Group Size and Collective Action: Third-Party Monitoring in Common-Pool Resources

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ABSTRACT

This paper examines the hypothesis that group size is inversely related to successful collective action. A distinctive aspect of the paper is that it combines a non-cooperative game-theoretic approach with the analysis of primary data collected by the authors.

The game-theoretic model considers a group of people protecting a commonly owned resource from excessive exploitation. The monitoring of individual actions is a collective good. Our analysis focuses on third-party monitoring. We examine two significant aspects of all common-pool resources protected by third parties: one, the lumpiness of the monitoring technology and two, imperfect excludability from the common. We propose a general argument as to why costs of third-party monitoring will rise more than proportionately as group size increases. In combination with the lumpiness assumption, it yields us the following theoretical conclusion: medium sized groups are more likely than small or large groups to provide third-party monitoring.

The empirical analysis investigates the validity of this conclusion in a real life situation. We consider data on 28 forest councils from Kumaon in the Indian Himalaya. In consonance with the theoretical result, medium sized councils are the ones that successfully raise the funds necessary for third-party monitoring. Small and large councils fare badly. We present additional evidence to support our argument, and point toward future arenas of research on the relationship between monitoring and group size.

*Keywords:*Collective Action, Monitoring, Common-pool resources, Forests, Kumaon

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1 Introduction

This paper examines the relationship between group size and collective action in the following setting: There is a group of people who have to protect a common-pool resource from overexploitation.[1] They formulate rules of extraction. Enforcement of rules requires monitoring of individual actions. Monitoring is a collective good and incentives to provide it on an individual basis will typically be inadequate. Therefore, in most cases, monitoring is collectively provided. We ask the question, how does the size of the group affect the collective provision of third-party monitoring? A distinctive aspect of our answer is that it combines a non-cooperative game-theoretic approach with empirical work based on primary data collected by the authors.

In our theoretical model we investigate the influence of two variables: one, lumpiness in the technology of monitoring and two, imperfect excludability of the common-pool resource. Lumpiness arises naturally in third-party monitoring, as when a guard or a police official is hired by a group.[2] Monitoring below a minimum level – a certain duration for instance – does not affect extraction of resources in any significant way since individuals can simply circumvent monitoring. In the context of forest resources, lumpiness of monitoring arises because hiring a guard for a very short period of time means individual agents can avoid detection by extracting needed forest resources at other times. Monitoring for less than a certain duration thus provides negligible protection. Similarly in the distribution of water from an irrigation system, it is necessary to monitor how much water different irrigators are taking for the entire period that irrigation is needed for cultivation. If monitoring of water distribution occurs for a smaller duration, cultivators can take water whenever monitoring is not in force (Ostrom 1992a).

Whereas open-access resources are non-excludable, common-pool resources are characterized by differing degrees of excludability (Ciriacy-Wantrup and Bishop 1975, Ostrom 1990: 91). Variations in levels of excludability are best seen as depending on the nature of available technology and prevalent institutions. Thus, for example, the invention of barbed wire

[1] Familiar examples of common-pool resources include forests, pastures, fisheries, and irrigation works owned and managed by villagers.

[2] The analysis and conclusions of this paper pertain primarily to third-party monitoring. There may be very small groups where other monitoring arrangements exist. These can include mutual monitoring during joint performance of tasks, or by gossip and snooping. Our model and data do not cover such cases. Also see section 2 for further discussion on the scope of mutual monitoring.

permitted cheap fencing, and helped convert rangelands in the American West into an excludable resource.[3] For Japanese forests, McKean (1992: 258) shows that villagers used a variety of enforcement mechanisms to render them excludable to non-group members. Almost no resources are perfectly excludable since institutions governing their disposition are always subject to breakdown, and perfect excludability is prohibitively expensive to ensure. These considerations motivate our formulation that common-pool resources are imperfectly excludable.

Lumpiness of a collective good implies that there are either large setup costs or a minimum viable scale. Small groups, therefore, are likely to be at a relative disadvantage in providing such collective goods (proposition 1). Large groups do not suffer this disadvantage. But in comparison to small or medium size groups, they must expend greater effort and higher monitoring expenses to exclude non-contributors from the resource. With increases in group size, the aggregate level of resource that needs protection also increases as does the number of people from whom the resource needs protection. These two forces act in the same direction and imply that monitoring costs necessary to maintain a given level of excludability rise sharply as group size increases.

To understand the reasoning behind the sharp rise in the costs of monitoring, consider the example of common forest resources. Let there be two groups where one group is twice as large as the other but both have the same per capita level of forest. Suppose that the number of guards is 1 for the small group and 2 in the large group. If each guard in the large group monitors half the forest, the area to be monitored is the same for all guards. However, the guards in the large group have to protect against infringements by twice the number of people. To maintain an equivalent level of excludability the number of guards in the large group has to be more than doubled. Hence groups beyond a certain size will not find it worthwhile to have any monitoring (proposition 2). We conclude that for a given technology, medium size groups will be more successful than small and large groups in providing required levels of monitoring.

We examine the empirical validity of the above hypothesis by studying the efforts of 28 villages to protect their forests in Kumaon in the Indian Himalaya. The analysis is based on primary data collected between 1990 and 1993. Many villages have organized community-level forest councils that help residents use and protect forest resources in accordance with

[3] Hechter (1987: 38) discusses how new technology in the cable television industry determined excludability.

rules they craft. Since individuals have incentives to harvest products such as fodder and fuelwood in excess of what is permitted, the forest councils attempt to monitor and thereby restrict extraction of scarce forest products. In this setting monitoring is lumpy and the common-pool resource imperfectly excludable. In consonance with the two propositions above, we find medium-size villages to be more successful than small and large villages in providing adequate levels of monitoring. We also present evidence from other sources that supports our finding.

Our paper is a contribution to the study of collective action. Starting with Mancur Olson, group size has been seen as a crucial factor in understanding the likelihood of collective action. Olson hypothesized, "unless the number of individuals in a group is quite small, ..., rational, self-interested individuals will not act to achieve their common or group interests" (1965: p.2). Since then, a substantial literature in economics, political science, and sociology has examined his hypothesis.[4] There is little agreement on the subject however. For instance, Baland and Platteau (1999: 773) reiterate Olson, "(t)he smaller the group the stronger its ability to perform collectively." Tang's (1992) study of irrigators also suggests that smaller groups perform better than larger ones.

Equally often, however, scholars writing on the subject have remarked on the ambiguities in Olson's argument and suggested that the relationship between group size and collective action is not very straightforward. Wade's (1988) research on irrigation groups in South India suggests that small size is not necessary to facilitate successful collective action. Marwell and Oliver (1993) emphatically claim, "a significant body of empirical research . . . finds that the size of a group is positively related to its level of collective action" (p. 38). Isaac and Walker's (1988) experimental work on the voluntary provision of public goods also leads them to conclude that there is no pure group-size effect. The current state of knowledge is, perhaps, best summarized by Ostrom (1997) who says that the impact of group size on collective action is usually mediated by a variety of other variables. These variables include, among others, the production technology of the collective good, its degree of excludability, jointness of supply, and the level of heterogeneity in the group (Hardin 1982: 44-49).[5]

[4]For recent surveys see Baland and Platteau (1996), Marwell and Oliver (1993), Sandler (1992) and Ostrom (1990).

[5]In an early paper, Chamberlin (1974) argues that the relationship between group size and public good depends on the nature of the public good, i.e., whether it is a normal good or an inferior good.

The precise relationship of group size with these mediating variables, however, is difficult to decipher owing to two reasons: the paucity of systematic empirical work[6] and the lack of work that relates theoretical development to empirical research. Our paper is an attempt to bridge these gaps by analyzing systematically collected original data in light of a theoretical model that brings together existing insights in the literature on collective action and common property. Our model shows how the interaction of two important variables produces a non-monotonic relationship between group size and collective action. The data from our empirical research support the above relationship.

Our paper is especially closely related to the literature on common-pool resources. In a careful and comprehensive analysis, Ostrom (1990) derives some common features of successfully managed common-pool resources, ranging from forests in Switzerland and Japan to irrigation systems in Spain. One of the central features is the well-defined nature of appropriation rights that determine limits on access and use of common-pool resources. A second common feature she identifies is monitoring. Monitoring of the actions of different persons ensures that users as well as non-users respect appropriation rights.

Our paper makes two contributions to the literatures on common pool resources and collective action. One, it provides a model of imperfect excludability. Earlier work has emphasized the importance of appropriation rights, but to the best of our knowledge, our paper is the first to provide a model that explicitly incorporates the costs of defining and enforcing appropriation rights in the context of common-pool resources. Two, we develop an argument that links the nature of these costs to the size of the group.

We develop our arguments in the following five sections. A theoretical analysis is presented in section 2. In section 3, we provide a description of the forest councils and analyze the empirical data. We discuss the scope of the argument in section 4. The model we provide assumes the existence of an institution in a village. Section 5 discusses the question of how group size may relate to the formation of institutions, while section 6 concludes the paper.

[6]cf. Lam (1994). His analysis of irrigation systems in Nepal did not discover any significant relationship between performance and group size.

2 The Model

We consider a group of agents who own a common-pool resource. Easy access to the resource can lead to excessive exploitation because of the externalities related to individual resource extraction. This and other factors prompt members of the group to set up an organization, henceforth referred to as a council, to devise rules for resource use. This council creates mechanisms to monitor individual actions and ensure that the rules are followed. The council also determines the appropriate level of monitoring and decides on how to finance monitoring. It can choose from a menu of arrangements ranging from mutual monitoring by individual agents to third-party monitoring. Individual monitoring is particularly prone to the temptations of free riding. Mutual monitoring, therefore, is unlikely to be incentive compatible in any but the smallest communities.

The general problem of third-party *vs* mutual monitoring and enforcement has attracted considerable attention from several scholars. Singleton and Taylor (1992), for example, suggest that community enforcement of rules is more important than the presence of specialized monitoring and sanctioning positions. Ostrom (1992), in contrast, argues that specialist third-party monitoring and enforcement may be necessary to the maintenance of community itself. Baland and Platteau (1996: 345), in a wide ranging survey of common-pool resources, highlight the importance of specialized monitoring: "External sanction systems are often needed to make up for several deficiencies of decentralized publishment mechanisms, whether the latter are embodied in strategies of conditional co-operation or involve payoff transfers among agents. Since individual levels of monitoring are difficult to observe the problem of incentives is likely to persist even if we take into account the possibilities of repeated interaction. These considerations motivate a formulation in which there is a single monitoring arrangement: third-party monitoring. We shall assume that the main source of funds for monitoring are contributions from group members, not from outside agents such as a government.

This is the setting of the voluntary contribution game played between the council and the individual members of the group. Individuals choose whether to contribute, based on a comparison of the relative payoffs. The council has to determine a monitoring level that is optimal subject to the constraint that individual agents have an incentive to cover the corresponding cost. To focus on this optimization problem we take as given the formation of the council. Of particular interest to us is the relationship between the optimal level of sustainable monitoring and the size of the group.

We now set up the contribution game. Consider a group of homogeneous agents, n, where the typical agent is $i = 1, 2, \cdots, n$. This group has a resource, with the per capita level given by f. Thus the total resource level is given by $F = f \times n$. In what follows, we shall use the expressions nf and F, interchangeably. Let $m \in \mathcal{R}_+$ denote the level of monitoring. We denote by $C(m)$ the total cost of monitoring. We shall assume that $C(m)$ is a continuously differentiable and increasing function of m. Thus $c(m,n) = C(m)/n$ is the per capita cost when a group of size n monitors at a level m. In general, the returns from monitoring will depend on the size of resource, the number of people, the level of monitoring and the proportion of people who have to be monitored.

The council announces the per capita level of contribution. An individual has the choice of contributing $c(m, nf)$ or abstaining from contribution. The strategy of agent i is denoted by $s_i \in S_i$ where $S_i = \{0, 1\}$. We use 0 to denote non-contribution and 1 to denote contribution. In what follows, we simplify the decision problem and assume that agents who contribute abide by the rules devised by the council, while the agents who choose not to contribute try and extract resources illegally. This binary choice formulation is standard in the literature on collective action (Baland and Platteau 1996).[7]

Let $s = (s_1, \cdots, s_n)$ be the strategy profile of the n agents. Thus $s \in S$, where $S = \prod_{i=1}^{i=n} S_i$. Also let s_{-i} denote the strategies of all agents other than i. Let $q_i(s_{-i}) = \sum_{j \neq i} s_j/n$ represent the proportion of agents, other than i, who contribute. Similarly, let $q(s) = \sum_j s_j/n$ represent the proportion of agents who contribute in a strategy profile s. We shall suppress the dependence of q on s, to avoid excessive notation. Define $r(q, m, nf)$ as the per capita reward to individual i from contributing, given a strategy profile s. We suppose that $r(q, m, nf)$ is (weakly) increasing in q and m, and also increasing in f. The assumption that returns are increasing in the number of members who contribute implicitly reflects the idea that if more members violate the extraction

[7]It may be argued that a more general model would allow contributors to violate extraction rules in the same manner as non-contributors. However, if penalties for different types of agents are the same, then it can be checked easily that contributing and at the same time violating the extraction rules is clearly payoff dominated by the strategy of not-contributing and violating extraction rules. Contributing is worthwhile only if it is accompanied with non-violation of extraction rules. Therefore, our assumption of a binary strategic choice is not as restrictive as it might appear.

rules then, over time, the resource will be overused and will deteriorate. This incorporates, in a limited manner, a dynamic aspect of common-pool resource management in our model.

Moreover, it seems reasonable to suppose that for a fixed level of per capita resource there is a maximum level of return from monitoring. We shall assume that $r(q, m, nf) \leq r(f) < \infty$, for any q, m and n.

Given the strategies of other players, s_{-i}, the payoff to agent i from contribution is expressed as:

$$\Pi_i(s_i = 1, s_{-i}, m, n) = r(q, m, nf) - c(m, n) = r(q_i + 1/n, m, nf) - c(m, n) \tag{1}$$

If, on the other hand, an agent chooses not to contribute then she is not entitled to extract resources. This prohibition, however, does not imply that the individual cannot derive any benefits from the common-pool resource. The extent of benefits she derives depends on the degree of excludability of the resource. We shall assume that the common-pool resource is only imperfectly excludable: the council attempts to exclude villagers who have not paid their contributions and such villagers try, with varying degrees of success, to extract benefits to which they are not entitled.

Let $p(q_i, m, n)$ denote the probability of successful exclusion of agent i, in a group of size n, with monitoring level m and a proportion q_i of contributors. Given a monitoring level m and a profile of contribution strategies of other agents, s_{-i}, the payoff from non-contribution to agent i is given by

$$\Pi_i(s_i = 0, s_{-i}, m, n) = p(q_i, m, n).0 + [1 - p(q_i, m, n)].r(q_i, m, nf) \tag{2}$$

This payoff reflects the idea that if an agent is succesfully excluded, then her benefits are zero, while if she is not excluded then she can access the resource like other agents, without incurring any costs. If the good is perfectly excludable, then the probability of exclusion is 1 and $p(q_i, m, n) = 1$, for all values of q_i, m and n. The behavior of the $p(., ., .)$ function will play an important role in the analysis.

We note that if the common resource is non-excludable then $p(., ., .) = 0$, and the resource is effectively an open-access resource. In this case, no individual will willingly contribute to the council, and we will arrive at the classical tragedy of the commons outcome. Likewise, if the resource is perfectly excludable then a non-contributing individual gets a zero payoff and will willingly contribute as long as the returns from monitoring are positive. This leads us to a simple game of perfect monitoring. In such a setting, group size has no significant role to play. Thus imperfect excludability of the common-pool resource is a crucial element of our model, as it is in real life.

When deciding on whether to contribute, an individual compares the payoffs given in (1) and (2). In general, these payoffs depend on q, in other words, the choices of others. We are examining a simultaneous moves game, and so individuals have to decide without knowing the choices of others. This means that their calculations concerning payoffs depend on expectations about the choice of others. We would like to impose some restrictions on these expectations: that they be self-fulfilling and that they are consistent with the objectives of individual agents. The notion of Nash equilibrium captures these two considerations. Formally, a strategy profile $s = (s_1, s_2, ..., s_n)$ is said to be a Nash equilibrium if for every agent i,

$$\Pi_i(s_i, s_{-i}, m, n) \geq \Pi_i(s'_i, s_{-i}, n), \quad \forall\ s'_i \in S_i. \tag{3}$$

In our analysis we restrict attention to symmetric Nash equilibria of the contribution game. This restriction is a natural one in a situation where individuals are relatively homogeneous. We will focus on the equilibrium where everyone contributes. Thus we need to examine the incentives of individual agents to contribute given that every other agent does so, in other words, $q_i = (n-1)/n$.

¿From expressions (1) and (2), we can infer that an agent i will choose to contribute only if

$$r(1, m, nf) - c(m, n) \geq [1 - p(\frac{n-1}{n}, m, n)]r(\frac{n-1}{n}/n, m, nf) \tag{4}$$

Rearranging terms gives us the inequality,

$$r(1, m, nf) - r(\frac{n-1}{n}, m, nf) + p(\frac{n-1}{n}, m, n)r(\frac{n-1}{n}, m, nf) \geq c(m, n) \tag{5}$$

In what follows we shall assume, for simplicity, that $r(1, m, nf) = r((n-1)/n, m, nf)$.[8] The council will choose a level of monitoring that maximizes the returns to the group members, subject to the constraint that the costs of the monitoring are recovered via contributions from group members. The council's contrained optimization problem can be written as follows:

$$\max_{m} \quad r(1, m, nf) - c(m, n)$$

$$\text{s.t.} \quad p(\frac{n-1}{n}, m, n)r(1, m, nf) \geq c(m, n) \tag{6}$$

This completes the description of the contribution game.

The level of contribution is endogenously determined by the council. We examine optimal levels of monitoring that can be supported in a symmetric Nash equilibrium. We shall assume that for any n and f, the optimization problem of the council has a unique solution. Let $m(n, f)$ denote this unique optimal level of monitoring.

In this general setting, a wide range of monitoring patterns are possible. To be able to say anything worthwhile, we need to restrict the class of functions $c(.,)$, $r(.,.)$ and $p(.,.,.)$. We assume that the monitoring technology has to be above a certain level to yield positive returns. In the context of forest councils this "lumpiness" of monitoring arises as follows: if a guard is hired for very short periods of time, then individual agents can easily circumvent the monitoring by simply extracting needed forest resources at other times. More generally, we note that lumpiness in monitoring can arise due to a variety of factors, such as technological constraints and the fixed costs involved in hiring personnel. These considerations motivate our next assumption.

(A.1). *There is a minimum effective level of monitoring, m_l, where $m_l > 0$. Given any n and f, $r(1, m, nf) = 0$, for all $m \leq m_l$.*

Taken along with the upper bound on returns, $r(f)$, the lumpiness assumption has the following immediate implication.

Proposition 1: *Suppose that (A.1) holds and $C(m_l) > 0$. Given any f, there exists a minimum group size $n_l(f)$, such that for all $n \leq n_l(f)$, the optimal level of monitoring $m(n, f) = 0$.*

[8]This assumption is not critical for the results derived. Allowing for r to strictly increase at all levels of q has no effect on Proposition 1, but complicates the computations in Proposition 2 significantly. It can be shown that the result still holds, under a slightly stronger version of (A.2).

Define $n_l(f)$ to be such that $n_l(f).r(f) = C(m_l)$. Since $C(m_l) > 0$, and $r(f)$ is finite, this implies that $n_l(f) > 0$. The proof of the proposition is completed by noting that for groups of size $n \leq n_l(f)$, the maximum aggregate returns from monitoring, $n.r(f)$, are lower than the costs of the minimum effective level of monitoring, $C(m_l)$.

This proposition says that if group size is small then the council may not find it worthwhile to organize third-party monitoring of the common-pool resource.[9]

Now consider the nature of monitoring in larger groups. The constraint in the optimization problem in (6) suggests that, in general, the level of sustainable monitoring depends on the effectiveness of exclusion. The function $p(.,.,.)$ models the effectiveness of exclusion. We assume that the function is increasing in m. Further, for a group of size n, and a given level of monitoring, m, the probability of exclusion is increasing in the proportion of contributors, q_i. An increase in the proportion of contributors reduces the pool of agents to be monitored. Therefore, it is easier to exclude any individual agent from using the resource. We also note that for a given proportion of contributors, q_i, the number of agents to be monitored increases with group size. This suggests that for a fixed level of monitoring, the likelihood of detecting non-contributing rule-violators will decrease.

For a given level of monitoring, the per capita contribution, $c(m, n)$, is clearly declining with respect to the size of n. This makes individual contributions more likely. On the other hand, increases in group size require a far higher level of monitoring. There are two important reasons. The first relates to the spatial distribution of forests; the second to how subgroups form within larger groups. Consider the spatial aspects of monitoring in larger groups first. Take two groups of size k and $2k$ with the same per capita level of resources. Suppose that the number of guards is 1 in the small group and 2 in the large group. A plausible arrangement would be to have each guard monitor half the forest: an area equal to that under the single guard in the small group. However each guard in the large group has to protect his area against twice the number of people. This means that he will typically be less successful than the guard in the small group. To maintain the level of

[9] The above argument can be used to show that for group sizes $n < n_l(f)$, the socially optimal level of third-party monitoring is zero. In such groups, however, a positive level of mutual monitoring may be socially optimal since the level of lumpiness associated with individual monitoring is not significant. As mentioned above mutual monitoring is generally not incentive compatible even in small groups. Thus, for small groups there is a divergence between the socially optimal and the incentive feasible level of monitoring.

excludability existing in the small group with 1 guard, the number of guards in the large group has to be more than doubled.

A different logic applies if the size of the resource remains the same and the population doubles, halving the per capita availability. Then, each guard will have to protect a resource that is half the size in the small group, but against twice the number of potential rule-breakers. However, in this new scenario, each potential rule-breaker has a much greater incentive to break rules because of the decline by half in the availability of per capita benefits. Although the doubling of the guards provides a similar level of protection, each member of the group has a far greater incentive to extract higher levels of benefits. A higher than proportional increase in monitoring will therefore still be necessary to counter the higher incentives of each group member to break rules.

There is another important reason why increases in group size call for more than proportionate increases in monitoring effort. Harvesting of forest products typically takes place in teams of two to four individuals. In a small group, the number of teams that can potentially be formed is far smaller than those in larger groups. Consider again two groups of size k and $2k$, with 1 guard in the small and 2 guards in the large group. For the sake of simplicity assume that harvesting teams can have only two individuals. In the first group, the guard will have to monitor a total of $k^2 - k/2$ teams. But in the larger group, the number of potential teams that the two guards must monitor will be $(4k^2 - 2k)/2$, which is more than twice the number of 2-person teams in the smaller group. It is easy to see that if teams of 3 and 4 individuals are allowed, the number of teams to be monitored in larger groups will increase even faster.[10]

We sumarize these considerations in an assumption about the behaviour of the ratio of costs of monitoring and the probability of exclusion. Let $t(m,n) = c(m,n)/p((n-1)/n, m, n)$.

(A.2). *(i)* $t(m',n) > t(m,n)$, *for* $m' > m$; *(ii) There exists a* $\hat{n} > 0$, *such that* $t(m,n') > t(m,n)$, *for* $n' > n \geq \hat{n}$; *and* $lim_{n \to \infty}\, t(m,n) = \infty$, *for* $m \geq 0$.

We can now state the following result concerning monitoring in large groups.

[10] We thank Bala Venkatesh at McGill University for drawing this point to our attention.

Proposition 2: *Suppose (A.1)-(A.2) hold. Then for every f, there exists a critical number $n_u(f) < \infty$ such that positive levels of monitoring are not sustainable for group sizes $n \geq n_u(f)$.*

Proposition 2 establishes that a council in a large group will be constrained optimally to choose a level of monitoring equal to zero. This is due to a collapse in individual incentives to contribute in large groups. This fall in incentives, in turn, arises due to a sharp rise in costs of monitoring and fall in the degree of excludability as group size increases. The proof of this proposition is provided in Appendix 1.

We have thus shown that for every f, there exist critical numbers, $n_l(f)$ and $n_u(f)$ such that for group sizes $n \leq n_l(f)$ and $n \geq n_u(f)$, the optimal sustainable level of monitoring is zero. The two cut-off points arise out of the two assumptions we have made. Lumpiness gives rise to the lower bound, $n_l(f)$ and groups of size lower than this cannot provide third-party monitoring. On the other hand, the increasing difficulty of excluding errant group members in large groups gives rise to the upper bound, $n_u(f)$, and groups of size greater than this fail, owing to incentive conditions, to provide any third-party monitoring.

The assumptions (A.1) and (A.2) are clearly used in our results. This raises the question: how reasonable are these conditions? It can be shown that some standard functional forms satisfy these assumptions. Additionally, we have developed an example which shows that the assumption on lumpiness, (A.1) is not necessary for the results. This result holds so long as the returns are sufficiently small for low levels of monitoring.[11]

Our examination of the relationship between group size and collective action may be summarized in the following words:

> *Consider a setting in which a group of people have to protect a common-pool resource from overuse. Suppose that monitoring is lumpy and the resource is imperfectly excludable. Then, medium size groups are relatively more likely to sustain adequate levels of monitoring as compared to small and large groups. This suggests that success in collective action bears a non-monotonic, curvilinear relationship with group size.*

[11] Although the example is not presented here owing to limited space, the authors can be contacted directly for it.

3 The Forest Councils of Kumaon

In this section we examine the theoretical arguments of section 2 in the context of decentralized forest protection in the Kumaon Himalaya in India. The sample of local forest councils in our study was carefully chosen to ensure similar climatic, socio-economic, and policy conditions across the cases. At the same time, the selected cases differ from each other along local institutional factors, group size, and the period over which formal collective action has occurred in each.

Today, more than 3,000 village-level forest councils (Van Panchayats) formally control more than a quarter of the forests in Kumaon. They form one of the earliest instances worldwide of decentralized resource management through formal state-community partnerships. As governments in more than 50 countries begin now to experiment with resource management partnerships with village-level actors (FAO 1999),[12] the example of the forest councils assumes greater practical significance.

The birth of the forest councils can be traced back to the 1880s when the British colonial government attempted to transfer vast areas of the Himalayan forests in Kumaon to the newly created Forest Department.[13] By 1917, more than 60% of the total forests in the mountains were under the formal control of the Forest Department. The process greatly limited the customary subsistence rights of the villagers. Elaborate rules specified new restrictions on the lopping of tree fodder, regulated grazing, prohibited the extension of cultivation, strengthened the number of official forest guards, increased the labor extracted from the villagers, and banned the use of forest fires that villagers used to promote the growth of grass.

The restrictions spurred the villagers into widespread protests. Their incessant, often violent, demonstrations led the government to appoint a committee to look into local disaffection: the Kumaon Forest Grievances Committee. On the basis of the Committee's recommendations, the government enacted the Forest Council Rules of 1931. The relatively autonomous forest management councils in Kumaon have been formed over the past 60 years under the provisions of this set of rules, as modified in 1976.[14]

[12] There is a vast literature on this subject. See Baland and Platteau (1996) for a comprehensive review. For a review of specific studies, see Agrawal and Gibson (1999).

[13] This discussion of the history of the forest councils owes much to Agrawal and Yadama (1997), Shrivastava (1996), and Somanathan (1991).

[14] A detailed description of these rules is available from the authors upon request. We have omitted the description from this paper owing to space constraints.

The Forest Council Rules also lay down the broad parameters defining management practices of the forest councils. These rules delineate how new councils can be formed and existing ones dissolved, outline the duties of the councils in terms of demarcation of forests, auditing of accounts and relationship with government officials, empower the councils to manage the forests, and specify restrictions that prevent councils from destroying the forests by, for example, harvesting and selling all the trees. The existing rules grant the councils the power to harvest and allocate subsistence benefits from the forests. But they do not provide them significant formal rights to sanction rule-breakers. Enforcement of rules, therefore, depends to a great extent on the financial capacity of individual councils and the ability of their leaders to network with higher-level government officials.

Government officials also help village residents set up councils. Costs are relatively low. Rural inhabitants already exist as informal groups by virtue of their contiguous residence in specific settlements. Supervisory government officials encourage villagers to create new councils, further lowering the costs of formation. Those who initiate the formation of the council often emerge as its office holders, gaining some status in the village. For an average village resident, the costs of joining a council are also low since all s/he need do is sign a petition to that effect. Agreement by one-third of the villagers is sufficient to initiate a council. The existing rules, thus, lead to a situation where the benefits of creating a council are relatively high for the entrepreneurs initiating formation, and the costs for an average participant low. The formation of a council depends critically on whether forested areas exist within the boundaries of the village, or whether spare land can be set aside for the growth of new trees.

The head of the councils and the council members are elected posts. Elections for fixed terms of office are held every five years. All village residents can vote. Candidates receiving a simple majority of the votes gain office. However, in some councils elections are outstanding. In 1990, for example, about 20 percent of the councils had not held elections that had become due (TERI 1993: 45).

The specific rules for the daily management of forests are a result of local action. In most cases, forest councils are elected, they hold meetings, and attempt to allocate benefits from their forests among the villagers. All councils are formally empowered to craft and implement rules to govern the use of village forests. But it is primarily the successful ones that elect office holders, meet frequently, and discuss and create rules to govern the withdrawal of fodder, fuelwood and other products from the forests. They also select guards, raise funds, fine rule breakers, and arbiter disputes to settle the vast majority of management questions within the village.

Crafting institutions to manage and protect forests is critical because considerable pressures to harvest fodder and fuelwood resources exist in Kumaon.[15] In the past four decades, these pressures have grown with population, numbers of towns, and length of roads linking settlements (GOI, 1981). The success of councils in safeguarding village forests depends, therefore, on their ability to restrict the offtake of forest products through protection mechanisms. Such mechanisms come in three forms in Kumaon: mutual monitoring around the year by village households, rotational selection of households to guard the forest, or use of a specialist guard(s). Forest councils have experimented with the different alternatives but converged toward the option of hiring a guard.[16]

The forest councils must raise sufficient resources to pay a salary to the hired guard. The major sources are sale of forest products such as fodder, firewood, timber, and pine resin, contributions from village households in lieu of forest products they harvest, and fines villagers pay when their rule violations are detected. In terms of absolute amounts, commercial sales of timber and resin from council forests in Kumaon produce significant sums. But these revenues are controlled by the government, and make their way to the councils only with great difficulty. The more important sources for the daily functioning of the councils are the contributions from village households, sale of non-timber forest products such as fodder and firewood to forest users, and fines. Most councils charge each household the same amount for the products harvested from the council-managed forest. This reflects the relatively equal endowments of Kumaon villagers, and suggests an equitable distribution of forest products.[17] For the councils on whose activities we have data, contributions from households and revenues from sale of forest products provide between 60 and 70 percent of total revenues. Much of the money that the councils raise is used to pay a salary to the hired guard(s).

[15]Indeed, this is a circumstance that is common to rural areas in most developing countries (see Davis and Bernstam, 1991).

[16]In this paper we do not develop a formal argument to explain why a particular protection technology – hiring of guards in specialist positions – has emerged as a stable outcome. We simply note that most forest councils, after experimentation, have settled upon the hiring of guard(s) as the solution to problems of illegal harvesting.

[17]See Guha for a discussion of the minimal social and economic stratification in Kumaon. According to him, "hill society exhibits an absence of sharp class divisions" (1990: 16). See also Shrivastava (1996) and Gururani (1996) on additional historical and contemporary evidence.

Villagers follow rules made by the councils, but not always. Illegal harvests are more common during the four winter months – from mid-November to mid-March – when villagers have few alternative sources of fodder and fuelwood. To monitor successfully, the council must, therefore, hire a guard for at least these four months. Else, rule infractions occur frequently, and hiring a guard is meaningless. Typically, councils try to hire a guard for the entire year. The guards monitor forest use and report rule breakers to the council. The most common rule infractions are harvests beyond specified quantitative or time limits and non-payment of dues.

The forest councils can impose a wide range of penalties on those caught breaking rules. The pattern corresponds to what Ostrom (1990) calls graduated sanctions. Among the sanctions that are most widely used when users are caught breaking harvesting rules the first time are verbal chastisements and small cash fines lower than the wages for a day's work. If individuals break rules recurrently, a council can bring other mechanisms to bear. It often imposes higher levels of fines, demands public apologies from offenders, and imposes temporary restrictions on harvesting. The Council Rules of 1931 and 1976 limit the maximum fines that a council can impose. So when local residents break rules recurrently, a council is forced to appeal to higher-level government officials. Only then can recalcitrant repeat offenders be adequately sanctioned. Typically, most rule-breakers pay up their fines within a year of being found in violation of rules.

3.1 Description of Data

We selected 28 forest councils at random[18] and collected data on these councils between 1991 and 1993 using instruments developed at Indiana University. We gathered detailed information on a host of bio-physical, socio-cultural, demographic, institutional, and economic indicators to aid analysis. We also collected information from village-level records of meetings and income and expenditure accounts that the councils maintain. Successful councils keep detailed minutes of meetings. They are also able to mobilize far greater contributions from their members than the unsuccessful councils.

[18]Each of the three hill districts in Kumaon contains smaller administrative divisions called "development blocks". Nainital has five blocks that occupy a hilly terrain, Almora has eleven, and Pithoragarh has ten. The development blocks are sub-divided into 15 to 20 'patwari circles'. A patwari circle has about 15 villages on the average, of which approximately a fifth to a half have forest councils. The sample for this paper was selected as follows: five develolpment blocks were selected from the three districts using random number tables: one from Nainital and two each from Almora and Pithoragarh. Two patwari circles were then selected at random from each of the blocks. Within each patwari circle, we selected three to four forest councils, again at random. Some data were unusable.

The selected councils are distributed across the three districts (administrative subdivisions) of Kumaon: Nainital, Almora, and Pithoragarh. We are interested in explaining variations in the performance of these councils with regard to their ability to raise contributions from resident members, and other indicators of collective action (number of meetings and per capita contributions. We first present some basic information about the councils, especially with regard to their contextual variables and size in table 1

—– Table 1 here —–

All the councils, it is clear, are close to motorable roads: Few of them are as far away as three kilometers from a road, twenty are less than 2 kilometers from roads. Thus, they face similar pressures from market forces.[19] They range in elevation from 1,100 to 2,000 meters, lying squarely in the Middle Himalaya. The forests they possess belong to one of two major types: mixed broad-leaved trees, or needle-leaved stands of pine and cedar. In either case, the major products villagers harvest from the forest are fodder and fuelwood. Since all the councils are formed under the Forest Council Rules, they share the same overall administrative framework. Differences in the performance of the councils in terms of variations in numbers of meetings, or contributions raised from members, thus, cannot be explained by appealing to market pressures, ecological conditions, or administrative arrangements.

On the other hand, there are striking differences among the forest councils in their forest size and the number of households. It is worthwhile to point out that group size in Kumaon is not a function of resource size or its productivity. The forests available to a village result from government action at the beginning of the century. Further, even today, there is almost no inter-village migration in Kumaon. Such mobility is extremely costly owing to the difficulty in buying and selling land, and high costs of movement relative to possible gains from greater availability of forests.[20] Table 2 presents evidence on the relationship between forest size and number of households.

—– Table 2 here —–

Membership of councils varies between 10 and 175 households. Ten councils have 30 or fewer members. We refer to these councils as "small". Three councils have more than 100

[19] The relationship between distance from roads and market pressure is well established in the literature (Southgate, Sierra and Brown, 1991).

[20] We are thankful to one of our anonymous reviewers who asked us to clarify the point.

members and we classify these as "large". The rest of the councils belong to the "medium" category. The variation in size is important because the number of households a council governs has a significant impact on all the performance indicators of forest councils that we present in the next table.

Success in achieving collective action can be measured in different ways. In our work, we look at three variables – number of meetings, total protection budget, and per capita contributions (see table 3 below). Some other variables for measuring successful collective action could be the condition of forest, or the income that villagers earn from forest products. Although we have collected data on these variables, the measurement problems are acute. For the species that exist in the forests in Kumaon, there are no generally agreed methods for measuring biomass, and forest biodiversity is similarly difficult to estimate. Further, since a large proportion of benefits from forests are not exchanged in markets, their exchange value is also difficult to assess. As a result, we rely in our analysis on the three variables mentioned above. At least two of them, levels of monitoring and amounts spent on enforcement, have been found to be highly correlated with forest conditions (Agrawal and Yadama 1997, Gibson and Lehoucq 1999, Shrivastava 1996).[21]

—— Table 3 here ——

It is evident that the councils differ widely on each of these three performance-related variables. The table indicates that small councils typically hold four or less meetings a year. The same is true of the large councils. The fact that many of the small and large councils hold as many as four meetings a year may be explained by the requirement in the Revised Forest Council Rules of 1976 that all councils should meet regularly, preferably every quarter. We should infer, therefore, that fewer than four meetings indicates poor performance on this indicator. An examination of the minutes maintained by the small and large councils reveals that they meet infrequently, that their records are sketchy, that they have been relatively lax in creating management rules, and that they are rather ineffective in enforcing the few rules they have created.

The meeting records of the medium-size councils are a study in contrast. They contain lists of rule breakers, the dates when guards detected rule infractions, the nature of infractions and the fines imposed. The minutes maintained in the small and the large councils are

[21] Also see Wade (1988) for the importance of third-party monitoring and enforcement.

sparse, bereft of such details. If one looked simply at the records, one could conclude that few rules were ever broken in councils like Gunialekh, Kana, Ladamairoli, Malta, Pokhri, Raukjangal, or Tangnua. It would be a wrong conclusion. In conversations, office holders of nearly all councils talked about the problems faced in containing rule-breaking behavior. The absence of evidence indicates the absence of efforts to collect it, not the absence of wrong doing.

The figures in table 3 show that many councils are unable to collect much by way of contributions and some of them have very low protection budgets. On the other hand, members of some councils provide high levels of contributions. These performance indicators demonstrate the differential ability of councils to mount protection. Variations in the amounts spent on guards have an interesting relationship to group size.

3.2 Data Analysis

To tease out the relationship between group size and level of monitoring (as indicated by the number of meetings held by the councils, the size of the protection budget spent on paying guards, and per capita contributions toward monitoring and enforcement) we present three figures. Figure 1 examines distribution of meetings in relation to group size.[22] It is clear from the figure that the relationship between group size and the number of meetings is non-monotonic.

— Figure 1 about here —

Small and large forest councils are also different from the medium-size ones in the contributions made by households to monitor and protect the forest. We first consider total contributions (C). Councils typically pay a guard Rs. 200 a month for performing monitoring duties. Four months of protection during the winter months is the critical level of monitoring and protection to prevent excessive rule-breaking and illegal extraction. We notice from table 1 and 2 that only eight councils are able to raise more than this critical amount, and of these eight, seven are in the medium-size category. [23] Councils that

[22] In this and the subsequent figures we have averaged across different levels of per household forest resource. The computations we carried out after controlling for per household forest cover did not reveal any significant difference from reported patterns.

[23] Lohathal, which also raises more than Rs. 1,000 every year, is credited with having a very entrepreneurial council headman. But its forest is large and divided into several scattered plots. As a result, the council must hire several guards every year. Council members complained about the scarcity of funds and their limited ability to pay a guard.

are able to raise only small amounts to pay guards have sometimes tried other means to monitor rule infractions and impose sanctions, but mostly unsuccessfully. Figure 2 plots group size against aggregate contributions for the councils. We observe that small and large councils have considerably smaller budgets in comparison to the medium size councils.

— Figure 2 about here —

When we move to discussing per household contributions (c), the limited capacity of the councils in the large and the small villages becomes clear. In Figure 3, almost all the small and the large councils raise very low per household contributions from village residents. Contributions from members of medium-size councils are far higher.

— Figure 3 about here —

To explain these variations in per household contributions consider, first, the small groups. Recall that effective monitoring requires hiring a guard for at least four months and an expenditure of around Rs. 800. The villagers in small groups, it seems, recognize the fact that when they are a part of a small group the ability of the group to protect its forests is limited unless all of them contribute funds toward monitoring at a substantially higher level than their capacity. All groups must protect their forests from intra-group cheating as well as possible depredations by members of other villages.[24] Residents of small villages realize that the best strategy for them is not to contribute.

The story is somewhat different for the large villages. Resident members of these groups realize that given the larger size of their groups, monitoring is likely to become less effective, especially if the group hires only one guard. Further, as group size increases, the ability of the council to sanction an increasing number of rule breakers also diminishes. The incentives of village households not to pay, therefore, become high. In contrast, we find the highest levels of contributions in the medium-size groups. They are able to commit a sufficiently high surplus to the hiring of a guard, and to the organization of protection, for much of the year.

[24]The problem of inter-village rule infractions does not appear to be vicious in Kumaon, owing perhaps to a) the wide distribution of forests across villages, b) strong ties within villages in the face of threats from residents of other villages, and c) legal protection of forests in one village from residents of another village. But the problem of rule-infractions by outsiders can be significant if resources are easily accessible to them.

The above discussion and the three figures reveal a non-monotonic relationship between group size and provision of monitoring. We find that medium-size councils are the most succssful along all the three performance indicators we have used. This finding is consistent with the prediction of the theoretical model developed in the previous section.

4 Scope of the Argument

Olson's influential work argued for an inverse relationship between the likelihood of collective action and group size. However, subsequent research – whether theoretical, empirical, or experimental – indicates that there are many different ways group size can influence collective action, and that it may be impossible to study a 'pure' group size effect (Ledyard 1995). Scholarship on common property resources has found it especially difficult to address this issue because of the paucity of systematic analysis and carefully collected data. Whether the resource is fisheries, forests, pastures, or irrigation, little systematic work has focused on the relationship between group size, provision of monitoring, and success in achieving collective action by using data on a large number of cases. This paper considers two prominent analytical features of common-pool resources: a lumpy monitoring technology and difficult exclusion. We show, using a non-cooperative game-theoretic model and data on 28 cases, that where both conditions are present, it is likely that medium-size groups will be better equipped in comparison to large and small groups to provide collective goods such as third-party monitoring.

Intuition suggests that the effects of imperfect excludability and lumpiness, the two variables we specifically model, will occur in the directions we indicate. Imperfect excludability of a common good, as the group using it becomes large, will likely make it difficult to prevent high levels of use and less attractive to invest in protection. Small groups are often unable to generate sufficiently high levels of surplus needed to invest in a lumpy monitoring technology.

Independent evidence, although scattered across a variety of sources, bears out the intuition. In the context of irrigation, Tang's (1992) work suggests that out of 27 farmer-managed irrigation systems of varying size, the larger ones were more likely to have guards in fixed positions. In addition, the likelihood that sanctions would be imposed and group members would follow rules was far higher in systems with guards than those without (1994: 241). Guards were also present in larger, government-managed irrigation systems, but their incentives to monitor were insufficient (1994: 242). Schlager (1994), in her work on common-pool fishery resources, also highlights the importance of monitoring and enforcement of rules, especially where it is necessary to allocate the best fishing spots.

In related research, Taylor (1976: 93) argues that informal monitoring mechanisms – such as mutual monitoring – and controls to gain information on group members' behavior arise primarily in small and stable communities. His later research suggests that formal controls – such as third-party monitoring involving the hiring of specialized personnel – are necessary to prevent free riding even in relatively small tribal societies and intentional communities (Taylor 1982). Formal controls, however, are likely to be characterized by lumpiness. This intuition is also borne out by Wade's study of 31 villages with irrigation institutions in South India. He found that of the 17 cases where guards were hired, 15 had standing funds from which they were paid (1988: 136-39).[25]

Hechter's (1984, 1987: 75) work similarly, emphasizes the importance of monitoring and formal controls (1987: 75), and that such controls can be especially costly in large groups. Sanctions and exclusion, themselves public goods, become more difficult to implement as group size increases.[26] The importance of monitoring to maintain order in large groups, and simultaneously the difficulty of crafting mechanisms to monitor, is unexpectedly illustrated also in the work of Marwell and Oliver (1993). Their work disputes Olson's principal conclusion concerning the inverse relationship between group size and collective action. Instead they argue, using several examples, that large groups have more resources and more people who may constitute a critical mass for producing collective action in the form of riots or social movements. This paper's argument suggests that the maintenance of law and order through monitoring is also a form of collective action, and that it is precisely in large groups that effective monitoring to prevent social movements or riots would be more difficult.

Our paper, using the evidence from common property resources on difficulty of exclusion and lumpiness of third-party monitoring, constructs a theoretical argument that considers these two variables simultaneously. It also formalizes the intuitions that a) mutual monitoring is usually replaced by third-party monitoring as group size increases, and b)

[25] Although in Wade's study a lumpy monitoring technology is clearly dependent on the ability of villagers to generate a surplus, the location of villages along an irrigation channel significantly affects the surplus in a standing fund rather than group size alone.

[26] In a discussion on the evolution of reciprocity, Boyd and Richerson (1988: 340) suggest that in large groups reciprocity may not develop because of problems related to enforcement: its benefits flow to the entire group, but its costs are borne only by the enforcing individuals.

outlines causal mechanisms that may explain why monitoring costs increase more than proportionately in larger groups.

5 The Formation of Institutions

In our analysis above we implicitly conceptualize the management of a common-pool resource as a two-stage process. In the first stage, individuals set up a council, and in the second stage this council chooses a level of monitoring and determines individual contributions to cover the cost of protection, subject to the constraint that contributions be individually incentive compatible. The formal analysis, however, takes the existence of the institution as given and focuses on the second stage of the process. This approach was motivated by our empirical data where the costs of institution formation were low owing to the prior existence of villages and settlements as groups.

We expect that in other settings, e.g., the formation of a labor union, a peasant cooperative, or a lobbying group, the institution-formation process will not be so straightforward. We briefly discuss how the incentives to form institutions might relate to our results above. Individuals choose whether to participate in creating an institution after assessing the rewards and the costs of doing so. The benefits from participation are reflected in an increase in the likelihood of the formation of the institution. Once the institution is formed, it makes decisions concerning the provision of some collective good that can be sustained via individual contributions. Consequently, in deciding whether or not to participate in the process of institution formation, an individual takes into account both the marginal increase in the likelihood of institution formation (as a result of her efforts), and the payoffs from the subsequent activities of the institution.

Standard considerations suggest that the marginal impact of an individual's efforts will be inversely related to the size of the group engaged in institution formation. Now consider an environment where the collective good provided by the institution has significant set-up costs or displays lumpiness. In such a setting, small groups will be unable to provide the monitoring, due to technological constraints, and thus no institution will be worthwhile. On the other hand, large groups will be unable to generate a council due to free riding effects. Medium-sized groups will be best placed to provide collective action. These two forces are likely to generate a non-monotonic curvilinear relationship between group size and collective action.

This suggests that increasing difficulty in excluding non-contributing members may not be critical for the conclusion in section 3. However, if the problems of exclusion that we analyze in the paper are serious in large groups, then they will reinforce the usual free-riding effects and make collective action particularly difficult in large groups.

6 Conclusion

This paper has examined the hypothesis that group size is inversely related to successful collective action. A distinctive aspect of our paper is that it combines a non-cooperative game-theoretic approach with empirical work based on primary data collected by the authors.

The specific form of collective action we examine is the provision of third-party monitoring in the context of common-pool resources. The paper focuses on two significant features of common-pool resources: the lumpiness of third-party monitoring and imperfect excludability of the resource. We develop a general argument as to why costs of providing third party monitoring will rise more than proportionately as group size increases. Taken in combination with the lumpiness assumption, this yields us the following conclusion: medium sized groups are more likely than small or large groups to provide third-party monitoring. We believe that this conclusion is relevant for a large class of common-pool resources. In our analysis we have assumed that mutual monitoring is not preferred by individuals in itself, that monitoring technologies do not change as groups become larger, and that production technologies are not interlinked with monitoring. These assumptions need to be examined further. Where they are not met, the relationship between group size and successful monitoring will be different, but not necessarily that smaller groups will perform better. Our paper points to the complexity of this relationship, and shows that it can be a productive arena of theoretical and empirical research.

The empirical analysis investigates the theoretical argument in a real life situation. We consider data on 28 forest councils from Kumaon in India. We find that in consonance with the theoretical result, medium sized forest councils are the ones that successfully raise the resources necessary for third-party monitoring. Small and large forest councils fare badly. To examine our argument more generally, we also draw from existing work that indicates the difficulty small groups face in organizing resources needed to hire specialized monitors. Many of these authors suggest that mutual monitoring is the form typically chosen by small groups and that such monitoring quickly becomes difficult as group size increases. There is also some evidence to indicate the difficulty of effective monitoring as groups become large.

The group size effects we identify are especially relevant in the context of the recent turn toward decentralized resource management in most developing countries. With the failure of centralized solutions to resource management, many scholars and policy-makers alike have become disillusioned with state-centered efforts to manage resources. Concurrently, advocacy on behalf of local-level institutions and their role in management of resources has gained ground. Ostrom (1990) provides a measured defence of decentralized community involvement in resource use. More than 52 developing countries have currently initiated programs through which their governments enter into agreements with local actors to manage common-pool forest resources (FAO 1999: 35). Tremendous difficulties face these fledgling programs, among them the problem of enforcing local regulations. As a seventy-year old effort of this type, the example of the forest councils prefigures much of the recent shift in the field of resource use.

The findings discussed in this paper about group size and its relationship to provision of collective goods suggest that care must be exercised in decentralizing resource management. Small and large groups may not be able to protect resources effectively if they are unable to raise sufficient resources to undertake monitoring, or because of limits on effective monitoring that are related to problems of coordination. The precise numerical sizes connoted by small, medium, and large depends on the parameters of the two crucial variables we identify and analyze in sections 2 and 3: lumpiness and the degree of excludability of the collective good. They may also depend on other contextual and institutional variables related to production technologies and costs of living. We hint at these additional issues in our paper. But the formal analysis of these factors, and whether, under what conditions, and how they offset the effects of group size promises to be a fruitful source for future research.

7 References

Agrawal, A. and G. Yadama. 1997. "How do Local Institutions Mediate Market and Population Pressures on Resources: Forest Panchayats in Kumaon, India." *Development and Change*, 28(3): 435-65.

Agrawal, Arun and Clark Gibson. 1999. "Community and Conservation: Beyond Enchantment and Disenchantment", *World Development*, 27(4):

Baland, Jean-Marie and Jean-Philippe Platteau. 1996. *Halting Degradation of Natural Resources: Is There a Role for Rural Communities,* Oxford: Clarendon Press.

Baland, Jean-Marie and Jean-Philippe Platteau. 1999. "The Ambiguous impact of Inequality on Local Resource Management", *World Development*, 27(5): 773-88.

Boyd, Robert and Peter J. Richerson. 1988. "The Evolution of Reciprocity in Sizable Groups", *Journal of Theoretical Biology* 132: 337-56.

Chamberlin, J. 1974. "The Provision of Public Goods as a Function of Group Size", *American Political Science Review,* 68: 707-16.

Ciriacy-Wantrup, S. V. and R. C. Bishop. 1975. "'Common Property' as a Concept in Natural Resource Policy", *Natural Resources Journal* 15: 713-27.

Davis, K. and M. Bernstam. 1991. *Resources, Environment, and Population: Present Knowledge, Future Options.* New York: Oxford University Press.

FAO (Food and Agriculture Organization) 1999. Status and Progress in the Implementation of National Forest Programmes: Outcomes of an FAO Worldwide Survey", Mimeo, Rome: FAO.

Gibson, Clark, Fabrice Lehoucq, and John Williams. 1999. Does Tenure Matter to Resource Management: Property Rights and Forests in Guatemala", Mimeo, Department of Political Science, Indiana University, Bloomington.

GOI (Government of India) 1981. *General Population Tables: Uttar Pradesh.* New Delhi: Census of India.

Guha, Ramachandra. 1990. *The Unquiet Woods: Ecological Change and Peasant Resistance in the Himalaya.* Berkeley: University of California Press.

Gururani, Shubhra. 1996. "Fuel, Fodder, and Forests: Politics of Forest Use and Abuse in Uttarakhand Himalaya, India", Unpublished PhD Dissertation, Syracuse University, Syracuse.

Hardin, Russell. 1982. *Collective Action.* Baltimore: Johns Hopkins University Press.

Hechter, Michael. 1984. "When Actors Comply: Monitoring Costs and the Production of Social Order", *Acta Sociology*, 27: 161-83.

Hechter, Michael. (1987) *Principles of Group Solidarity.* Berkeley: University of California Press.

Isaac, M. and J. M. Walker. 1988. "Group-Size Effects in Public Goods Provision: The Voluntary Contributions Mechanism", *Quarterly Journal of Economics*, 103: 179-99.

Lam, W. F. 1994. *Governing Irrigation Systems in Nepal: Institutions, Infrastructure, and Collective Action.* Oakland, CA: Institute for Contemporary Studies Press.

Ledyard, J. O. 1995. "Public Goods: A Survey of Experimental Research", In *The Handbook of Experimental Economics* eds. J. H. Kagel and A. E. Roth, pp. 111-94. Princeton: Princeton University Press.

McKean, Margaret. 1992. "Success on the Commons: A Comparative Examination of Institutions for common property resource management", *Journal of Theoretical Politics*, 4(3): 247-81.

Marwell, Gerald and Pamela Oliver. 1993. *The Critical Mass in Collective Action: A Micro-Social Theory.* Cambridge: Cambridge University Press.

Olson, Mancur. 1965. *The Logic of Collective Action.* Cambridge, Mass.: Harvard University Press.

Ostrom, Elinor. 1990. *Governing the Commons.* Cambridge: Cambridge University Press.

Ostrom, Elinor. 1992. "Community and the Endogenous Solution of Commons Problems", *Journal of Theoretical Politics* 4(3): 343-51.

Ostrom, Elinor. 1992a. *Crafting Institutions for Self-Governing Irrigation Systems*, San Francisco: Institute for Contemporary Studies.

Ostrom, Elinor. 1997. "Self-Governance of Common-Pool Resouces", W97-2, Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington.

Sandler, Todd. 1993. *Collective Action: Theory and Applications.* Ann Arbor: The University of Michigan Press.

Schlager, Edella. 1994. "Fishers' Institutional Responses to Common-Pool Resource Dilemmas", *Rules, Games, and Common-Pool Resources*, Elinor Ostrom, Roy Gardner, and James Walker, pp.225-46. Ann Arbor: Michigan University Press.

Shrivastava, Aseem. 1996. "Property Rights, Deforestation, and Community Forest Management in the Himalayas: An Analysis of Forest Policy in British Kumaon, 1815-1949", Unpublished PhD Dissertation, University of Massachusetts, Amherst.

Singleton, Sara and Michael Taylor. 1992. "Common Property, Collective Action, and Community", *Journal of Theoretical Politics*, 4(3): 309-24.

Somanathan, E. 1991. "Deforestation, Property Rights, and Incentives in Central Himalaya", *Economic and Political Weekly*, 26: PE37-46

Southgate, D., R. Sierra, and L. Brown. 1991. "The Causes of Tropical Deforestation in Ecuador: A Statistical Analysis", *World Development* 19(9): 1145-51.

Tang, Shui Yan. 1992. *Institutions and Collective Action: Self Governance in Irrigation Systems.* San Francisco: ICS Press.

Tang, Shui Yan. 1994. "Institutions and Performance in Irrigation Systems", *Rules, Games, and Common-Pool Resources*, Elinor Ostrom, Roy Gardner, and James Walker, pp.225-46. Ann Arbor: Michigan University Press.

Taylor, Michael. 1976. *Anarchy and Cooperation.* London: Wiley.

Taylor, Michael. 1982. *Community, Anarchy, and Liberty.* Cambridge: Cambridge University Press.

TERI (Tata Energy Research Institute) 1993. "Alternatives for the Management of Biomass Resources on Common Lands in the Hill Districts of Uttar Pradesh, India." Report Submitted to the World Wildlife Fund. New Delhi: TERI.

Wade, Robert. 1988. *Village Republics: Economic Conditions for Collective Action in South India.* Cambridge: Cambridge University Press.

8 Appendix I: Proof of Proposition 2

Proof of Proposition 2: Fix some f. Recall that under the assumption, $r(1, m, nf) = r((n-1)/n, m, nf)$, the constraint in the optimization problem (6) may be written as follows.

$$r(1, m, nf) \geq c(m, n)/p((n-1)/n, m, n) \tag{7}$$

We next note that under (A.1), positive monitoring levels less than m_l are never optimal. Thus we can restrict attention to monitoring levels $m = 0$ and $m \geq m_l$. Under (A.2)((ii), there exists some $\bar{n}$ such that

$$t(m_l, \bar{n}) \geq r(f) + \epsilon, \quad \text{for some } \epsilon > 0. \tag{8}$$

Given (A.2)(i), the above inequality implies that for all $m \geq m_l$,

$$t(m, \bar{n}) \geq r(f) + \epsilon. \tag{9}$$

Since $r(1, m, nf) \leq r(f) < \infty$, it follows that for all $m \geq m_l$,

$$r(1, m, nf) \leq r(f) < r(f) + \epsilon. \tag{10}$$

¿From (A.2)(ii) we know that there exists an $\hat{n}$ such that $t(m, n)$ is increasing in n for all $n \geq \hat{n}$. We can without loss of generality take $\bar{n}$ to be larger than this $\hat{n}$. Hence, for all $n > \bar{n}$, and for all $m \geq m_l$, we have

$$r(1, m, nf) < r(f) + \epsilon \leq t(m, n) = c(m, n)/p((n-1)/n, m, n). \tag{11}$$

Thus no individual has an incentive to contribute toward monitoring in groups of size $n \geq \bar{n}$. Hence the council will be obliged to set a monitoring level of zero for these group sizes. Let $\bar{n} = n_u(f)$. Since f was arbitrary, this completes the proof. □