Simulating Group Preferences and Ecology with Agent-Based Modeling to Increase Management and Sustainability of Resources

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Elias Rivera and Hardy Jones

In the study of socioecological systems, group formation has not been examined together with the stability of resource management. Analytical models and agent-based models have been created for common-pool resource management focusing on relations between beliefs and institutions.These models, however, inadequately represent agents in natural resource systems. Although frameworks have been developed that represent boundaries of agents across natural resouce contexts, the behavioral models miss the situational and behavioral aspects of actors in the simulated contexts. The decision-making process has been simulated by agents, yet the simulations do not reflect real biological and social situations. Previous research has looked at each “tree”, but not the whole “forest”. We will use agent-based models to examine group member preferences (race, ethnicity, gender, and skills) and local ecology to discern how cooperation is maintained over time. We will travel to Austin, TX to collect data on group preferences in new member interest and the current conservation practices. Modeling will be done to create preliminary agents and run simulations on group preferences producing a quantitative and qualitative understanding of resource management. We hope to find characteristics that groups choose for new members resulting in stable cooperation over time. Focusing on stable cooperation will lead to better management and sustainability of a resource.

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# Introduction

The University of California, Davis request [insert money] from [the grant giving institution] for the pursuit of a two-year study examining group member preferences, such as, race, ethnicity, gender, skills, etc. and local ecology to see how cooperation is maintained over time of a resource with data from an ongoing study in Austin, TX.

In order to understand why sustaining cooperation in common pool resources needs to be further examined, one must first understand the common-pool dilemma, followed by the relevance of future work.

In economics, *common goods* are resources that every individual has access to, like fresh air. These goods are *non-excludable*, meaning any one has access to the resource. Moreover, resources in common good games remain *rivalrous*, meaning individuals have to compete for access to the resource. Though everyone shares common goods, few borne the cost to maintain them, those that do not maintain the resource but share the benefit are called, *free-riders*.

To illustrate, Figure 1 represents the common goods game, cooperation, and free-riders. As you can see at point (A) in Figure 1 shows six players, players 1 through 6 engaging around a common pool resource. These players represent any one community, like a city, say New York, or represent an island community, like Hawaii. In these communities, as illustrated by point (B) in Figure 1, *cooperators* pay costs to maintain the common good and in turn get benefits from the good. For example, in terms of fresh air, cooperators in Alaska might pay the cost to not use coal to warm their house for a month, so as not to pollute. Though, within these communities free-riders exist, as illustrated by point (C) in Figure 1. Free-riders benefit from the good without paying any cost. For example, going back to the Alaskan community, free-riders might continue to use coal to warm their houses even though others in that community are abstaining from the use of coal. As you can see at point (D) in Figure 1, cooperators, players 1 through 4, maintain and contribute to the public good. In this case, players 1 through 4 would be abstaining from the use of coal to warm their houses for a month. As you can see at point (E) in Figure 1, the resource, say fresh air, benefits from the maintenance and contribution of cooperators. Hence, point (F) in Figure 1 represents the benefits from abstaining from the use of coal for a month. For example, these benefits in the Alaskan community might be in the form of cleaner, breathable air. As a result, players 1 through 6 are given these benefits, even though players 5 and 6, the free-riders did not maintain and contribute to the public good. To summarize common goods dilemma showcases the issue that arises from the use and maintenance of consuming a resource, that is individuals will pay a cost to maintain the resource, cooperators, and individuals that do not pay any cost but get the same benefits from the resource, the free-riders.

Though free-riders benefit from the common good without paying any cost, communities may use societal tools to maintain the common good without free-riders. Groups may use punishment, like enforcing rules, to reduce the *payoff*, meaning benefits of free-riders. For example, individuals who abstain from using coal for a month in the Alaskan community may begin using a tax for those individuals who do not abstain from using coal for a month. Free-riders are coerced to maintain and contribute to the common good. For example, now that a tax imposed on free-riders, free-riders have the incentive to not use coal and instead assist in maintaining and contributing to the common good. The outcome from using punishment, players all share in the benefits from the public good and the cost of maintaining it.

Another useful societal tool that communities may use to maintain a common good without free-riders is reputation. Reputation is like gossip. Communities can refuse to interact with free-riders if they know the reputation of others. Cooperators may refuse to interact with free-riders because of their reputation of benefitting from the good without paying the cost of maintaining and contributing to the common good. For example, those that abstain from using coal for a month in the Alaskan community may now choose to not cooperate with those who break the rules and do use coal for a month, this tradeoff may mean kicking those that break the rules out of the community. Now that cooperators are not interacting with free-riders, players only maintain and contribute to the common good. Cooperators only share the benefits from maintaining and contributing to the common good. The combination of the tools, punishment and reputation, may lead to higher cooperation rates around a common good. Though, cooperation with strangers may be enhanced with reputation systems, net benefits from maintaining and contributing to a resource is greater when punishment is present, however higher cooperation rates are maintained when punishment is exercised on defectors. While these methods are useful to understand common pool resource management, they remain limited to their applicability to case studies.

We propose to examine further the societal tools that communities use in Austin, TX for group member entrance. These societal tools along with modeling species interactions across local ecologies will be used to examine the proliferation of cooperation over this two-year span study. By examining the relationship between these variables, we aim to advance the decision-making in conservation beyond protected areas.

# Background

Though, agent-based models can statistically test the different components of a resource system from which the empirical data is derived, they have not been tested to examine group member preferences, such as, race, ethnicity, gender, skills, etc. and local ecology to see how cooperation is maintained over time of a resource (Ostrom 2010; Bravo 2011).However, subsequent studies have created agent-based models for describing the decision processes of simulated actors on the micro-level and the structures that emerge at the macro-level from the action and interactions of agents with other agents within these resource systems (Bravo 2011).

Bravo proposes both an analytical model and a more complex agent-based model designed to study common-pool resource management problems with a specific focus on the relation between agents’ beliefs and institutions, that moves beyond the empirical approach to a theory of collective action using computational statistics (2010). These models begin to statistically simulate the different components of the resource system using empirical data. Bravo models the relationship between the beliefs among actors involved in exploiting the common resource and the development of management institutions (2010). In this article, Bravo found that the conditions where agents are allowed to build management institutions, outcomes were much better than the ones where agents can only rely on individual beliefs in order to limit the resource consumption (2010). Though, in order to keep the model simple, many rules that are fundamental in real social and biological systems were only assumed in his research (Bravo 2010). Moreover, these models inadequately represent the behaviors of individual agents in natural and human-made resource systems.

However, Smajgl et al. develops a framework for representing the boundaries of behavior in agent-based models across various modeling contexts (2011). Smajgl et al. classified and formalized various modeling contexts according to the size of the agent population, their behavioral diversity and the ability of researchers to acquire a representative sample of agent behaviors (2011). These classifications provide a structure that can be used to evaluate the suitability of various combinations of methods in different context using behavioral data (Smajgl et al. 2011). Though, Smajgl et al. does not provide a framework for examining the ways agents engage with their environment and how agents form social networks in solving common pool resource problems (2011). These behavioral models do not convey the effects of situational and behavioral aspects of actors on simulated communities.

Instead, Vallino uses agent-based simulations to develop a theoretical model to simulate the implications of decision-making processes in simulated communities (2013). Vallino addresses a particular situation of natural resource management, that of a protected area (2013). By addressing a particular situation of natural resource management, agent-based models may better reflect the dynamics of natural and human-made resource systems. The presence of institutions and enforcement from an external entity such as the state, a donor, an NGO or some combination thereof, improves the management of the resource with respect to an open-access situation (Vallino 2013). The results from Vallino’s findings suggest that an exogenous institution imposed by external agents (i.e., the state, a donor, an NGO or some combination thereof) may crowd out agents’ intrinsic environmental motivations, and when an imposed exogenous institution is in place, the most effective rule is one allowing a sufficient degree of access to resources for the agents, provided that adequate rule enforcement is implemented (2013). Though theoretical agent-based models explore the consequences of different kinds of institutions for its users using simulated environments, it does not reflect the behavior of agents in real biological and social situations.

Though, Wijermans et al. develops an agent-based model case study that real biological and social situations that contextualize the real world phenomena. The Wijermans case study is situated in the rice terraces of Bali and involves irrigation management. In this article, Wijermans et al. model explores cultural factors, such as regional temples that control water flow into these terraces and rice paddy farmer communities (2014). The model created is contextualized so as to relate previous theories/models from the literature to empirical data and later focusing it more for case-study specification (Wijermans et al. 2014). Wijermans et al. model provides real world social dilemmas to somewhat abstract theoretical models, making the model useful to explain the dynamics of common pool resource management and adaptation over time (2014). These case-study agent-based models entwine the empirical component, the qualitative method, with agent-based modeling, the quantitative method, using a framework or representing the behavioral aspects of real biological and social situations. Future work should focus on enriching generalized models with context sensitive social dilemma factors, as these provide a more realistic and useful insight into the dynamics of natural and human-made resource systems (Wijermans 2014).

# Description of Proposed Research

In order to advance the decision-making in conservation beyond protected areas, our proposed research aims to study societal tools along with modeling species interactions across local ecologies to examine the proliferation of cooperation in Austin, TX. This study enhances the efficiency of biodiversity management by monitoring resource decision-making from groups who select for members that understand management impacts on a landscape. We believe when groups select for members that share a common characteristic, e.g., race, gender, ethnicity, sex, etc., groups can enhance cooperation across their local ecologies. We will be using data from Austin, TX to track cooperation efforts around a common resource over a two-year span.

*Software for Agent Based Modeling*:

In order to simulate the actions and interactions of individual and collective entities in Austin, TX with a view to assessing their effects on the resource system, we will be using AnyLogic Multimethod Simulation Software. AnyLogic Multimethod Simulation Software allows us track patterns across, agent synchronization, space (continuous, discrete or GIS-map), mobility and spatial animation, agent connections and communication, and dynamic creation and destruction of agents (AnyLogic Website 2014). This software allows us to insert data from Austin, TX and cultural characteristics of [insert people being studied] in order to better understand cooperative efforts of resource management.

*Field Study Data Gathering:*

We will travel to Austin, TX in order to collect data of group preferences in new member entrance along with data from current conservation practices. We will use a series of surveys and data collected previously from [insert citation] to create a large database of the [insert people being studied].

*Simulated Group Preferences*:

We will use group preferences for new member entrance in order to understand how cooperative groups form. Knowing how cooperative groups form is important because groups that select for members with similar characteristics have a higher chance of avoiding the free-rider problem, thus allowing more group members to maintain and contribute to a common pool resource. These characteristics (such as gender) will be modelled in AnyLogic Multimethod Simulation Software, in order to simulate the community of Austin, TX. By simulating group preferences in AnyLogic Multimethod Simulation Software, we can take a quantitative and qualitative understanding to resource management. As group preferences change in [insert people being studied], we will continue to track these in AnyLogic Multimethod Simulation Software over a longer period of time, along with other variables such as ecological dynamics.

*Simulated Ecology*:

We will use AnyLogic Multimethod Simulation Software to model the Austin, TX population with predator-prey dynamics and density-dependent migration to study how resource managers modify the ecosystem to achieve conservation goals. We will look at current conservation practices and create an idealized landscape in AnyLogic Multimethod Simulation Software. By examining simulated group preferences and conservation practices, we hope to see any relational aspects in maintaining high cooperative efforts.

*Relevancy:*

The goal of this study is to see advance the decision-making in conservation beyond protected areas. Currently, there isn’t a study that examines group member entrance and ecological dynamics in agent based modelling software. By using this software we can track changes over time. The ability to track these changes and preferences will allow agents in conservation practices to focus on where management effort should be emphasized.

## Proposed Timetable

|  |  |
| --- | --- |
| **Date** | **Event** |
| June 1, 2015 | Travel to Austin, TX |
| December 1, 2015 | Create preliminary agent based models |
| February 1, 2016 | Travel to Austin, TX |
| August 1, 2016 | Refine agent-based models |
| February 1, 2017 | Travel to Austin, TX |
| June 1, 2017 | Finalize agent-based models |

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Vallino, E. 2013. The tragedy of the park: an agent-based model of endogenous and exogenous institutions for forest management. *Ecology and Society* 19(1): 35.

Wijermans, N. and M. Schlüter. 2014. Agent-based case studies for understanding of social-ecological systems: cooperation on irrigation in Bali. *Advances in Intelligent Systems and Computing* 229: 295-305.

# Key Personnel

The key personnel from University of California, Davis will work together to ensure maximum efficiency. Personnel includes one principal investigator, two principal collaborators and four research assistants. The principal investigator manages all other collaborators, oversees model creation/refinement/finalization and travels to the Austin, TX. Each principal collaborator will choose one time to travel with the principal investigator to help with modeling, Both principal collaborators will travel to the Austin, TX the initial time. Each research assistant will implement the models with AnyLogic Multimethod Simulation Software and run simulations.

# Key Personnel Chart

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Degree** | **Organization** | **Role in Project** | **% of Time on Project** |
| Elias Rivera | Ph.D. | UC Davis | Principal Investigator | 75 |
| Hardy Jones | MBA | UC Davis | Principal Collaborator | 60 |
| Paul Smaldino | Ph.D. | UC Davis | Principal Collaborator | 60 |
| Richard McElreath | Ph.D. | UC Davis | Research Assistant | 50 |
| Jeffrery Schank | Ph.D. | UC Davis | Research Assistant | 40 |
| Mark Lubell | Ph.D. | UC Davis | Research Assistant | 30 |
| Max Dalmeyer | Ph.D. | UC Davis | Research Assistant | 20 |

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# Biographical Sketch

**Biographical Sketch: Elias Rivera**

Professor and Research Supervisor Professor of Anthropology

University of California, Davis Researcher of Anthropology

1 Shields Ave, Davis, CA 95616 UD Anthropology Lab Principal Investigator

Tel: (302) 875-5555

Email: xxxxxxxx@ucdavis.edu

Research Area of Expertise:

Economic Anthropology, Common Pool Resources Management

Education:

Ph.D., Anthropology, Arizona State University 1990

A.B., Anthropology, University of California, Davis 1984

Experience:

Assistant Professor, Stanford University 1991

Assistant Researcher, United Nations Environmental Program 1994

Professional Recognitions:

National Science Foundation Grant (C12456) 2000

Professional Affiliations:

American Anthropological Association 2004

Selected Publications:

Rivera, E. 2014. Co-op Housing: Conflict, Cooperation and Institutions for Collective-action. *Ecology and Society* 54(2):74-87.

# Biographical Sketch

**Biographical Sketch: Hardy Jones**

Professor and Research Supervisor Masters of Business Administration

University of California, Davis Researcher of Marketing

1 Shields Ave, Davis, CA 95616 UD Marketing Lab Principal Investigator

Tel: (302) 875-5555

Email: xxxxxxxx@ucdavis.edu

Research Area of Expertise:

Management and Finance

Education:

M.B.A., Management, University of California, Davis 2010

B.S., Marketing, California State University of Sacramento 2004

Experience:

Professor, University of California, Davis 2011-2014

Professor, California State University of Sacramento 2004-2011

Professional Affiliations:

American Marketing Association 2002-2014

Selected Publications:

Jones H. 2006. Management in the Small: How Small Ideas Make Big Changes for *Review of Business & Finance Studies* 3(2): 36-43

# Budget Justification

This study will total $604,000. The American Anthropological Association will contribute $405,500, requiring $207,000 to come from outside funding. The majority of the budget comes from the personnel involved in the research. The principal investigator has to dedicate the majority of their time to this study for two years, and also manage each individual in the group over the same time period. Each collaborator must also vest a large amount of time into modeling, travel and research, but without the need to manage all other persons. The research assistants primarily are concerned with modeling, but also need to interact with the other collaborators. AnyLogic Modelling Software was chosen as they offer partnerships with academic programs that lower costs and provide support. Hundreds of universities also use AnyLogic so the results should be more accessible to others looking to analyze or make further contributions. Each investigator and collaborator needs to travel to the Austin, TX multiple times, so travel expenses have been included. The costs calculated will provide for a comprehensive study.

# Research Budget

|  |  |  |  |
| --- | --- | --- | --- |
|  | **American Anthropological Association** | **Outside Funding** | **Total** |
| **Personnel** |  |  |  |
| Principal Investigator | 100,000 | 50,000 | 150,000 |
| Principal Collaborators (both) | 160,000 | 80,000 | 240,000 |
| Research Assistant 40% | 60,000 | 20,000 | 80,000 |
| Research Assistant 30% | 40,000 | 20,000 | 60,000 |
| Research Assistant 20% | 20,000 | 20,000 | 40,000 |
| **Equipment** |  |  |  |
| AnyLogic Software  (7 licenses) | 18,000 | 6,000 | 24,000 |
| **Travel** |  |  |  |
| Principal Investigator | 4,500 | 1,500 | 6,000 |
| Principal Collaborators (both) | 3,000 | 1,000 | 4,000 |
| **Total** | 405,500 | 198,500 | 604,000 |