a location named POI and about 1067 cells for a location named PIII.

Results. According to author when they applied various conditions like availability of water , land, food he received different results on three major aspects of life of people .The first is maize production, According to author if people prefer to live near water source they can produce good maize and will result in increase in population but if he chooses to live near a temporary source of water so at some time lack of water may cause decrease in maize production and then he would need to migrate in search for some better land area. And with this result he comes out with one more result that finding a place near a permanent water source is much more difficult than finding a place near temporary sources of water.

Conclusions. The author concludes that simulation is a process which enables sociologists to study how interaction between people started for the purpose of resources and skills sharing . The author states that simulation allow us in analyzing some of the conditions which can not be predicted from sociological study.

Citations By Others. There are no specific references to this paper by othere researchers in this survey.

4.8 Kohler et al. 2012

Citation.Kohler,T.,Cockburn, D., Hooper, P., Bocinsky, R., and Kobti, Z. 2012. The coevolution of group size and leadership: An agent-based public goods model for prehispanic pueblo societies. Advance in Complex Systems. 15,01(2012).

Problem. The authors state that there is always a difficulty in predicting the formation of complex hierarchical structure of society and. He further states that

its was hard enough to establish a relation between inter group cooperation between the members of the society on the grounds of socio-political movements in the group.

Previous work. The authors refer the work by Hooper et al [2010].

Shortcomings of Previous work. The authors state that the model given by Hooper et al [2010] is not defined for a big population and the members of the household were not certain. For example even no knowledge of the number of free riders in the society were given. It was restricted to short gaming and does not say anything about intra and inter group violence.

New Idea/Algorithm/Architecture. The author describes the work which they did on the model to get a clear picture of anasazi inhabitants. How the groups in the societies began. The factors which the authors included in the model are violence among member of societies regarding sharing of food and other matters. The model does not focus on big gaming and hunting for the survival and the other next steps is interaction by the people among different groups that each group which is been lead by one leader comes under the other group supervised by some other leader and inter group communication and interaction.

Experiments Conducted. The authors claim to have performed an experiment with individual agents by dividing them into groups and then studying their interaction under leadership and not under leadership.

Results . The authors claim to obtain results that suggest that the inhabitants found it better to be supervised under a leader, which resulted in the development of societies and even the mutual cooperation among members bringing benefits to the survival of societies. They also describe how the group developed strategies for monitoring and punishment by the experiments they performed with an artificial population of agents. They claim as this model is able to explain that why even if the leader is given a free ride, the members are still want to be under leadership.

Conclusions. The authors conclude that, they have sufficient proofs which demonstrate the advantages of living in groups and with in a complex hierarchical structure based society. It is more beneficial for the growth of society as compare to other non-hierarchical groups. The author further concludes that their goal was simple to devise a possible way for the beginning of leadership in small scale societies and their study includes to know that, why having a leader is a surety for making successful relationship with other groups. Their model also includes dynamics of inter-group relations and the beginning of hierarchy among those groups to support their relationship.

Citations By Others: There are no specific references to this paper by othere researchers in this survey.

4.9 Malsch et al 2007

Citation:Malsch,T., and Schulz-Schaeffer, I. 2007. 'Socionics: Sociological Concepts for Social Systems of Artificial (and Human) Agents'. Journal of Artificial Societies and Social Simulation 10(1)11 ¡http://jasss.soc.surrey.ac.uk/10/1/11.html¿.

Problem. The authors claim that sociologists were concerned about the effect of computation using parametrical analysis .They want to apply sociological concepts into simulation to obtain proper results. They mentioned that earlier Artificial Intelligence technics in social simulation were lacking in social concepts and hence they were unable to produce the exact human behavior and his way of interaction with the environment.

Previous Work. The authors refer the previous work by Doran and Gillbert [1994], Hewitt [1977], and Davis and Smith [1983].

Shortcomings of Previous Work. The authors claims that in the work done by Doran et al [1994] ,he is not concerned about individual agents ,but they are concentrating on the whole society. Which in result arises the problem of logical indeterminacy.

New Idea/Algorithm/Architecture. The authors claim that in multi-agent simulation model there could be a problem of redundancy of actions among agents and for that he suggests to put some very strict regulations with some security checks, They also claim that this idea of putting some negative factors in the implementation of social rules in the simulation could make an agent to think exactly as a human do. The authors also concerned about the number of agents interacting with each other if the quantity is larger, than this could be some time unmanageable and for this he suggests to use concepts of self-organization and emergence by which agent himself can maintain his states. They claim as this collective behaviors of the simulation is a result of behaviors of its individual agents it is necessary to put some self -learning and self-manageable rules on agent itself.

Experiments Conducted. The authors do not describe any experiments conducted.

Results. The author presented no results.

Conclusions. According to authors in history of evolution , competition between groups is the reason behind war fares which resulted in the extinction of some communities even ,and the author claims that migration is also a result of warfare and this migration is responsible for three various divergence present in the world .He claims that the competition among individuals to get higher positions in the complex hierarchy of large scale societies was one of the major reason behind war fares.

Citations By Others: There are no specific references to this paper by othere researchers in this survey.

4.10 Turchin 2009.

Citation:Turchin,P., and Gavrilets,S. 2009. Evolution of complex hierarchical societies. Soc. Evol. Hist 8 (2009), 167198.

Problem. The authors claim that this is a puzzle till now, that why the civilization switched from small scale societies to large scale societies. Why they felt a need to change their society structure from very simpler ones to the very complex ones as now at present. These societies are getting more complex from top to down in their hierarchy levels. The authors claim as, that it is even very hard to predict the correlation between formation of these large scale societies with complex hierarchy and the wars between small societies. They also doubt it that personnel competition between individuals are the reason behind the fall of small societies.

Previous Work. The author in his study include work by Jaspers [1953], Richerson et al [1958], Boehm [1993,97] and Earle[1991].

Shortcomings of Previous Work. The author presented a study of this papers and states no short comings. he starts with the work by Jasper [1953] , who in his early drafts with the topic explains the problem in very narrow manner . Than author talks about work by Richerson [1958] as he was unable to distinguish small scale societies and large scale societies with proper factors.

New Idea/Algorithm/Architecture. The authors state that this paper presents a review of same work done by anthropologists and sociologists. And here they present a discussion in a very broad view. The authors claim to have approached this topic in three ways, First they presented a discussion on the transition of small-scale societies into large-scale societies and the effect of this transition on the evolution of civilization. Secondly they defined the various changes in the hierarchy levels of the society and some major changes on the top level of hierarchy. Thirdly they claim to have devised a modeling approach through agent based simulation to answer various questions about the rise of large scale societies. Lastly they studied some pattern and tried to produce the same verified results to explain the transition.

Experiments Conducted. The authors do not describe any experiments conducted.

Results. The authors presented no results.

Conclusions. The authors conclude that large-scale society arose as a result of huge pressure followed by warfare. They argue that theory of evolution itself can explain the territorial dynamics in societies. He concludes that till now the only thing which is responsible for evolution of increased social scale is competition, fights in against with some other groups. He furthers states as till humanity will not experience a major breakthrough that will give a different picture for large scale cooperation, there is a doubt in getting a stable unified humanity.

Citations By Others: [Kohler et all 2012] and [Gavrilets et al 2010].

REFERENCES

Axtell, R., and Epstein, J. *Coordination in transient social networks: an agent-based computational model of the timing of retirement.* Princeton University Press, Princeton University Press,41 William Street, 1999.

Braun, D., and Plog, S. Evolution of" tribal" social networks: Theory and prehistoric north american evidence. *American Antiquity 47* (1982), 504–525.

Carley, K. Computational social science: Agents, interaction, and dynamics. *Simulation of Social Agents: Architectures and Institutions 10* (2000), 3–27.

Castelfranchi, C. Simulating with cognitive agents: The importance of cognitive emergence. In *Multi-agent Systems and Agent-Based Simulation* (1998), vol. 1534, Springer Berlin, Heidelberg, pp. 26–44.

Edmonds, B. The emergence of symbiotic groups resulting from skill-differentiation and tags. *Journal of Artificial Societies and Social Simulation 9*, 1, 10.

Fix, A. *Migration and colonization in human microevolution.* Cambridge Univ Pr, 1999.

Gavrilets, S., Anderson, D., and Turchin, P. Cycling in the complexity of early societies. *Cliodynamics, The journals of Theoretical and Mathematical History 1*, 1 (2010).

Gumerman, G., Swedlund, A., Dean, J., and Epstein, J. The evolution of social behavior in the prehistoric american southwest. *Artificial life 9*, 4 (2003), 435–444.

Hales, D. Stereotyping, groups and cultural evolution: A case of second order emergence ? In *Multi-Agent Systems and Agent-Based Simulation* (1998), vol. 1534, Springer Berlin, Heidelberg, pp. 141–145.

Janssen, M. Understanding artificial anasazi. *Journal of Artificial Societies and Social Simulation 12*, 4 (2009), 13.

Kohler, T. *Dynamics in human and primate societies: Agent-based modeling of social and spatial processes.* Oxford University Press, USA, 2000.

Kohler, T., Cockburn, D., Hooper, P., Bocinsky, R., and Kobti, Z. The coevolution of group size and leadership: An agent-based public goods model for prehispanic pueblo societies. *Advances in Complex Systems (ACS) 15*, 01 (2012), 1150007–1.

Lozano, S., Arenas, A., and Sánchez, A. Community connectivity and heterogeneity: clues and insights on cooperation on social networks. *Journal of Economic Interaction and Coordination 3*, 2 (2008), 183–199.

Malsch, T., and Schulz-Schaeffer, I. Socionics: Sociological concepts for social systems of artificial (and human) agents. *Journal of Artificial Societies and Social Simulation 10*, 1 (2007), 10–11.

Reynolds, R., Kohler, T., and Kobti, Z. The effects of generalized reciprocal exchange on the resilience of social networks: An example from the prehispanic mesa verde region. *Computational & Mathematical Organization Theory 9*, 3 (2003), 227–254.

Rima, I. *Development of economic analysis.* Taylor & Francis US, 2001.

Saitta, D., and Keene, A. Politics and surplus flow in prehistoric communal societies. *Journal of The Evolution of Political Systems: Sociopolitics in Small-Scale Sedentary Societies* (1990), 203–224.

Sawyer, R. Artificial societies. *Sociological Methods & Research 31*, 3 (2003), 325.

Sebastian, L. Sociopolitical complexity and the chaco system. *Journal of Chaco and Hohokam: Prehistoric regional systems in the American Southwest* (1991), 109–134.

Turchin, P., and Gavrilets, S. Evolution of complex hierarchical societies. *Soc. Evol. Hist 8* (2009), 167–198.

van den Bergh, J., and Gowdy, J. A group selection perspective on economic behavior, institutions and organizations. *Journal of Economic Behavior & Organization 72*, 1 (2009), 1–20.

Winterhalder, B. Diet choice, risk, and food sharing in a stochastic environment. *Journal of Anthropological Archaeology 5*, 4 (1986), 369–392.