Governing Complex Commons: Policy Networks and the Local Ecology of Games
Project Description

This proposal develops an "ecology of games" framework (Long 1957) to understand how political actors in complex policy systems interact with each other, and how these interactions affect the potential outcomes of collective-action dilemmas. Instead of the "evaluation" perspective used by policy studies that focus on single programs, the ecology of games framework grapples with the reality that most policy systems encompass multiple collective-action problems, multiple actors, and multiple governance institutions with overlapping jurisdictions. Understanding how policy actors cope with complex combinations of collective-action problems in the face of uncertainty is a central question of policy studies in political science, with direct implications for overall social welfare.

In this research, we define policy games as the institutional "venues" in which policy actors make collective decisions about the policies governing some range of issues. For example, city councils are games in which decisions about land-use and other issues are made, and fisheries management councils are games where actors make decisions about catch limits and gear restrictions. The utility of policy actors depends on the outcomes of these games; they have a "stake" in the collective decisions. The nature of the stakes in a given game may vary across policy actors; resource users may be directly affected by management decisions while politicians may be worried about electoral consequences and bureaucrats are concerned about budget support. Furthermore, uncertainty about outcomes varies across political actors and games, which affects each actor's choice of which games to participate in as well as whom to collaborate with in each game setting. The overall structure and performance of the policy networks that emerge from these decisions affects the potential for solving collective-action problems.

We study the ecology of games in the context of environmental policy, in particular water management in coastal watersheds or estuaries. Watersheds provide an excellent research setting because they encompass multiple collective-action problems (e.g., flood control, water supply, water quality, and biodiversity), many different actors have a stake in the resolution of these problems (e.g., landowners, environmental groups, utility companies), and multiple venues generally have jurisdiction over the issues (e.g., environmental planning, regulations, partnerships). Both the stakes and the uncertainties of actors vary considerably across venues and issues, providing the variance needed to test alternative explanations of actor choices and the consequences for collaboration.

Previous research in this area has focused on single institutions as coordinators of watershed issues, especially local "collaborative" partnerships (Lubell 2003; Weible 2006; Weber 2003; Koontz et al. 2004). This literature builds on Ostrom's (1990) work on common-pool resource management, but generally ignores the complexity arising when single partnerships are embedded in a more complex ecology of games. Hence, watersheds are not only a critical research site for studying our theoretical questions, but the field of study is ripe for innovation in research design and analysis. Lubell, Henry, McCoy's (2009a,b) analysis of how collaborative institutions reduce the amount of cooperation in other policy venues demonstrates the importance of considering multiple games.

Because macro-political arrangements strongly influence the stakes, uncertainties, and ultimately the structure of the local ecology of games in a watershed, the proposed research compares estuaries across countries. Many Western European democracies like the Netherlands have a long history of policy cooperation, with centralized institutional structures and peak associations of interest groups working closely with politicians and decision-makers (Kagan 1991; Klijn 2003). The United States has a more fragmented system with many institutions involved in different policy issues and loose coalitions of interest groups seeking to influence decisions at multiple entry and veto points. Developing countries like Argentina tend to have less matured and less stable institutional frameworks where institutions are being created as new problems emerge and conflict arises among interest groups (Berardo 2008). The different macro-political contexts allow us to analyze the ecology of games in political systems ranging from high to low in centralization and capacity to solve problems.

Our ultimate aim is to understand the factors most critical in affecting policy decisions and behaviors in complex institutional settings. The ecology of games model that we develop argues that actors choose venues and political partners in order to obtain three key political resources: information,

credibility, and political influence. The value of each resource depends on the relative *importance* of a given venue and the level of *uncertainty* confronting the actor in the venue. Information is most valued at lower levels of uncertainty and importance, while credibility and political influence become more valuable as uncertainty and the size of the stakes increases. The simple model we develop specifies testable hypotheses about the impact of centralization, capacity, uncertainty and importance on the choices of venues and partners and hence on the emergent structures and performance of the ecology of games.

We use this model as an initial tool to address the three specific research questions that we believe to be central to understanding patterns of cooperation and conflict in an ecology of games:

1. *How do issue characteristics and macro-political institutions shape actors' decisions about venue participation?* Actors participate in different policy venues in order to obtain the greatest individual gains from solving collective-action problems. We hypothesize the attributes of issues and macro-political institutions will influence the relative value of information, credibility, and influence and hence which venues actors select.
2. *How do issue characteristics and macro-political institutions affect the selection of partners within each venue?* The partner selection decisions by individuals determine the shape of the policy networks within each venue. We will test the hypothesis that different conditions of importance and uncertainty affect whether actors select partners that can provide better information (e.g., by having extensive contacts throughout the ecology), more credibility (by having overlapping friendships), or more influence (by their centrality and brokerage position in the ecology).
3. *How does the emergent pattern of participation and policy networks affect policy actors' level of collaborative activities and perceptions of the policy effectiveness*? One of the central hypotheses of our research is that behavior is strongly influenced by the position of the actor in the overall ecology of games. The overall pattern of participation in venues and the structure of policy networks both between and within venues will influence each actor's level of collaboration and perceptions of policy effectiveness.

Given the lack of a strong empirical research tradition in policy studies for exploring the ecology of games, our strategy is to test hypotheses that help clarify how actors jointly participate in policy venues, how they form links with others in each of the venues in which they decide to participate, and how their attitudes about collaboration and policy effectiveness are affected by the first two issues. Portions of the analysis will be descriptive, and some of these initial hypotheses are expected to be rejected as a means of determining the limits of the theoretical model and of suggesting modifications needed to provide an adequate basis for understanding the problems of governing complex commons. These challenges to empirical analysis are natural to a research topic and design that is innovative and attempting to tackle difficult questions.

This project further contributes to political science by applying recent advances in social network analysis (SNA) techniques to the study of governance and collective action in complex settings. Network methods are appropriate because decisions made in the ecology of games depend on the position of the actors and venues in relation to one another. In particular, we will estimate a variety of Exponential Random Graph Models (ERGMs) to analyze the behavior of political actors in the watersheds we study. ERGMs are particularly well-suited to account for the interdependency of observations that is inherent in an ecology of games and renders more common statistical approaches inappropriate for the analysis (Henry, Lubell, and McCoy 2008).

Empirical and Theoretical Approaches to Complex Policy Analysis

Long (1957) used the "ecology of games" metaphor to analyze the complexity of urban politics. He contended that actors participate in different but interdependent games through which a community is shaped, and that these games provide purpose for the actors, who fill roles and shape their strategies and tactics based on the games they play. Politics, according to Long (p.252), consists of "co-operation of particular social structures, each seeking particular goals and, in doing so, meshing with others". Long's basic intuition is applicable to myriad situations where the behavior of an actor can be explained only

through a comprehensive examination of the multiple settings where the actor participates. We build on Long's basic idea by linking to three other research traditions: 1) policy implementation in complex settings; 2) institutions and collective-action; and 3) policy network analysis.

The classic policy implementation literature beginning in the 1970s clearly emphasized complexity and cooperation in describing the "games" involved in getting policies to work. Bardach (1977; p.57) defines the implementation process as "(1): a process of assembling the elements required to produce a particular programmatic outcome, and (2) the playing out of a number of loosely inter-related games whereby these elements are withheld from or delivered to the program assembly process on particular terms." The use of game theory in political science has brought a more formal approach to these issues. Scharpf (1997) focuses on how to reduce the complexity of the "game constellation" to something that can be managed by boundedly rational actors. Tsebelis (1990; p.7) argues that when an actor is involved in a "network of games", a choice that seems suboptimal from the perspective of one game may be optimal when the decision-maker is considering how payoffs are linked across games. Bednar and Page (2007) illustrate how actors balance the performance and costs of strategic decision-making by the adopting similar strategies across multiple games, where optimization may require different strategies in each individual game. Similarly, we expect that behavior in any single policy game is best understood in the full context of the ecology of games.

The literature on institutions and collective-action emphasizes how institutional rules shape individual behavior. Most important for our purposes is Ostrom's Institutional Analysis and Development Framework (Ostrom 1990; 2005) and the environmental policy literature that has sprung from it. The IAD framework argues that collective-action outcomes are a function of the attributes of the problems, existing institutional arrangements, and community characteristics. The IAD framework is best known for identifying characteristics of long-enduring institutions that reduce the transaction costs of governing single common-pool resources (CPR). This theme is reflected in the extensive literature on local environmental partnerships (Leach, Pelkey, and Sabatier 2002; Lubell 2003; Lubell et al. 2002; Koontz et al 2004; Weber 2003), which suggest that local partnerships can solve ecosystem-scale collective action problems. The problem with the institutional literature on environmental governance is that it typically ignores the rich ecology of games in which most CPR institutions are nested. In many ways, our goal is to modify this institutional approach to understand not just individual institutions, but the complex adaptive system involving multiple formal institutions as well as dynamic informal relationships among political actors affected jointly by the formal institutions. The institutional literature is generally moving in this direction, with Ostrom's (2005) approach to institutional diversity and the work of Janssen (2005).

The study of informal relationships or political networks dates back at least to early community studies of the 1930s (Lynd and Lynd 1937), creating a rich tradition of increasing sophistication that has studied the structure of political networks in single communities (eg, Laumann and Pappi 1976), in multiple policy arenas within one country (Heinz et al. 1993) and in the same policy arena within multiple countries (Knoke et al. 1996). Although policy network analysis has been limited to more descriptive and metaphoric uses in the past (Dowding 1995, O'toole 1997), recent developments in statistical models for network analysis now provide the necessary tools for the tests we propose to undertake (Carrington, Scott and Wasserman 2005). The work of Snijders (2002) in developing the longitudinal *actor-oriented model*, its implementation in the SIENA software program (Snijders et al. 2008), and its extension to simultaneous estimation of behavioral and structural equations (Snijders, Steglich and Schweinberger 2007) provide a particularly important theoretical foundation for understanding not only political networks, but also for analyzing the complex structural relationships that emerge when actors jointly participate in policy venues.

Previous NSF-funded research by the PIs of this proposal has contributed to the ongoing resurgence of network analysis studies in political science, helping to integrate the new techniques into the analysis of governance and collective action problems. These published studies provide the substantive foundation for this study's emphasis on policy networks in an ecology of games. In particular, we have found that:

- The collaborative institution represented by EPA's National Estuary Program (NEP) increases the boundary spanning network of policy networks and interacts with stakeholder belief systems to influence collaboration attitudes and behaviors (Schneider et al. 2003; Lubell et al. 2002; Lubell 2003 —SBR 9729505 and 9815473; see full grant titles in reference section).
- Local political networks impact policy outputs and outcomes even when they play no formal role in the decision process: enforcement and compliance with the Clean Water Act is greater where local networks and partnerships are present (Scholz and Wang 2009—SES 0215426).
- Structural positions affect collaboration and policy perceptions—more central actors are more likely to engage in collaborative activities with their peers (Scholz, Berardo and Kile 2008—SES 0519459).
- Stakeholders in estuaries not selected for the NEP prefer popular partners that can coordinate choices with other stakeholders (Berardo and Scholz 2009—SES 0519459). This study demonstrates how the Snijders model (2002) can be applied to study partner selection in networks.
- Participation in collaborative partnerships increases collaborative activities, but so does collaboration in other venues—the greater the participation in other venues, the less the impact of participation in collaborative. (Lubell, Henry and McCoy 2009) This study first articulates the need for developing the ecology of games model.

The Actor-Oriented Model of the Ecology of Games

Figure 1 summarizes the primary relationships to be investigated in this proposal and how those relations affect the ability of the political system to resolve collective action dilemmas. Studies of governance are typically concerned with how the political system and the specific characteristics of the policy arena—portrayed in red boxes—affect the policy outputs and outcomes portrayed in the purple oval. Our research improves our understanding of this relationship by focusing on how the "black-box" of the local ecology of games acts as an intermediary in reshaping the political system response to policy issues.

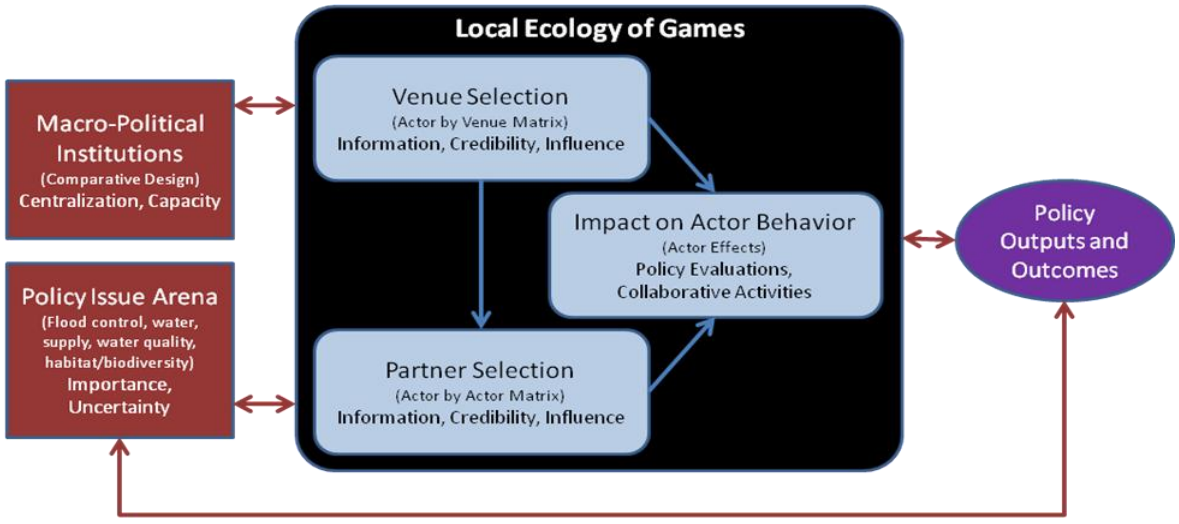

Figure 1: The Ecology of Games Model

The red double-headed arrows represent the long run relationships in which the local ecology of games evolves. While the nature of issues and macro-political institutions will change over time, the relatively short, three-year period of this proposal assumes that different attributes of issues and macro-political institutions are fixed exogenous variables influencing network structures. Alston, Eggertsson, and North (1996) note the importance of maintaining higher levels of the institutional context fixed in order to understand dynamics at lower levels.

The three blue boxes and associated arrows correspond to the three central research questions about venue selection, partner selection, and the impact of the resultant structures on behavior. This model assumes that individual actors select venues and partners to provide them with information,

credibility, and/or influence (noted in the blue boxes) that in turn will increase the expected value of the collective outcomes for the individual in the overall ecology of games, as discussed in greater detail below.

Policy Issue Factors Affecting Venue Selection and Partner Selection

One primary set of hypotheses explores how the *uncertainty* inherent in each issue area and the *importance* of an issue to a particular actor determine the relative value of information, credibility and political influence.

Uncertainty is a key feature of the ecology of games due to the overlapping jurisdictions of different policy games, interconnections between payoffs, and the dynamic nature of underlying causal processes (e.g.; biophysical processes in watersheds, climate change). Uncertainty increases the risk of reaching an undesirable outcome (i.e.; Pareto-inferior) because the behavior of other actors and expected payoffs are less predictable. When uncertainty is high, actors seek network structures that enhance credibility and the likelihood of cooperative behavior. When uncertainty is low, behavior and payoffs are more predictable and information about coordination activities is sufficient to reach a cooperative outcome (i.e.; Pareto-superior). Hence, as uncertainty diminishes, network structures that provide information about "focal" coordination points (Schelling 1978) becomes more valuable.

The logic of this argument is analogous to Williamson's (1985) idea that different types of institutional arrangements minimize the transaction costs of economic exchange, depending on the attributes of the goods being exchanged. In this case, we are arguing that different political resources minimize the transaction costs of cooperation, depending on the level of uncertainty. When uncertainty is low, the situation is more similar to a coordination game where actors need a focal point or bargain over multiple stable equilibria. As uncertainty increases, the risk of free-riding increases and thus more "closed" network structures will emerge.

There are at least three types of uncertainty that may affect the preferences for a given political resource. *Legal uncertainty* refers to how well stakeholders understand what policy venues have jurisdiction over a particular issue. Legal uncertainty is higher when there are many different venues operating in a particular ecology of games, which leads to the classic problem of fragmentation in public policy. *Scientific uncertainty* refers to how well policy actors understand the ecological, economic, or social forces affecting a particular problem. *Behavioral uncertainty* reflects how well policy actors are able to predict the behavior of the other actors in the game. Behavioral uncertainty is generally higher when there is a large and heterogeneous set of actors. We expect these dimensions to be positively correlated, but empirical testing will identify which is most important for influencing venue and partner selection. It is also possible to test whether the relevance of these dimensions vary for different types of actors (e.g.; Federal versus local government, or environmental versus conservative values).

Studying watershed governance provides an opportunity to study collective-action problems that vary in terms of uncertainty and importance. The research design will emphasize four primary collective-action problems: flood control, water supply, water quality, and habitat/biodiversity. We expect that for most actors, flood control has the lowest uncertainty followed by water supply and then water quality, while habitat/biodiversity has the highest uncertainty. These issues are arrayed along an underlying dimension of relative risk with flood control being most like a coordination problem where actors prefer efficient network structures and habitat/biodiversity being more like a cooperation problem where actors prefer network structures that provide credibility.

Actors presumably will care more about some issues than others; the *importance* of an issue reflects how much the policy outcomes will affect the actors' welfare. The more important an issue is to a particular actor, the more likely the actor is to seek network structures that increase political influence. This argument draws on bargaining models in neo-institutional economics (Knight, Libecap 1994), where actors will compete over the distribution of gains from solving collective-action problems. Actors are more likely to seek influence over collective outcomes where the gains are large. The argument also reflects Moe's (2005) criticism that cooperation models of public policy should pay more attention to the role of political power.

Macro-Political Factors Affecting Venue and Partner Selection

The four comparative study sites in this proposal allow us to analyze how the *centralization* and *capability* of a political system affect both the uncertainty and importance of a given policy issue, and thus the relative value of information, credibility, and influence.

Kagan (1991; see also Schmitter 1977) describes Western European countries like the Netherlands as having neo-corporatist, centralized systems where politicians and key interest groups make decisions in a small number of venues. Klijn (2003) describes the Netherlands as a "pillarized" system where political elites determine policy though consultation with peak associations of interest groups, and a largely passive citizenry. The decentralized pluralist system of the United States has many different games at the local level where many different interest groups and politicians interact to make policy decisions, and public participation is relatively high. With over 30 different types of water districts, California is a particularly good example of a decentralized system with associated problems of fragmentation. Florida is more centralized than California because of the existence of strong water management districts that integrate many functions. Developing countries like Argentina, on the other hand, have relative few formal institutions especially for managing environmental issues, and those institutions that do exist are rarely-well-defined or stable (Berardo 2008; Cavalli 2007, Foguelman and Brailovsky 1999).

These countries also have varying capacities to solve the collective-action problems associated with watershed management. The Netherlands has a long history of water management due to the amount of land below sea level, and consequently has powerful water management institutions that can do things like move existing settlements to improve flood management. The United States has solved many different water-related problems (e.g., point source pollution and clean drinking water), but the institutions are not as powerful as in the Netherlands. Argentina and other developing countries have weaker institutions, and as a result environmental problems are relatively severe.

Competing hypotheses are linked to macro-political institutions. More centralized countries like the Netherlands with well-defined rules may reduce legal and behavioral uncertainty and therefore increase the importance of network structures that enable efficient information transmission. On the other hand, centralization may lead more "closed" network structures that enhance credibility relative decentralized systems. Countries with greater capacity may decrease the importance of issues because the institutions have already solved many problems, and thus there are fewer remaining gains from cooperation that influential network structures would allow actors to capture. In countries with less capacity, actors will seek influential network structures because large gains from cooperation can still be achieved. Conversely, countries with greater capacity to implement policy may give actors a strong incentive to choose networks that help them influence real and not symbolic decisions. Where capacity is weak, no real changes will be made and thus influence may be less important. Our empirical analysis gives us the opportunity to sort out these competing arguments.

Modeling Partner and Venue Selection

Our theory draws on Snijders' actor-oriented ERGM model to analyze the relative importance of information, credibility, influence in the observed selection of partners and venues. In Snijders' model a randomly-selected actor, *ego*, evaluates her relationships at a randomly-determined point in time (t_1), based on the attributes and network position at that moment of known current and potential partners or venues. Ego then establishes a new relationship, terminates an old one, or maintains an existing relationship based on the expected utility of the resulting network (t_2), subject to error generated by the uncertainty in complex settings. Over time, these ongoing individual decisions shape the structure of the network. In network terminology, the results of partner selection relationships at a given time point in a given venue are represented by a square "association matrix" P with i rows and columns. An entry p_{ij} equals one when organization i reports a relationship with organization j, and 0 otherwise. We assume that relationships are directed in that i may rely on j for information, resources, and support even when j does not rely on i.

Snijders' (2001) ERGM-based model estimates the preferences of actors that best explain changes in partner selection between two or more periods of observations, as elaborated in the partner selection

context policy networks by Berardo and Scholz (2008). Specifically, the model estimates the log-odds of a link being changed using the following partner selection equation:

$$f^{net}(x_{ij}) = \sum_k \beta_k^{net} s_{ijk}^{net}(x_{ij}) + \beta_k a_{ik}(x_i) + \beta_k a_{jk}(x_j) + \beta_k [s_{ijk}^{net}(x_{ij}) * a_{ik}(x_i)] + \beta_k [s_{ijk}^{net}(x_{ij}) * a_{jk}(x_j)] + \beta_k d_{ijk}(x_{ij}) + \varepsilon^{net}$$

where the probability of change in the a link going from actor *i* to actor *j* (x_{ij}) is a function of specific structural characteristics *k* determined by the network structures affected by the link between *i* and *j* (s_{ijk}^{net}), specific attributes of ego *i* (a_{ik}) and alter *j* (a_{jk}), the interactions (terms in brackets) between the structural characteristics and individual characteristics, and specific attributes (e.g., similarity of beliefs) of the dyadic relationship between *i* and *j* (d_{ijk}).

Our ecology of games framework focuses on structural characteristics s_{ijk}^{net} of the network most associated with the political resources of information, credibility, and influence, as elaborated for partner selection in the next section and for venue selection in the following section. The inclusion of ego, alter, and dyadic variables in the ERGM model both control for and test existing theories of policy networks, such as whether actors increase the general size of their network in venues that are most important to them, whether actors primarily seek partners and venues with higher budget resources, or whether actors with similar policy beliefs are more likely to interact (Sabatier and Jenkins-Smith 1993). Most importantly for our research contribution, the coefficient of the interaction term will test whether the importance of different structural characteristics (representing different political resources) varies as a function of ego, alter, or dyadic attributes. For example, a significant positive interaction [$s_{ijk}^{net}(x_{ij}) * a_{ik}(x_i)$] between structures related to credibility and perceived legal uncertainty (an ego attribute) would support the hypothesis that greater legal uncertainty increases the role of credibility in partner selection. We can also test whether uncertainty affects partner selection primarily at the individual level, as in this example, or at the venue, issue area, or full ecology level, as discussed in the analytic methods section.

The same logic can be applied to venue selection, where actors evaluate their current pattern of participation in available venues, and decide to add or drop a venue or maintain their current set of venues in which they participate, dependent on which arrangement would increase utility based on the current network configuration. In network terminology, the observable results of venue selection at a given time can be represented by an "affiliation" or "two-mode" matrix *V* with *i* actor rows and *j* venue columns, with cell entries equal to 1 if an actor currently participates in a particular venue and zero otherwise. Once policy actors decide to participate in a venue, they engage—or not—in collaborative relationships with other actors who have also decided to participate in the same venue. ERGM models have recently been expanded to 2-mode networks (Wang et al. 2009), and this proposal includes funding to work with the developers of SIENA to include those models in their program.

Structures Providing Information, Credibility, and Influence for Partner Selection

Partner selection will be affected by the individual attributes that make a partner more attractive, as well as the position of the partner relative to the rest of the network. Different types of network structures are associated with the different political resources of information, credibility, and influence, and the relative value of each network structure depends on the level of uncertainty and risk involved with the collective-action problems at hand, plus the structure of the macro-political institutions in which the ecology of games is embedded.

Figure 2 illustrates five network positions for partners that offer different advantages to player *A*, who is evaluating potential partners. The circles represent the set of players in the policy arena being evaluated, and the solid arrows indicate the policy network in existence at the time of *A*'s choice. The illustration includes the smallest number of actors necessary to identify each structure, although many more actors are usually involved. The dotted arrow in each figure represents a new directed link that *A* evaluates; since all actors are assumed to share the same attributes in this illustration, the choice reveals a

preference for the network position of the selected alter. All of these network structures have a formal mathematical representation in the exponential random graph models that we will use for analysis. For example, reciprocity is calculated as $s_{i3} = \sum_j x_{ij} x_{ji}$; in the interest of brevity we do not show the formulas associated with every network structure, which are available online in the SIENA manual (http://stat.gamma.rug.nl/siena.html).

Figures 2A and 2B illustrate two network structures—*popular alters* and *open-two paths*— that enhance the availability of information to *A* by seeking well-connected alters with novel information. These choices are associated with efficient transmission of information because they shorten the network's average path length—the number of links or intermediaries required for information about one actor to reach another in the policy arena. For example, in Figure 2B actor B has the greatest number of existing links that depend on B for advice. By selecting B as the most popular alter, *A* can obtain information helpful in coordinating with *B, C*, and *D*.

Organizational theorists have advanced and empirically tested the idea that efficient structures of this type facilitate coordination because the central actors can provide information to other members of the group (Turk 1977, Hagen, Killinger, and Streeter 1997). In the classic example, Granovetter (1973) finds that the most valuable information in job searches came from alters who had fewer overlapping relationships (weak ties) rather than from alters with strong, overlapping links to ego. Popular policy actors with a broad range of contacts appear to play crucial roles in coordinating activities of suitable partners around particular "issues" relevant to the policy community (Heclo 1978, Bardach 1998). Carpenter et al. (2004) note that lobbyists seeking access to information might be expected to avoid alters with redundant links, and Carpenter et al. (1998) found evidence that lobbyists actively seek non-redundant relationships.

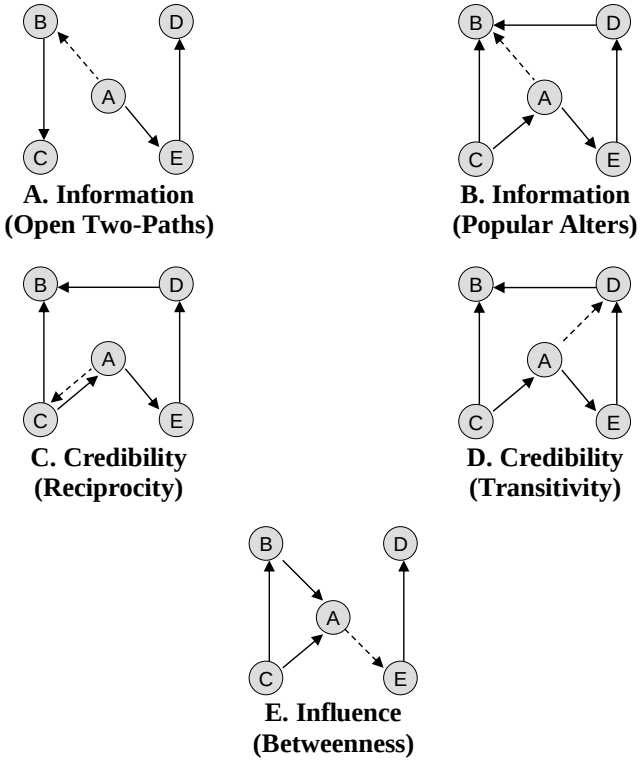

Figure 2. Network Structures for Coordination and Cooperation

While efficient transmission of information enables coordination on mutually beneficial outcomes, the risk of exploitation or "free riding" in cooperation problems where uncertainty is high

enhances the value of redundant, overlapping relationships that enable the evolution of credibility, reputation, and norms of reciprocity. Figures 2C and 2D illustrate the two primary structures associated with the search for credibility—*reciprocity* and *transitive triads*.

In Figure 2C, *A* could strengthen its relationship with *C* if it reciprocates the contact that *C* has already established. Putnam (1993) emphasized the importance of such reciprocal ties in the development of social capital. Mutual exchanges help developing stronger relationships that make punishment of defective behavior more likely and effective, which provides a mutual deterrence on which credible commitments can develop, increases the "shadow of the future" (Axelrod 1984), and increases behavioral predictability.

A similar argument can be extended to clusters of interconnected actors sharing redundant, overlapping links, which can best be represented by the *transitive triad* illustrated in Figure 2D (Carpenter et al 2004). A direct relationship from *A* to *D* would provide A with more information about the behavior of D relative to D's relationship with E. Redundant information about the reputation of a partner becomes increasingly important in cooperation problems where the risk of defection is large. Authors like Putnam (1995) and Coleman (1988) argue that denser, overlapping networks reduce monitoring and sanctioning costs involved in resolving collective action problems.

Figure 2E illustrates the structural holes hypothesis (Burt 1992, 2005) that individuals wishing to maximize their influence will seek relationships that bridge connections between groups that are otherwise not connected. *Betweeness centrality* is widely recognized as one of the main indicators of an actor's control over its environment and peers (Freeman 1987; Berardo 2009). By forming a new link to link to *E*, *A* to become the broker between the connected groups {*BC*} and {*DE*}. The central position allows *A* to control the flow of resources from actors B and C to actors D and A. In addition to betweeness centrality, actors seeking influence are likely to increase their activity by cultivating as many partners as possible, increasing ego's degree centrality. This is not illustrated in Figure 2 because it simply reflects ego's number of partners. As the importance of an issue increases, the relative value of degree and betweeness centrality will also increase.

Structures Providing Information, Credibility, Influence for Venue Selection

Multiple venues are likely to exist in each issue area, and organizational actors must choose in which game they will participate. The basic intuition is that actors will participate in venues that help them solve collective-action problems in ways that are more favorable to capturing the greatest gains from cooperation. In this model, actors select to participate in venues based on the characteristics of the venue and on the existing pattern of participation by other actors at the time of selection. Policy decisions depend crucially on which actors are jointly participating in different policy venues where authoritative, collective decisions are made about watershed issues.

Recently-developed analytic techniques for affiliation matrices allow us to develop and test hypotheses about the relationship between venues and actors in ways that parallel the partner selection model that we described above. Figure 3 presents the two-mode matrix structures that correspond to the one-mode structures related information, credibility, and influence. The circles represent actors, the squares represent venues, and a link in the diagram indicates that the actor participates in the venue. The links are not directed because only actors are assumed to choose venues. Venue characteristics of course influence participation by excluding or limiting participation, and these characteristics will be included in our models as control variables.

Figure 3A and 3B provide the information equivalents for two-mode networks. Like popular alters, a *popular venue* (3B) provides a centralized location in which multiple actors can coordinate their activities. The resultant pattern of participation will produce a few very popular venues in which coordination can take place, while most of the other venues will have a much more limited number of participants. However, centralized venues impose a risk because their decisions become increasingly influential in the ecology of games, and hence actors may seek to spread their efforts over more venues as uncertainty over outcomes increases.

As uncertainty increases, the *open venue structure* of Figure 3A provides an efficient coordination structure that is less subject to exploitation and still favors the rapid transmission of

information through the system. This structure reflects the preference of the actor in the upper right to select a second venue that is not shared in common with the other actor already participating in the upper left venue. Open venue structures are similar in function to the open two-path structure in the partner selection model, since they ensure a broader set of contacts than would be possible if the closed venue structure in Figure 3D were preferred. When the open venue structure is sought, actors and venues will be distributed with relatively few overlaps and few redundant connections through common participation in the same venues. Coordination will be distributed widely across the full range of venues.

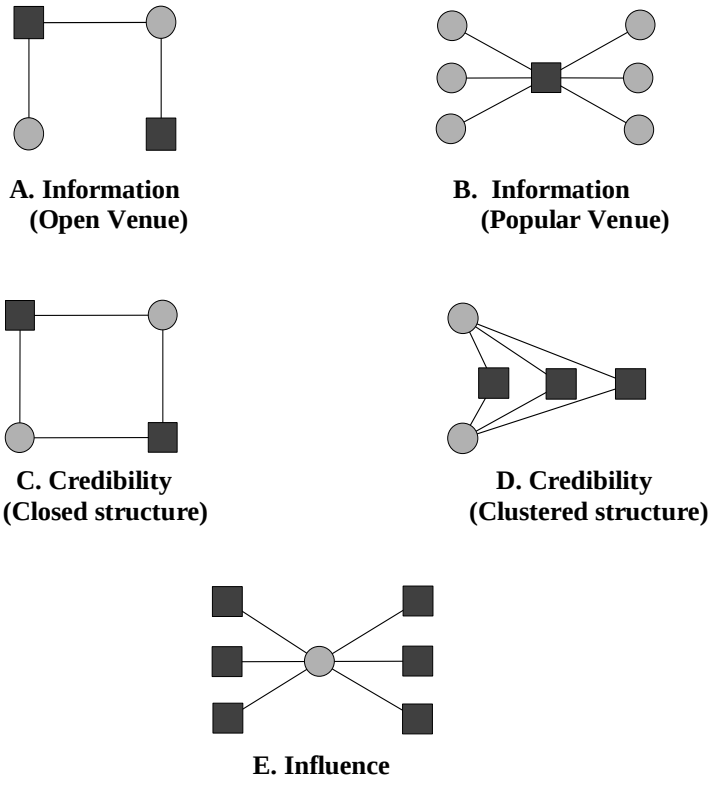

Figure 3. Two-mode structures of participation
(Squares = venues, Circles= actors, Connecting line represents decision by participant to participate)

When uncertainty increases and reputation becomes more important, the *closed venue structure* of Figure 3C provides common participation patterns that can enhance credibility. This structure reflects a preference for venues that are already connected through participation by a common set of partners, indicated by participation of the lower left actor in both other venues. The *clustered structure* in Figure 3D extends this basic idea to higher dimensions. Like the transitive triad in the one-mode matrix, the clustered structure ensures a common participation pattern in which the same actors will be involved in a common set of venues. When clustered structures are sought, clusters of actors and venues will emerge, with the number of clusters decreasing and the size of clusters increasing as the preference becomes stronger.

Finally, when *influence* becomes important, actors will seek to become central by participating in large numbers of venues. By participating in multiple arenas actors can attempt to steer the combined decisions in ways that favor. Of course, this strategy requires considerable resources, and would result in a very dense, highly interconnected ecology of games if all actors pursued this strategy. This strategy would presumably be more likely for particular categories of actors, such as those with greater concerns and those facing greater uncertainty.

In general, we expect the frequency of these two-mode structures will vary across the four issue areas of flood control, water supply, water quality, and habitat-biodiversity in a parallel fashion to the

partner selection network. That is, information structures will be emphasized for issues with lower levels of uncertainty (e.g.; flood control) and credibility structures for issues with more uncertainty (e.g.; habitat/biodiversity). Influence structures should increase in value as the issues become more important and the gains of cooperation are larger.

The Impact of Venue and Partner Selection on Individual Policy Evaluations and Collaborative Behavior

In addition to explaining venue and partner selection, our model also tests the impact of venue and partner selection on actor behavior relating to the collective-action problem. At this stage of theory development, it is appropriate to focus on policy outputs such as actors' subjective *policy evaluations* of effectiveness and engagement in *collaborative implementation* activities (Lubell, Henry, and McCoy 2009). Collaborative implementation measures the number of joint activities undertaken with other organizations as one indicator of the ability to resolve collective problems. Policy evaluations by actors provide a subjective measure of policy outputs that reflects perceived costs and benefits from existing and expected policies. Bardach (1998) argues the level of collaborative activities and associated attitudes is an indicator of the overall "interagency collaborative capacity" of a system.

The impact of network position on these measures provides another hypothesis for the ecology model: if rational actors seek specific relationships because of the assumed benefits of the political resources for them, then actors more embedded in such specific relationship should exhibit more positive attitudes towards policy effectiveness and more frequent collaborative activities as a result of having these relationships. For example, an actor with a greater number of reciprocal relationships or transitive triads should presumably obtain the benefits of greater credibility, which should translate into a higher probability of collaboration and higher policy evaluations in situations of greater uncertainty. This analysis is particularly appropriate for Snijder's actor-oriented longitudinal model, which is designed in part to simultaneously analyze the joint impacts of network structures on attitudes and collaborative behaviors as well as the impact of attitudes and behaviors on network structures (Scholz and Berardo 2007), as will be discussed further in the section on analytic methods.

The social capital perspective (Putnam 1995, Coleman 1990) argues that network relationships favoring credibility would enhance collaborative capacity, and hence actors that favor credibility structures should undertake more collaborative activities. On the other hand, actors in positions of greater influence have more power to shape joint activities to their own favor, which suggests that they would be more collaborative. Berardo and Scholz (2008) found that greater influence (betweeness centrality) best explained collaboration in the estuaries they studied, and concluded that partnership selection in these estuaries is driven by low-risk coordination concerns. The ecology of games model assumes that the importance and uncertainty of a particular issue will alter this relationships. We test the hypothesis that information structures enhance collaborative activities and attitudes when uncertainty is low, credibility structures are more important when uncertainty is high, and influence structures increase collaboration for important issues. In addition to analyzing how network structures influence collaborative behavior and attitudes, we will also control for other individual attitudes (e.g.; environmental versus conservative ideology) and attributes (e.g.; non-profit versus government organization) found by previous research to affect collaboration.

Research Design

We investigate these hypotheses for estuary water policy in four estuaries located in countries with different types of macro-political institutions: the South-Western Delta in the Netherlands; Tampa Bay, FL; San Francisco Bay/Delta, CA; and the Parana River delta in Argentina. As discussed earlier, these study sites vary in terms of the centralization and capacity of macro-political institutions. The comparative nature of the study provides a broader base to test more general hypotheses than is generally the case with the existing environmental policy literature, which very rarely looks across countries and thus inherently limits knowledge accumulation. The study regions do reflect the availability of data and the research team's existing background knowledge, since the PIs have conducted previous research in each of the selected estuaries. But the comparative study is more than a matter of convenience, since the research sites selected provide fertile ground to develop and test a stronger theory linking the macro-

political institutions to the policy networks that emerge and evolve. The international partnership provides broader impacts by linking together scientific communities and increasing representation of developing countries like Argentina in policy research.

The hydrological boundaries of each study estuary define the ecology of games under study, which as described earlier involve four main collective-action problems: flood-control, water quality and pollution control, and habitat conservation/ biological diversity. The research thus will collect data at three main levels of analysis—venue and partner selection matrices within each issue area (4 issues x 4 research sites=16 networks), partner selection networks within each venue (unknown number of networks at this time because there are multiple venues per issue area), and individual-level analysis of intensity of collaboration and policy evaluations, plus a variety of other individual variables.

Two critical data requirements for estimating our models shape our research design. First, the model assumes that actors consider relationships with all possible venues and partners, respectively, so relatively exhaustive surveys are required to identify as many potential venues and partners and observe as many relationships as possible. Second, at least two observations of these relationships are required. The first observation serves as a control for potential spurious relationships due to unmeasured exogenous factors. Estimates are based on the *changes* in the venue and partner selection matrices between the periods of observation, which should accurately reflect the selection preferences of those making the changes in the period between observations. Berardo and Scholz (2008) have shown that this longitudinal design is particularly important for policy network analysis in estuaries and similar dynamic policy arenas, since cross-sectional analyses produced misleading results in their study due to historical and exogenous factors that affect network structures even though they do not reflect the real preferences for partner selection. Since the ERGM estimation process requires information on venues, actors, and relationships at two points of time, our research design includes exhaustive surveys in each estuary in 2009 and again in 2011.

Pre-survey Data Collection: Determining Population Boundaries

Determining the boundaries of the policy actor population is challenging because there is no well-defined list of actors like those available for studies of Congressional committees (Heinz et al 1993) or individual legislators (Zhang et al. 2008, Fowler 2006). Thus we determine the boundaries of the study population by first identifying the major political actors and venues in each estuary and issue area through a combination of an online search (newspaper and official documents such as water management plans), and elite interviews. The *online search* will extend to the main local newspapers for the period ranging from January 2005 to December 2009. We will use a set of keywords that will help identify both venues and actors involved in them. In addition, we will conduct an exploration of websites of governmental agencies with stakes in water management processes in order to complement the previous step. Finally, we will combine the online search with elite interviews to help us both narrow the identification of key participants and obtain information about the venues that we will use as control variables in our analyses. This information will include:

- Jurisdiction of each venue over the particular issue areas we study (flood control, water supply, water quality, habitat/biodiversity)
- The main functional role of policy-making: general planning, regulatory rulemaking, permitting, and project funding, planning and implementation.
- Source of authority: Statutory origin, administrative, or court-ordered
- Level of public participation: None, notice-and-comment, collaborative process
- Voting rules: single decision-maker, majority, consensus

These attributes are partially based on Ostrom's (2005) classification of institutional rules and analysis of institutional diversity, and they could have an effect on how these venues perform and how actors that participate in them interact with each other.

Venue Survey

The primary goal of the venue survey is to provide a complete picture of the governance structure and participants in water policy within each of the four estuaries, which provides the basis for the partner

survey. The primary product will be the complete two-mode venue participation matrix, a secondary product will be a refined categorization of venues and actors by issue area, and a final product will be a preliminary listing of partner selection information from respondents that can be compared for accuracy with the final listing from the partner survey.

All stakeholders in the estuary identified in the pre-survey phase will be contacted by telephone for a brief survey, and any new stakeholder names identified in this survey will also be contacted. This snowball process will be continued until no new names are identified. The survey will ask respondents:

- Which of the four issue areas do you deal with?
- Which venues have you participated in during the last two years, and who is best spokesperson for the organization in that venue? The survey will present a "check-list" of the most central venues as derived from the archival work, plus allow for write-in responses.
- For each venue in which they participate, the respondent will answer Likert-scale questions about the level of conflict, collaboration, uncertainty, and importance of that venue for affecting the involved issues.

We believe that the added expense of this initial survey is necessary to improve on previous policy network studies: it identifies the full universe of network actors assumed in our analytic methods, it provides a complete list of participants to be used in the partner survey (reducing the censored responses obtained by asking respondents to list partners from memory), it provides information from the most appropriate contact for the organization (rather than relying on a single informant to know all aspects of the organization's activities), it ensures appropriate matching of partner names across different respondents, and it reduces the length of the partner survey by providing snowball data as well as information on the closest contacts that need not be repeated.

This short, informal survey will enhance interest and hence response rates in the partner selection survey. Before the survey we will pretest the potential interest in a public directory to listing participants by venue and issue area to be provided to all participants to provide an incentive to participate. If problems are encountered in this pretest or if we find that the venue survey reduces response rates in the partner survey in the first estuary (Tampa Bay) to be surveyed, we will consider collapsing the two surveys so each respondent would only be contacted once.

Partner Survey

The partner survey will provide all remaining information about partner selection, perceived issue and venue characteristics, and collaboration activities. Respondents indentified through the snowball process will first identify the most important venue in which they participate (as determined in the venue survey). Focusing on the most important venue reduces the length of the survey and allows measurement of the intra-venue partner network. The "hybrid name-generator" methodology developed by Henry, Lubell, and McCoy (2008) will measure partner relationships, where each respondent is asked to identify contacts from categorical prompts (e.g., federal government, state government, local government, etc):

- Who from the stakeholder list have they contacted regularly for any period in the past two years to discuss and coordinate policy matters related to the most important venue they participate in?
- Which stakeholders have the most influence over policy decisions in the most important venue?

We continue by asking the following venue-related questions for the independent capacity and risk variables, using a standard seven-point Likert scales:

- *Importance:* How important are the decisions made in this venue for your organization, compared with the other venues. How important relative to the other venues,
- *Legal Uncertainty:* How much agreement is there among affected stakeholders about the current policies in this venue?
- *Scientific Uncertainty:* How much agreement is there among affected stakeholders about the adequacy of existing scientific knowledge?

- *Behavioral Uncertainty:* In general, how much do you know the goals of other participants in the venue?

We next ask the following questions about policy evaluation:

- *Evaluation questions:* We use a standard battery of questions about subjective evaluations of the policy output of the venue, issue area, and estuary as a whole in terms of adequacy in addressing the central problems, satisfaction in terms of organizational goals, of the public interest.
- *Collaborative activities:* The scale developed for previous studies asking which of a list of collaborative activities the organization is involved in, ranging from sharing information and data to coordinating policy strategies, joining multi-party joint projects, etc.

As in prior studies (Berardo and Scholz 2008), whenever an organizational actor is represented by multiple respondents, we aggregate respondent reports to the organizational level by summing contact reports and averaging attribute reports for all respondents in the same organization.

Analytic Methods

The thorough documentation of actors and venues provides the basis for multiple methods of analysis, including clear visualizations of the ecology of games through sociogram analysis using Visone and UCINET programs. Since our hypothesis testing relies primarily on estimation of ERGM models, we will limit our discussion to this method. The ERGM method was first suggested over 20 years ago to account for the natural interdependence of network data in which one actor's choices of partners and venues are conditional on the choices made by others, an interdependence that rules out more conventional regression approaches to data analysis (Frank and Strauss 1986). The recent development of Markov Chain Monte Carlo estimation techniques provide the means for estimating increasingly sophisticated models (Carrington, Scott and Wasserman 2005), including the SIENA implementation of the longitudinal model by Snijders (2001, Snijders et al 2007) that controls for unmeasured influences on policy networks.

Each of our three major research questions can be analyzed by ERGM equations similar to the one introduced previously (p.7). To test the *venue selection hypotheses*, the venue survey data will be aggregated into 16 two-mode affiliation matrices (four estuaries by four issues). The models estimating the probability of observing the structures we described in Figure 3 can currently be estimated in P-NET, a freeware program (http://www.sna.unimelb.edu.au/pnet/pnet.html). The proposal includes some funding to continue working with SIENA developers to include longitudinal analysis of affiliation matrices in the program, contributing to the broader impact of the research. The hypotheses specify which network structures should have greater impacts, as indicated by larger significant coefficients, in issue areas with greater importance and uncertainty, and macro-political institutions with greater capacity or centralization.

To test the *partner selection hypotheses*, we make use of the greater range of techniques for analyzing one-mode networks that are already available in SIENA (Snijders et al. 2007). To provide the broadest tests of our hypotheses, for example, the raw venue-level data can be aggregated to the issue area level by pooling reported contacts across all venues identified with a given issue area and similarly to the estuary level by including all venues in the estuary. Berardo and Scholz (2009) illustrate how "structural zeroes" can indicate that certain relationships are excluded from the analysis in the pooled matrix in order to use the information from multiple sites. For example, to test the hypothesis that the uncertainty perceived in a given venue increases the preference for credibility and hence for transitive triads, the longitudinal SIENA model would include the pooled attribute matrix containing the perceived uncertainty score for all actors in t_1 and the pooled policy network matrices in t_1 and t_2. The hypothesis would be verified if the interaction term of transitive triads and the perceived uncertainty scale (measured in the partner survey) were positive and significant in a model with appropriate control variables.

Just as in regression analysis, pooling across multiple venues in ERGM models allows a test of whether the coefficients differ significantly in different venues. For example, dummy variables can categorize venues in terms of higher versus lower average levels of uncertainty reported by respondents. The magnitude and significance of the interaction coefficients between the dummy and the hypothesized

structural characteristics would then provide a test of the same hypotheses at the level of the venue. Similar tests could be done for other venue or issue characteristics, depending on the level of data aggregation. Estimating models at multiple scales (pooling data to estuary, issue, or venue) provides a means of investigating the relative importance of variation within and between these different scales of organization.

Finally, to test the *policy evaluations and collaborative behavior hypotheses*, we estimate SIENA models in which individual level collaboration and evaluations at t_2 are a function of network structure at t_1; the network structures are analogous to independent variables. For instance, the hypothesis that credibility structures increase collaborative activities is tested by analyzing whether actors that are part of transitive triads in t_1 are more likely to increase their level of collaboration in t_2. A positive significant coefficient for transitive triads indicates that participation in a transitive triad in observation 1 increases the level of collaboration between the two observations. Just as simultaneous estimation in general regression models can account for endogenous influences in both directions between the dependent variables, the simultaneous estimation of the behavioral and partner selection equations in SIENA models accounts for the ongoing simultaneous influences between partner selection and collaborative activity (Snijders, Steglich and Schweinberger 2007). Again, differences across countries and issue areas can be explored in the same way using the interaction of the independent variable with a dummy variable to distinguish the relevant country or issue relationships in the pooled matrix.

Research Tasks and Schedule

All PIs will share equally in the design and analysis of all research, and each PI will direct the implementation in the estuary research site they know best: Berardo will lead activities in the Parana Delta in Argentina, Lubell will lead in the SF Delta in California, and Scholz will be in charge of the research activities in the Tampa Bay area in Florida. Funding for each site is linked in this collaborative research proposal. No funding is requested for research activities in the Netherlands; since a separate team of researchers led by Erik Hans-Klijn and Jurian Edelenbos at Erasmus University in Rotterdam is seeking separate funding opportunities in Dutch governmental agencies (see letters of support and Klijn vitae in supplementary documents). Klijn and Edelenbos are two of the best-known European scholars working on issues of governance, complexity, and networks. All research planning will be coordinated with the Dutch regardless of the status of their funding search and we are requesting funding for annual meetings of the PIs, including one trip to the Netherlands. Support for international cooperation increases the broader impacts of this proposal.

In the first year, each PI will oversee a requested graduate assistant in the newspaper and online searches and elite interview follow-ups in each estuary; we expect this first stage to extend for a period of six months. The PIs will then meet to finalize the questionnaire, updating several existing questionnaires from previous projects based on information from the initial studies. The surveys will be contracted separately in each estuary, although we are pursuing the possibility of using a single contractor. The PIs have in the past worked with Schulman, Ronca and Bucuvalis from New York, Survey Research Center at Indiana University, and the Survey Research Center at San Diego State University. Surveys will be done in Spanish in Argentina, and partnerships will Argentine survey research companies will be explored. We anticipate completing the venue survey in one month, pausing one month between contacts, and completing the more elaborate partner survey in two months. Cross-sectional analyses of the primary data should commence before the end of the first year, and the newspaper, project, and cross-sectional analyses will be completed during the second year, when PI will meet in the Netherlands to assess progress and consider necessary changes for the third-year survey.

In the third year, the newspaper and project update will take considerably less time. We plan to begin the venue survey 24 months after the beginning of the first survey, following the same schedule for completion. The final longitudinal analysis will then commence. We expect to publish results in papers focusing on each set of relationships, first within each estuary and then across estuaries, as well as a book "Governing Complex Commons: Cooperation, Policy Networks, and Water Management Institutions in a Comparative Focus" that will integrate the findings and develop a more nuanced model of how stakeholders participate in the complex system of water management.