The Effect of Heterogeneity on Institutional Success and Conservation Outcomes

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June 7, 2004
First Draft

Paper prepared for the International Association for the Study of Common Property meetings, August 9-13, 2004.

Summary. - The gains to society from collective action can be very high. For this reason, understanding what factors facilitate or hinder trust and cooperation is a critical endeavor, and one that has engaged a great many researchers drawn from multiple fields in the natural and social sciences. In the research reported here, the specific aim is to understand how heterogeneities among individuals affect the success of community based resource management. The method for doing so is a meta-analysis of data from case studies that have been encoded in the "Common-pool Resource Database," compiled by researchers at the Workshop in Political Theory and Policy Analysis at Indiana University. The database contains records from approximately 150 different case studies across a variety of resource types, e.g. fisheries, forests, irrigation systems, pastures, etc. A central focus of the analysis is an investigation into the multiple ways field researchers have incorporated heterogeneity (material and cultural) into their findings and linked those concepts to collective action outcomes. Because researchers have tended to interpret 'success' in a variety of ways and to conflate multiple stages of collective action, it has thus far been difficult to come to firm conclusions about the impact of heterogeneity.

Key words -

1. INTRODUCTION

While we may celebrate diversity in all its forms, we also recognize that diversity can present challenges to cooperation. Yet, in a globalizing world, the scale of diversity is increasing all the while that increases in population and affluence make it increasingly important to work together for the common good. Management of common-pool resources (CPRs), such as fisheries, forests, and water resources, presents a special case in which such cooperation is needed. Although fewer and fewer communities operate entirely outside the provenance of state or national governance structures, there has been a trend of devolving rights, or formalizing traditional rights to manage CPRs, to local users who depend on those resources for their livelihoods. The fact that national governments and donor agencies have begun to accept this approach is largely the result of the extensive research that has been done to improve our understanding of the institutional structures that underpin successful self-governance. However, we still do not have a clear understanding of how diversity, or heterogeneity as it is more often termed in the literature, impacts communities' abilities to self-govern their use of CPRs. In recent years, controversy has emerged as to whether heterogeneity hinders or facilitates conservation of resources, and whether those impacts are equitable.

In discussing diversity, more commonly referred to as heterogeneity or asymmetry in the technical literature, most authors construct two main classes of differences; those that reflect differing economic endowments among individuals, and those that reflect different social or cultural values (Baland and Platteau 1995, Bardhan and Dayton-Johnson 2002). In the first case, we may have differences in capital, in access to credit, in resource holdings, exit options (differences in outside earning opportunities), discount rates, etc. The second case would include differences in cultural view of the resource, levels of trust, or social norms about cooperation, that themselves are generated by ethnic differences, class differences, gender differences etc. Each of these economic and sociocultural factors may affect how desirable collective action is to a particular resource user. A third class is also occasionally considered which might broadly be considered to be ecological or locational heterogeneities that affect access to the resource or withdrawal capabilities, for example, irrigators at the tail end of a system often experience reduced flows compared to those at the head end.

2. CONCEPTUAL APPROACHES TO THE PROBLEM OF HETEROGENEITY

As a caricature, it might be argued that two broad perspectives on the role of heterogeneity dominate the literature: that of Elinor Ostrom (1990) and Mancur Olson (1965). In her groundbreaking book, Governing the Commons, Ostrom developed a set of principles that characterize successful instances of self-governance of common-pool resources. While this section of her book continues to receive the greatest share of attention, in later pages she also enumerated a list of six characteristics that she suspected enabled groups to create new institutions for solving collective action problems and that in part reflected the broad understanding in CPR research at the time (p. 211). Several of these characteristics emphasize the benefits of homogeneity. In order of importance, particular aspects that were emphasized are for resource users to share a belief that management change is both necessary and in their own interest (#1), and to have a similar view of how such change might affect them (#2). These conditions would presumably reduce the possibility of the sort of distributional fights that were so cogently raised by Johnson and Libecap in the context of shrimp fisheries (1982). Ostrom also argued that users should be similar in having low discount rates (#3). That is, they should value the future use of the resource. Finally, users should have some initial social capital based on relationships of trust and reciprocity (#5). Many other authors have taken this argument to mean that heterogeneity must hinder collective action, although Ostrom herself does *not* make this same generalization. In fact, in recent work she and George Varughese (Varughese and Ostrom 2000) argue for a much more complex view of the role of heterogeneity on the basis of their empirical findings regarding forest management practices in Nepal.

Mancur Olson provides an alternative perspective in his book, "The Logic of Collective Action" (1965). Olson was dubious of the prospects of collective action in general, however, he did suggest that 'privileged' individual(s) might be willing to bear the costs of providing a collective good in return for a greater share of the returns. Having done so, others may then be able to free-ride and experience the benefits of the good. In his words, there is room for the "exploitation of the great by the small" (p. 29). Note that a similar logic is also applied in the field of international relations with the provision that there may be political as well as economic incentives for individual actors to organize collective action (Snidel 1995), and most recently in the context of adaptive resource management. However, the question of whether 'Olson effects' occur has been repeatedly cropping up in the context of common-pool resource management in last 10 to

15 years, but without resolution (e.g. Baland and Platteau 1997, 1999, Bardhan and Dayton-Johnson 2002, Dayton-Johnson and Bardhan 1999, Ruttan 1998, Ruttan and Borgerhoff Mulder 1999, Schlager 1990, Varughese and Ostrom 2001).

Baland and Platteau evaluate the Olsonian argument in some detail (1999). In a game theoretic treatment of their more formal models, they explore how the Nash equilibrium varies with increasing economic inequality. In contrast to Olson, they argue that heterogeneity has an ambiguous impact on the provisioning of collective goods. Their gist of their reasoning is that as the 'large' parties' interest in preserving a resource grows, the 'small' parties' interest declines. Clearly an underlying assumption must be that the rewards from collective action constitute a fixed sum. This idea that the interests of the some individuals may diminish as the interests of others' grows has also been theoretically explored by Bardhan et al. (2000 in Bardhan and Dayton-Johnson (2002)), and by Ruttan and Borgerhoff Mulder (1999) in a game theoretic context of pastoralist grazing decisions.

Of course, Olson was primarily focused on the provision of public goods and it is a characteristic of public goods that they can be provisioned by a few, permitting the many to free-ride. In the CPR case, the provision of institutions to manage the resource may constitute a public good, however, individual compliance with regulations also yields a collective good in the form of sustained resources. Thus, in this case the actions of the 'small' are usually thought to matter. However, Baland and Platteau (1999) make the important point that exploitation technology matters greatly. For some types of resources, that are exploited by some kinds of technologies, an economically efficient or conservation oriented outcome may result even if only a portion of individuals comply with regulations, or, behave in a conservation oriented manner. That is, taking actions that have short-term costs and long-term benefits (Hames 1987). The example Baland and Platteau use is if a significant proportion of the nets in a fishery are owned by a large fisher, it may pay that large fisher to use large rather than small meshed nets even if small fishers continue to use small meshed nets. However for other resource/technology combinations full participation is required for successful outcomes; their example being restraint from using dynamite fishing techniques.

A conclusion that can be drawn is that, in some subset of cases, it may not be necessary to solve the collective action problem in order to provide collective goods. In other words, the problem at hand is not how to get all individuals to cooperate but rather is how to provision the collective good, how to provide institutions that encourage sustainable use of a common-pool resource. When the resource extraction technology is such that initial contributions of (or restraints on) effort provide large returns in terms of conservation outcomes, and a large portion of those benefits can be captured by the main contributor, then ‘large’ users may contribute to the collective good unilaterally, and in fact, participation by all may not be required for a good outcome. For this reason, it is problematic that success of community management is so often evaluated in terms of levels of participation rather than final conservation outcome. Of course, there are very practical reasons for doing so, not least of which is that users themselves have difficulty assessing the impact of management strategies on abundance of resources, but also environmental conditions may have a strong impact on resource level.

The kind of situation described above is an example of a non-linear production function. That is, marginal returns vary with amount of effort invested in providing the collective good. We can also imagine there are threshold effects, or non-convexities in the language of economists. In any case, the impacts of non-linear production functions on levels of collective action has been explored in much more detail by Marwell and Oliver (1993) (and by Heckathorn 1993). In their book on the role of the critical mass in collective action, Marwell and Oliver note that an implicit assumption underlying Olson's conclusions is that the production function is linear. In other words, each additional unit of effort (or harvesting restraint) produces the same amount of collective good, e.g. the marginal returns are constant. Thus, actors either find that the per capita marginal return is sufficient for them to contribute to the collective good regardless of what others do, or they do not. If they do not, if non-contributing is the Nash equilibrium, they may still find themselves in a social dilemma that is worth solving. Thus, individuals in homogeneous groups either all contribute to collective action, or are all in a social dilemma where collective action will only result given a particular set of conditions in which actors can assure each other of their intentions. In contrast, in heterogeneous groups, some individuals will find it in their own self-interest to contribute while others never do; the result being Olson's scenario of privileged individuals supporting the public good. Yet, as Marwell and Oliver note, real world production functions are most likely sigmoidal; early increases in effort produce increasing marginal returns and later additions to effort produce declining returns.

The significance of non-linear production functions is that per capita returns vary with how much effort, or restraint, is already being applied. Let us separately consider the two parts of a sigmoidal production function, the accelerating and decelerating portions (Figure 1). Thus, in a case where returns are accelerating and actors are heterogeneous, initially only one or a few actors may find that the benefits of independently contributing to the collective good outweigh the costs. However, because their contributions increase the marginal returns of subsequent units of effort, others may then find it in their direct self-interest to contribute to the collective good as well. Thus accelerating returns, in combination with heterogeneity, may lead to an explosive increase in voluntary participation. More and more individuals join, not because they have the assurance that others will cooperate and thus are solving a social dilemma, but simply because it is in their self-interest to do so. However, there must be an individual, or critical mass, for which it is worthwhile to make early contributions to initiate the process.

The case of a decelerating production function is the inverse. Here, early contributions to the collective good yield large increases in marginal returns, but marginal returns decline with later contributions. The effect of this dynamic is that collective action may easily be initiated but taper off without all individuals joining in the collective effort. However, as was discussed earlier, it may be the case that collective action by a significant fraction of the population is sufficient to conserve the resource.

It must be emphasized that an additional, key parameter in Marwell and Oliver's models is the level at which individuals 'value' the resource. For our purposes we may think of such a value threshold as being a function of the time-discounted, benefit to cost ratio. Thus we might imagine that in the accelerating case, there is some threshold above which early contributors must value the resource in order to wish to contribute unilaterally. Individuals whose net gains from the resource are below the threshold may still 'value' the resource, but not enough to contribute unilaterally. In such case, the classic collective action problem is the result.

In practice, it may be difficult to predict who might 'value' a resource most, wealthy or poor. Although economically disadvantaged individuals may value the resource because they are dependent on it for subsistence and/or income, they may also have such a short time horizon that contributions to collective effort, or harvesting restraint, are not viable options. On the other hand, while the wealthy may be able to afford longer time horizons and thus be able to afford the short term costs associated with conservation, they may also have access to other means of earning an income, or to substitutes for the resource in which case they may not place a high value on the resource. Another way of thinking about this is that the wealthy may have less to gain from the economies of scale that common property represents (Quiggen 1993). For this reason, in analyzing the effect of wealth on collective action it is important to consider whether the wealthy 'value' the resource. Do increasing contributions to the collective good yield benefits that they can capture? If not, there is no reason to expect that economic heterogeneity would lead to better provisioning of the collective good. As a further caveat, it is important to note that efforts to conserve the resource by the wealthy may yield beneficial conservation outcomes without necessarily being equitable. In the worst case scenario, we have rich users who wish to conserve the resource by limiting exploitation by poor individuals, individuals who are highly dependent on the resource for short-term subsistence needs. This is the scenario described by Agrawal (1998). Vedeld (2003) describes a similar scenario of cattle-wealthy elites in the Inner Niger Delta preventing the conversion of common pastureland to agricultural fields desired by low caste groups.

More recently, other authors have advanced the view that the relationship between heterogeneity and any particular measure of success is U-shaped; ‘success’ is least likely at moderate levels of heterogeneity (Dayton-Johnson and Bardhan 2002). Note that the theoretical basis for this argument relies in part on the assumption of a linear production function; increases in production are at all points proportional to increases in participation. One might imagine that the U-shaped relationship can be interpreted in the context of Baland and Platteau’s model in the sense that at high levels of heterogeneity we have the situation where the ‘rich’ can completely supply the collective good. At very low levels of heterogeneity, common interests are great enough that individuals have the social capital necessary to solve collective action problems. Finally, at moderate levels of heterogeneity the tension between the growing interests of the rich and the declining interest of the poor is at its peak, the result being very little, if any, collective goods being provisioned.

Integrating these varied perspectives on collective action provides a rich set of empirical predictions. There are three broad classes of outcomes. First, there are two conditions under which users can escape a collective action dilemma. That is, the collective good is provided because some individuals find it in their self-interest to do so. This occurs in the condition when only partial collective action is needed to achieve successful outcomes and at least a few individuals have the resources and/or interest to motivate them to do (this is the Olson effect), or, in the condition where the production function is accelerating. In the latter condition, potentially all individuals escape a social dilemma and voluntarily contribute to the collective good because the marginal benefits to themselves are higher than the individual costs. This can happen only when individuals 'value' the resource sufficiently. It is not clear, however, whether this scenario entailing a relatively strongly accelerating production function is very common in resource management situations.

The second class of outcomes is over-exploitation. Unless population density is very low, overexploitation is an almost certain result when appropriators use but do not sufficiently value the resource, perhaps because they have alternative sources of income or resource.

Third, there is a broad class of cases where true social dilemmas prevail. Several might be imagined. First, when the wealthy value the resource but the technology is such that full participation is needed for conservation and simultaneously, production functions are not accelerating. Second, when the poor value the resource but the wealthy do not. Third, when economically homogeneous groups value the resource. Even if individuals are sufficiently wealthy to be able to provide the good, a collective action problem would be predicted since each would prefer the other to do so (e.g. they are caught in a chicken game). In each of these instances, success is more likely under the conditions that Ostrom highlights. These are high levels of trust and social capital, similar views about how the resource should be used, similar long time horizons, all of which may be engendered by similarities in social or cultural status. Gaspart and Seki (2003), in particular, make the case that preferences for status can generate cooperative norms. In the case of shrimp fishing cooperatives in Toyama prefecture, Japan, greatest efficiency is achieved by the group where such norms lead the least capable fishers to work harder while the most able fishers restrain their effort.

3. EMPIRICAL RESEARCH ON HETEROGENEITY

An increasing numbers of papers have been published specifically investigating the impact of heterogeneity, however, there are some important works tangentially dealing with the topic. Of particular importance are the dissertations and resulting papers by Edella Schlager and Shui-Yan Tang who worked in collaboration with Elinor Ostrom to compile the 'Common-pool Resource Database'. In their project, information from a large number of case studies was quantified by Schlager and Tang using a set of detailed coding forms. This data set is the basis for the statistical analysis subsequently reported in this paper and thus, further details of the data set are discussed below.

In his study of the subset of 47 irrigation cases, Tang began by grappling with the issue of how best to measure success (1989, 1994). Ultimately, abundance of water is the desired outcome, however, it was clear that in some cases abundance is largely a factor of local hydrological conditions not under the control of the group. Looking at cases, where abundance could be increased with successful management, he determined that the best proxies for success are high levels of rule conformance and high levels of maintenance of irrigation works. Although heterogeneity was not the principal focus of his dissertation or subsequent works, he did find that low variance in income was associated with success in the 27 cases where sufficient information was available. Social cleavages, measured as the differences in ethnic, cultural, clan, racial, caste identity, or similar factors, were present in seven cases. Of these seven cases with social cleavage, only two exhibited both high rule conformance and high maintenance. He notes however, that these two cases are also the only two under which the resource is community managed. The other five cases are bureaucratically managed, e.g. by a state or national agency. The perfect correlation between social cleavages and management systems makes it impossible identify the underlying cause of failure. At the same time, however, he did find that the frequency of success was significantly lower in cases where at least one subgroup was in a consistently disadvantaged position, e.g. lacking hereditary rights to water. Although he was not able to test the impact of locational differences statistically, he did observe that when the powerful have an incentive to conserve, as when their fields are served by the tail end of an irrigation system, then level of maintenance is higher. However, success was not statistically associated with dependence on the resource, where dependence is measured in two ways; as either whether most family income is derived from the resource, or, whether the family has an alternative water supply.

Schlager analyzed the subset of 44 fisheries in the Common-pool Resource DataBase (1990, 1994). While Schlager was principally interested in analyzing the institutional conditions that permit fishers to resolve appropriation problems and technological externalities, she did briefly evaluate the effect of some of the variables of interest here, albeit at a subgroup level rather than the case level that will be reported below. Thus, she found that among 33 subgroups who organized themselves to use the fishery and for which there was relevant information, there were high levels of dependence on the fishery for income in 87% of the subgroups, with moderate levels of dependence in the remaining groups that organized themselves. In comparison, of the 11 subgroups who did not organize themselves, only 30% were highly dependent on the resource. No statistical tests of these comparisons are reported. With respect to the Olson effect, Schlager found that 58% of the subgroups that developed rules-in-use for the fishery had an individual who took on an entrepreneurial role. No institutional entrepreneurs were reported in cases where subgroups did not organize themselves. Schlager reported that she was not able to examine the impact of socio-cultural diversity within subgroups since there were no within subgroup differences.

Bardhan and Dayton-Johnson (2002) make a broader review of large N studies of irrigation, specifically investigating the impact of heterogeneity and whether an Olson effect occurs. In their work, Tang's meta-analysis and five other large N studies are reviewed. Their broad conclusion is that heterogeneity generally has a negative effect or no effect. Measures of social or cultural heterogeneity appear to have the strongest negative impact on success. In a few cases, they do find a U-shaped correlation between various economic indicators of heterogeneity and 'success'. The only evidence for an Olson effect is from Dayton-Johnson's work in central Mexico, in which he reports that landholding inequality is associated with better canal maintenance (2000). Dayton-Johnson notes that this may be explained by his finding that inequality is also associated with proportional maintenance rules.

While there are a multitude of other case studies that also deal with heterogeneity peripherally, there are a few key papers that make explicit consideration of the problem. As noted earlier, Johnson and Libecap (1982) found that differences in technologies used by large and small shrimp fisheries in the Gulf of Mexico mean that any potential solution to problems of over exploitation differentially impact one group or the other. The result was and continues to be a stalemate with no institutional change occurring. Singleton (2001) also documents stalemates due to distributional concerns among Native

American groups in the Puget Sound area; in this case, heterogeneities are based largely on geographic positions in a manner analogous to head end/tail end issues in irrigation systems.

Beyond fisheries, a few studies do report Olson effects. Agrawal (1998) found that closure of the commons was associated with caste heterogeneity in Rajasthan. However, his study makes it clear that environmental improvement comes at the expense negative social impacts on the groups that are most dependent on the resource who become excluded from the resource. In their model of a pastoral commons, Ruttan and Borgerhoff Mulder (1999) also observe that heterogeneity in power and wealth can lead to improved management outcomes while at the same time being inequitable. Vedeld (2003) found that various forms sociocultural heterogeneity had little impact on conservation of traditional common pastures. However, moderate differences in wealth and endowments, did lead to Olson effects in that wealthy individuals found conservation of CPRs to be in their own direct economic (and political) interests. At the same time, as he showed in a comparison of institutional change in two Malian villages, differences in economic interests among elites, differences in how they 'value' the commons, can have a strong negative effect on conservation outcomes.

Many more studies find little evidence of Olson effects. For example, Varughese and Ostrom (2001) find that wealth disparity has a weakly negative effect on levels of collective action while no effect of sociocultural heterogeneity is found. They emphasize in fact, that it is a mistake to focus on heterogeneity as a determinant of cooperation, and rather, look to the structure of incentives facing users. Where incentives are high, and users are similar in this one respect, and those with power are not in a position to obstruct change, users are more likely to be able new and innovative means of overcoming collective action problems.

The papers reviewed here are unusual in that they look at both conservation outcomes as well as institutional success. However, although many of these papers aim to examine the Olson effect by looking for positive correlations between measures of heterogeneity and various outcome variables, few explicitly evaluate whether the outcome variables should in fact, be expected to respond to an Olson effect as Baland and Platteau's work would suggest. The one exception is Dayton-Johnson's work examining the relations between the use of proportional vs. equal allocation and maintenance rules, and measures of heterogeneity and success (2000). No papers explicitly attempt to describe production functions in accelerating or decelerating terms and this will not be attempted here either as meta-analyses provide nowhere near the detailed information required to make this kind of a judgement. In fact, laboratory settings might make the most suitable environment for looking at these relationships.

Thus far, relatively few experimental papers have been published that deal with the role of heterogeneity. Their findings are mixed. On the one hand, Budescu, Rapoport and Sulieman (1990) report no difference in mean levels of requests to withdraw units in an asymmetrical, 5-person, one-shot, resource dilemma game, as compared to a symmetrical version of the game. However, most other papers report heterogeneity to be associated with either diminished per capita returns, or with increasing difficulty in agreeing to resource sharing rules. Hackett, Schlager and Walker (1994) found that in n-person, collective goods settings with and without communication, heterogeneity in endowments reduced rents relative to the symmetric setting. Furthermore, heterogeneity was associated with a reduced ability of group members to agree on allocation rules. Ahn et al. (n.d.) also found that for the most part, heterogeneity in payoffs reduced levels of cooperation among subjects in both the US and in Korea. However, institutional conditions did mitigate the impact of asymmetrical conditions. For example, cooperation was more likely to occur when an advantaged player, who stood to earn more, made their decision after a disadvantaged player rather than before. Presumably in that case, disadvantaged first movers believe advantaged players have a greater incentive to cooperate. Recently, experimentalists have taken games to the field, utilizing existing differences in wealth or other economic indicators. Cardenas (2001) examined decisions made by rural Columbians, some of who actually use common-pool forest resources. Using an 8-person, commons resource dilemma design, he found that real, economic inequality among players reduced levels of cooperation. Conversely, increased levels of cooperation were observed among group members who were similar in having had real life experiences with commons dilemmas.

4. METHODS

(a) *The Data Set*

In this paper, a few initial predictions are based on the broad conceptual framework presented earlier. First, economic heterogeneity will have a positive effect on success when the indicator of success has public goods properties, in other words, when one or a few individuals can supply all, or most, of the good. Economic heterogeneity should be expected to have a negative or no effect for other outcomes. Second, that any measure of success will be more likely when users value the resource. They may value the resource insofar as they depend on it for a large portion of their income, spend most of their time working with this resource, and have few alternative sources of the resource (or income). Dependence on the resource will be most closely associated with success for those outcomes that require only partial cooperation, and where there are wealthy individuals who depend on the resource and thus may be willing to supply the collective good. Third, low levels of social heterogeneity are expected to be positively associated with all measures of success. Fourth, high levels of trust are expected to be associated with all measures of success, as will similar cultural views of the resource. Predictions concerning the shape of production functions are not evaluated due to practical difficulties in ascertaining the shape of production functions from this kind of data.

These predictions are tested against the Common-pool Resource DataBase described earlier in the context of Schlager's (1990, 1994) and Tang's (1989, 1994) work. Recall their method was to select published cases studies that gave sufficiently detailed information on the rules-in-use governing common-pool resource management, and then quantify the data contained therein with the use of a set of detailed coding forms. These coding forms contained over several hundred different questions, with questions being grouped into five different sections or forms covering characteristics of the resource itself as well as aspects of both the operational and organization levels of governance. Cases were chosen that provided clear information on the rules-in-use governing a common-pool resource system. In most instances, several source materials were used for each case. In five of the resource settings used here, multiple cases were derived from the same set of written materials with each case corresponding to a different 'time slice' of that particular socio-ecological system. All but a handful of cases were drawn from fisheries or irrigation systems. More details of the original methods for choosing and coding cases can be found in the dissertations of Schlager (1990) and Tang (1989).

In this analysis, only fisheries or irrigation cases were used giving a total of 94 cases (Table 1). For the purposes of this project, it was very useful that 24 of the 94 cases were defined as having subgroups. Members of subgroups were characterized by having similar legal rights to appropriation, similar withdrawal rates, similar exposure to variation in supply, similar method of using the resource and similar level of dependence on the resource (Schlager 1990). A complete list of cases and source material can be found in Table 1.

(b) *Construction of Variables*

All data used are responses to questions contained in either the operational level or the subgroup coding forms. Data from operational level coding forms was generally used directly, with one exception discussed further below. Data from subgroup coding forms was generally summarized across subgroups to give one score per case, or population. For this reason, results from the analysis of fisheries cases may differ from those reported by Schlager (1990) who performed an analysis of subgroups rather than populations. Results may also differ from those reported by Tang since he recoded many of the original 5 point scales into 2 or 3 categories to facilitate his analysis.

Choice of outcome variables, measures of success, was in part justified by the findings of Schlager and Tang. In the context of fisheries, Schlager (1990) discusses several outcome variables in this data set that are particularly salient. These are abundance relative to demand, and quality of units being withdrawn at the end of the period (**Abundance**, **Quality**). Both of these are scored along a five-point scale. Ultimately, abundance and quality of the resource are the outcomes of most concern, being measures of conservation outcomes. However, as Schlager makes clear, resource users typically do not find it easy to assess the impact of their own harvesting levels on stock sizes. Furthermore, as Schlager and Tang both emphasize, external factors such as weather or hydrology may impact resource abundance. For this reason, and despite earlier cautions, three institutional criteria identified by Tang and Schlager as being important are also used. The first of these is the degree to which group members follow operational rules-in-use which are related to the appropriation process. Since subgroups were scored independently on this question, here the mean of all subgroup scores was used (**RuleFollow**). The second measure of institutional success is the likelihood of rule-breaking being sanctioned in one of three ways; social sanctions, physical sanctions imposed by other appropriators, or sanctions imposed by official monitors or guards. Since these may be substitutes rather than complements to each other, and to minimize number of variables used in the analysis, the mean score of these is used in the analysis (**Sanction**). The third measure is whether "appropriators [are] exercising or attempting to exercise closed access to the resource" with responses ranging on a 7 point scale from de jure and effective, to no attempts made at all (**Closure**). Finally, a fourth measure of institutional success is used in the subset of irrigation studies. This is the level of maintenance of appropriation resources at the end of the period (**Maintain**). Of all the criteria of success considered here, a system of sanctions (particularly formal sanctions) seems the most likely to be able to be provisioned through partial collective action; in other words to be subject to an Olson effect. For this reason, we might expect economic heterogeneity to have the strongest positive effect on the likelihood of sanctions. By definition, the outcome of most group members following rules-in-use is more successful the more individuals participate, and thus, we would expect to see the strongest negative effect of economic heterogeneity on this variable.

Seven measures of heterogeneity and six other group characteristics were used. General categories these fall in to are economic measures, level of dependence on the resource, sociocultural heterogeneity, and overall levels of trust. Considering economic indicators first, in the original data set, wealth is estimated as the percentage of a subgroup that owns assets such as land or capital. Here, variation in wealth at the population level is estimated by taking the largest difference in asset score of any two subgroups (**DIFASSET**). Overall level of wealth for the population was estimated by taking the mean of all subgroups' scores (**AVEASSET**). Overall level of income was also estimated by taking the mean of subgroup scores on income level (**AVEINC**), where income was an estimate of that subgroups' average annual family income relative to the local economy. Heterogeneity in income at the population level was estimated by taking the largest difference between any two subgroups scores (**DIFINC**). A second estimate of income variation was also generated since the previous measure does not pick up differences *within* subgroups. For example, a case would be scored as homogeneous if subgroups had the same average level of income even if there were lots of within group variation in income. This second measure is based on a subgroup form question that asks what level of variation in income there is within the subgroup. The measure used here is the highest level of variation in any one subgroup (**HIVARINC**).

Although levels of wealth and assets are in part measures of dependence, dependence on the resource was measured in four additional ways. Heterogeneity in dependence was estimated using data from a different, bivariate, question that compared levels of dependence across each subgroup dyad; scores were 1 or 2 depending on whether the dyad had the same or different levels of dependence. I arrived at a single value per case by scoring the population as heterogeneous, if at least one dyad differed in level of dependence on the resource, the justification being that we are looking for any kind of heterogeneity (**DIFDEPEN**). One issue that arose in deciding how best to summarize scores across subgroups for the remaining measures was whether to use mean scores across subgroups, or to take an extreme high or low score. The latter was chosen in that the aim here is to find whether there are any subgroups that are not dependent and thus might influence the behavior of the entire population. Thus, the second measure of dependence is the highest score from a question measuring level of dependence on the resource for family income (**HIDEPEN**). A third measure of dependence is the lowest score from a question asking whether low cost alternatives to the resource are available; a low score is used since this would indicate that many alternatives are available and thus that dependence is low (**LOALTSUPLY**). The rationale for picking the lowest level of dependence is based on the assumption that the actions of members of a single subgroup can disrupt collective action. The fourth measure, is the lowest subgroup score for a question asking whether a substantial amount of time is spent in activities not related to the appropriating the resource in question; again a low score is chosen since this indicates that lots of time is spent in alternative activities and thus dependence is low (**LOSUBNOT**).

Social and cultural heterogeneity was expressed as three variables. Here, I drew upon an operational level coding question that asked whether differences among subgroups existed along a number of different dimensions and whether those differences affected communication. These are what Tang referred to as social cleavages (1989, 1994). The dimensions included were; gender identification, ethnic identification, clan identification, racial identification, caste identification, religious identification, languages spoken and cultural view of the resource. Because of its fundamentally important role, differences in cultural view of the resource system was used a variable on its own (**CULTVWR**). In addition, two summary variables were constructed by taking the mean across all other dimensions that were scored (**AVEHET**), and secondly, by taking the highest dyadic score along any dimension of difference (**HIHET**). In addition, level of trust among the population of appropriators at the end of the study period was included (**TRUST**). It is conceivable that levels of trust are themselves influenced by level of heterogeneity and thus, it is somewhat arbitrary that this variable is included with the independent variables.

Finally, a bivariate grouping variable was created to indicate in which cases there were subgroups, or subpopulations, whose members were above average in wealth relative to the local economy, and who were also above average in how dependent they are on the resource (**RICHDEPEND**). Four other variables were drawn from the original data set to be used as outcome variables in a separate set of tests that were used to test the idea that some outcomes may be achieved with only partial cooperation (**Informal sanctions**, **Formal sanctions**, **MaintainD**, **MaintainP**). Outcomes thought to require full cooperation are: the use of informal social or physical sanctions, calculated as the average of those two variables (**Informal Sanctions**), as well as the previously described variables relating to rule compliance, (**RuleFollow)**, and maintenance of appropriation resources (**Maintain)**. Outcomes that might be possible with only partial cooperation are; the use of formal sanctions by official guards or monitors (**Formal Sanctions**), maintenance of distribution resources at the end of the study period (**MaintainD**) and maintenance of production works at the end of the period (**MaintainP**). Recall that in the case of irrigation works, production works include dams or other headworks holding back the flow of water while distribution works are the main canal(s) bringing water to individual irrigation areas. In turn, appropriation works are the canal, tanks or pumps that directly supply fields.

To facilitate interpretation of results, many of the variables were rescaled so that high levels of heterogeneity, high levels of dependence and high levels of success would always correspond with high scores on questions, while low levels of each correspond with low scores. This manipulation facilitates easier interpretation of correlations since any finding of significant negative correlations indicates a negative effect of heterogeneity (or dependence etc.) while positive correlations indicate beneficial effects of the variable in question.

(c) *Statistical Analyses*

Non-parametric statistics were chosen since most variables are ordinal. Five sets of tests were done. First, to test Olson's general proposition that economic heterogeneity has a positive impact, a series of two-tailed Spearman's rank correlations were performed using each of the six measures of success (**Abundance**, **Quality**, **Rulefol**, **Sanction,**

Closure, Maintain) against the suite of measures of economic heterogeneity and status (average assets, range of assets, average income, range of income across subgroups, variation in income within subgroups). Second, to examine Baland and Platteau's more specific hypothesis that the effect of economic heterogeneity depends on the specific outcome variable in question, the Wilcoxon signed ranks test was used to compare the level of success between outcomes that are thought to need full participation versus those in which success might be obtained with only partial cooperation. The pairings that were analyzed were; **Sanction** vs. **RuleFollow**, **Formal Sanctions** vs. **Informal Sanctions**, **Maintain** vs. **MaintainD,** and **Maintain** vs. **MaintainP**. All Wilcoxon tests were performed using the subset of data in which the wealthy had a greater than average dependence on the resource for income. The latter two comparisons of maintenance types were done only with data from the irrigation studies. Third, Spearman's correlations were used to evaluate the relationship between dependence on the resource (similarity in dependence, level of dependence, alternative supplies, and other subsistence activities) and the main outcome variables. Fourth, the Mann-Whitney U test was used to test whether better outcomes obtained in cases where there were wealthy individuals who were dependent on the resource versus all other cases. The test was done for each of the five main outcomes using the grouping variable, **RICHDEPEND**. Fifth, Spearman's correlations were used to evaluate the relationship between the main outcome variables and each of the measures of socio-cultural heterogeneity (cultural view of the resource, average and high social cleavages), as well as with levels of trust. All of the Spearman's correlations and the Mann-Whitney tests were done on the entire dataset, on the set of irrigation cases, and on the set of fisheries cases. Analyses were conducted using SPSS 11 for Mac OSX.

5. RESULTS

(a) Economic Indicators

The broad impact of economic indicators on success is varied (Table 3). It can be seen that average level of assets has no significant effect, however range of variation in assets does have a negative effect on the quality of units harvested (p=.035), and the likelihood that access to the resource is closed (p=.03). While neither of these effects are seen in the irrigation only data, both are present in the fisheries only data, and in fact, the impact on quality of units is highly significant in the latter case (p=.01). In the fisheries data, there is, in addition, a positive impact of heterogeneity in assets on the likelihood that some type of sanction will be give for rule violations.

Average level of income across subgroups also has a significantly negative effect on quality of units extracted (p=.008), however, this effect is not observed when the data is disaggregated by resource type. In the fisheries case, average income does have a negative effect on the likelihood of sanctions being imposed (p=.019). The effect of range in income across subgroups is more varied. Considering the aggregated data, one can observe a positive effect on the likelihood that sanctions will be applied (p=.033). This effect is also observed in the fisheries case (p=.02). Range in income also has a significantly negative effect on quality of appropriation units in the fisheries case (p=.006) but a positive effect on abundance of units in the irrigation studies (p=.033). Finally, variation in income within a subgroup, a measure that is used to find variation that may be masked by cross subgroup comparisons, has no effect when the fisheries data is considered alone. It does have negative effects on abundance in both the aggregated data (p=.024) and the irrigation only data (p=.007). In the aggregated data, there is a negative effect on the likelihood that rules will be followed (p=.016), and in the irrigation data there is a negative effect on the likelihood that sanctions will be applied (p=.038) and on the level of maintenance of the appropriation resource (p=.011).

To evaluate the more specific prediction that economic heterogeneity will have a differential impact on types of outcome variables, comparisons of level of success are made for outcomes where full cooperation is thought to be necessary versus those outcomes where partial cooperation may by sufficient. The former include **RuleFollow**, **Informal Sanctions**, and **Maintain** while the latter includes **Sanction**, **Formal Sanction**, **MaintainD** and **MaintainP**. All of these variables were measured on five point scales. Only cases are used where there are individuals of higher than average wealth that have higher than average dependence on the resource for income. Contrary to predictions, it is found that the mean level of sanctions is lower than the mean level of rule compliance (Wilcoxon signed ranks test, Z = -3.985, N= 26, p=.000). However, when sanctions are broken down into categories of informal and formal sanctions, it is found that formal sanctions occur more frequently than informal sanctions (Wilcoxon signed ranks test, Z = -2.136, N= 12, p=.033). Note that when all cases are included, not only those where there are wealthy who depend on the resource, the latter test is no longer significant, while the broader test of sanctions versus rule following retains significance (Wilcoxon signed ranks test, Z = -5.752, N = 68, p=.000). Looking only at the irrigation cases, we can compare levels of maintenance of appropriation works versus distribution works, and maintenance of appropriation works versus production works, the logic being that appropriation works directly supply individual plots and thus a greater number of individuals would have a clear incentive to cooperate in building and servicing these systems. When only cases where the rich depend on the resource are included, we find no difference in levels of outcomes in the first case (Wilcoxon signed ranks test, Z = -1.160, N = 16, p=.246). However, we do observe that maintenance of production works is significantly better than appropriation works (Wilcoxon signed ranks test, Z = -2.036, N = 17. p=.042). This relationship is no longer significant when all data are used (Wilcoxon signed ranks test, Z = -.914, N = 43, p=.361).

(b) Resource Dependence as Indicators of Value

The importance of valuing the resource was examined by looking at levels of dependence on the resource using four different measures of dependence (Table 4). In both the aggregated and fisheries only data sets, heterogeneity in dependence on the resource for income, taken across subgroups, had a positive effect on quality (aggregated: p=.022, fisheries: p=.045) and a negative effect on closure (p<0 for both). In other words, when groups were similar in their level of dependence they experienced lower quality resources but were more likely to be able to close access to the resource. Overall level of dependence on the resource for income, taken as the highest score of any subgroup, had no effect on outcomes. The proportion of time spent in subsistence activities not associated with this resource (scaled so that high proportions of time receive low scores), had a negative effect on quality of resource in the aggregated case (p=.011), and also a negative effect on the likelihood of rules being followed in the aggregated (p=.015) and fisheries cases (p=.028). In other words, when individuals are highly dependent on the resource, in that they spend very little time in other resource generating activities, they have a negative effect on quality and a negative effect on rule following. It had no effect on irrigation systems. The cost of alternative sources of supply, measured as the lowest score of any one subgroup, had a negative effect on closed access to the resource in both the aggregated data (p=.001) and the fisheries data (p=.001).

The previous analyses only looked at the effects of average level of dependence, or, similarities in level of dependence on the resource. Here, Mann-Whitney U tests were performed specifically to examine the hypothesis that outcomes are improved when there are wealthy individuals who depend on and thus value the resource (Table 5). The test was done with each of the five outcome variables used in the previous analysis, using the grouping variable RICHDEPE. Recall that this variable does not define rich individuals or subgroups as those who are richest in the case study, but rather as those who have higher than average income relative to the local economy. Thus for any case, it is possible that there may be no wealthy subgroups at all, or vice versa, that all subgroups are wealthy. We find that the mean level of resource quality is lower when the wealthy depend on the resource in using both the aggregated data (p=.018) and the irrigation only cases (p=.034). However, in the fisheries studies, the mean likelihood of the commons being closed is higher when the wealthy depend on the resource (p=.037).

(c) Sociocultural Heterogeneity and Trust

Heterogeneity across subgroups' cultural view of the resource has a pronounced, but varied, effect on the data (Table 6). In the aggregated data set, it has a positive effect on abundance (p=.029) and quality (p=.005). Oddly enough, when the data is disaggregated it instead has a negative effect on quality, both in the fisheries case (p=.004) and the irrigation case (p=.043). A negative effect of this measure of heterogeneity on rule following is also seen in the aggregated data (p=.04), while in the fisheries data a positive effect is observed on sanctions (p=.028). Average social heterogeneity, that is, differences in gender, race, caste, language, clan, and religion that affect communication, had no effect in the irrigation cases, but in the aggregated case had a highly significant negative effect on quality of resources (p=.007), simultaneous with a highly significant positive effect on the likelihood of closure (p=.001). In other words, heterogeneous groups were more likely to have low quality units available to them but be more likely to close access to the commons. The latter effect is also seen in the fisheries only cases (p=.03). The variable, HIHET, which simply takes the highest heterogeneity score from any of the categories of differences, has a negative effect on rule following in the aggregated data (p=.039) and the irrigation data (p=.002), and also a significantly negative effect on resource quality (p=.007) and maintenance (p=.021) in the irrigation cases.

Trust has no impact on abundance, quality or closure of the resource (Table 6). However, it does have a significant positive effect on rule following in the aggregated data set (p<0), in the fisheries data (p=.019), and in the irrigation data (p<0). It also has a positive effect on the likelihood of sanctions being applied in the aggregated data (p=.045) and the irrigation data (p=.011), and it has a positive effect on maintenance levels of irrigation systems (p<0).

6. DISCUSSION

Of primary interest here is the issue of whether Olson effects occur. In its simplest formulation, this is the question of whether economic heterogeneity has a positive impact on success, measured either in terms of conservation outcomes, provisioning of useful institutions, or in participation with rules-in-use. The analysis presented here provides little support for this general proposition but rather supports the proposition that economic heterogeneity has an ambiguous impact on success. Most of the correlations presented in Table 3 are insignificant and the majority of significant relationships are in fact negative rather than positive. In particular, quality of fisheries resources are negatively impacted by heterogeneity in assets and in income across subgroups, while abundance of water in irrigation systems is negatively impacted by variation in income within subgroups. However, this gross test of Olson effects ignores two more nuanced refinements to the model. In the first place, this simple analysis ignores the issue that Olson effects should only occur if the wealthy actually could gain from providing the collective good, in the terminology used here they ‘value’ the resource. Here, ‘value’ is interpreted as dependence on the resource for income. It is found that, in general, measures of dependence have very little impact on outcomes, or if anything, have a negative rather than positive effect; one exception being that fishers are better able to close access to the resource when there are few alternatives supplies of the resource. However, it is notable that when we compare outcomes in the subset of cases where there are individuals of higher than average income (relative to the local economy) who also have higher than average levels of dependence on the resource for family income against all other cases, we find that the mean level of resource quality is actually lower when the wealthy depend on the resource. This occurs in analyses with both the aggregated data and the irrigation only cases. In the fisheries studies, the mean likelihood of the commons being closed is higher when the wealthy depend on the resource, a finding that suggests Olson effects.

A second refinement to the broad notion of Olson effects, is the idea that rather than assuming that Olson effects could occur in all kinds of domains, we should look more carefully at the measure of success that we are evaluating. Some types of outcomes, institutions, etc. may require full participation for success to be achieved while others do not. Some types of resources may be exploited by technologies that require full cooperation with rules-in-use in order for conservation to occur, while other resource/technology combinations may be able to withstand a certain amount of noncompliance. In a first attempt to classify these outcomes in this way, we imagine that high levels of success in the outcome variables, **Sanction**, **Formal sanction**, and of irrigation distribution works (**MaintainD**) and provision works (**MaintainP**), would not require full compliance. In contrast, by definition high levels of success in rule following requires high levels of compliance. It is also imagined that high levels of participation are needed for success in applying informal sanctions and in maintaining irrigation appropriation works. This hypothesis that levels of success are higher for those outcomes requiring partial cooperation, when there are wealthy who depend on the resource, is relatively well supported. On the one hand, counter to predictions, levels of rule compliance are higher than levels of all types of sanctions combined. However, when sanctions are disaggregated into formal and informal sanctions, we find that levels of formal sanctions are significantly higher in the subset of cases where there are wealthy who depend on the resource; precisely the case where we would expect this outcome. Providing further support, when the analysis is performed using all cases, there is no significant difference between levels of the two types of sanctions. We can interpret this as meaning that only when there are wealthy who value the resource do they take it upon themselves to provide a formal system of sanctioning rule violators. Support for this idea also comes from comparing levels of success in maintaining irrigation works. When there are wealthy who depend on the resource, provision works are better maintained than appropriation works on average. There is no significant difference in maintenance levels when all cases are included, once again providing support for the concept that when the wealthy value the resource they may be willing and able to provide certain specific types of collective goods.

The prediction that successful outcomes are positively related to low sociocultural heterogeneity is not broadly supported. However, neither is there clear evidence that sociocultural heterogeneity leads to success. As a matter of fact, of those cases where relationships are significant, we find seven cases where there are positive effects, and eight instances of a negative correlation (out of 48 tests total). Positive correlations are most frequently associated with differences in cultural view of the resource, although with respect to quality, the association is positive when the data are aggregated but negative for both the fisheries and irrigation data when disaggregated. One way of interpreting the positive effect of differences in cultural view of the resource is that heterogeneity in view is preferable to a uniformly dim view of the resource. Note, that this contrasts with Vedeld's (2003) finding among pastoralists that differences among elites in views of how the resource should be used was the most likely explanation for conversion of common pastures. Where significant, social cleavages (differences is social categories such as race, clan, caste, language, religion) have positive effects in fisheries but negative effects in irrigation systems. In fisheries, the positive effects are on ability to close access and on abundance. Given that closure itself has such a strong impact on abundance, the latter result is not surprising. Negative effects of sociocultural heterogeneity in irrigation systems are primarily associated with resource quality, rule conformance and maintenance of appropriation resources.

As predicted high levels of trust do have a positive effect, but only on some outcomes. Trust has no effect on abundance or quality, nor does it have any effect on closure of access to the resource. These are intriguing findings given that the first two variables are both measures of the outcome of ultimate interest, and closure is also thought to have a particularly strong impact on conservation outcomes, particularly in fisheries. However, when it is significant, trust has a uniformly positive effect. The impact is on three of the outcome variables; rule compliance in all three data sets, sanctions in the irrigation and the aggregated data sets, and maintenance in the irrigation data set. The effect of trust is thus weakest in fisheries and strongest in irrigation systems.

Finally, what evidence is there that although heterogeneity may lead to improved conservation outcomes it may come at the expense of social equity? On the one hand, social cleavages are associated with higher levels of closure. It is not clear, however, whether closure is exclusion of one subgroup by another, or occurs in situations with a hierarchical but stable structure. As mentioned earlier, success in closing access is in fact, negatively associated with variation in income in the aggregated data and in the fisheries cases.

7. CONCLUSION

Clearly, well-planned, large N, studies are a preferable research instrument for making generalizations about heterogeneity insofar as detailed information relevant to the research project can be gathered (Bardhan and Dayton-Johnson 2002). However, meta-analysis using a pre-existing data set does provide some initial traction in exploring this rich area of study. The analysis presented here provides varied support for the arguments articulated earlier in the paper. First, there is little support for a broad Olson effect, that is, economic heterogeneity does not have an overwhelmingly positive impact on outcomes. Rather, the notion that economic differences should have an ambiguous effect is better supported. However, there is fairly strong support for the proposition that we should only expect Olson effects under two specific conditions. In the first place, where there are wealthy individuals who place value on the resource outcomes are improved. In the second place, when institution type, and the resource/technology combination are such that the actions of one or a few individuals can have a large impact on conserving the resource, or providing institutions designed to do so, then we measure higher levels of success.

Predictions that high levels of trust should be associated with positive outcomes are weakly supported. Most of the tests for correlations between trust and the main outcome variables are non-significant. However, where significant, trust has a universally positive effect; this being on institutional outcomes such as rule compliance, the probability of sanctions being applied, and levels of maintenance of appropriation resources in irrigation systems. The evidence is less clear with respect to sociocultural differences, such as race, caste, ethnicity, cultural view of the resource. Sociocultural heterogeneity has more varied relationships with outcome variables, with significant outcomes being nearly evenly split between positive and negative correlations. Notably, social cleavages based on categories such as caste, clan, race, religion and language, have positive effects in fisheries but negative effects in irrigation systems. Unexpectedly, dependence on the resource (measured as dependence on the resource for family income, time spent in alternative subsistence activities, and availability of alternative supplies of the resource) has a negligible effect on outcomes. Furthermore, where significant, the relationship is negative rather than positive.

The differences in results in the fisheries and irrigation cases are among the most unexpected. It might be hypothesized that some of the differences between irrigation and fisheries systems may stem from the fact that in fisheries, diversity may provide opportunities for complementary, or at least different, uses of the resource insofar as there are a variety of species to be caught, whereas in irrigation systems there may be more scope for direct competition over limited resources. Thus, in irrigation systems diversity may be more problematic, making negotiations over water and labor sharing activities more difficult, and thus necessitating even higher levels of trust or social capital. Further empirical research would be helpful in better understanding when heterogeneity provides the opportunity for complementary uses of resources (but see Varughese and Ostrom (2001) for an example relating to firewood collection). As Agrawal and Gibson (1999) emphasize, we may find that particular features of communities, such as heterogeneity in its various guises, do not directly predict success but rather the defining feature of success may be the particular processes of institutional formation, processes that provide institutional legitimacy (see also Vedeld 2003). In this light, it would be useful to pay more attention to the shape of real world production functions to learn whether particular systems can be characterized in these ways. For example, if irrigation systems were generally characterized as having accelerating functions, and thus collective action is hard to start but grows explosively once initiated, limited interventions that help facilitate the initiation of collective action would be most productive. In contrast, in systems that could be characterized as having decelerating functions, where collective action is easily initiated by a few but seldom attracts full participation, communities may benefit most when they can find institutions that help mitigate the effects of differences, or level the playing field in the way that Japanese shrimp fishers do (Gaspart and Seki 2003).

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Figure 1. (a) Accelerating and (b) decelerating production functions with high and low value thresholds. Individuals who find themselves above the threshold have a benefit to cost ratio greater than 1. Individuals below the threshold have a ratio less than 1.

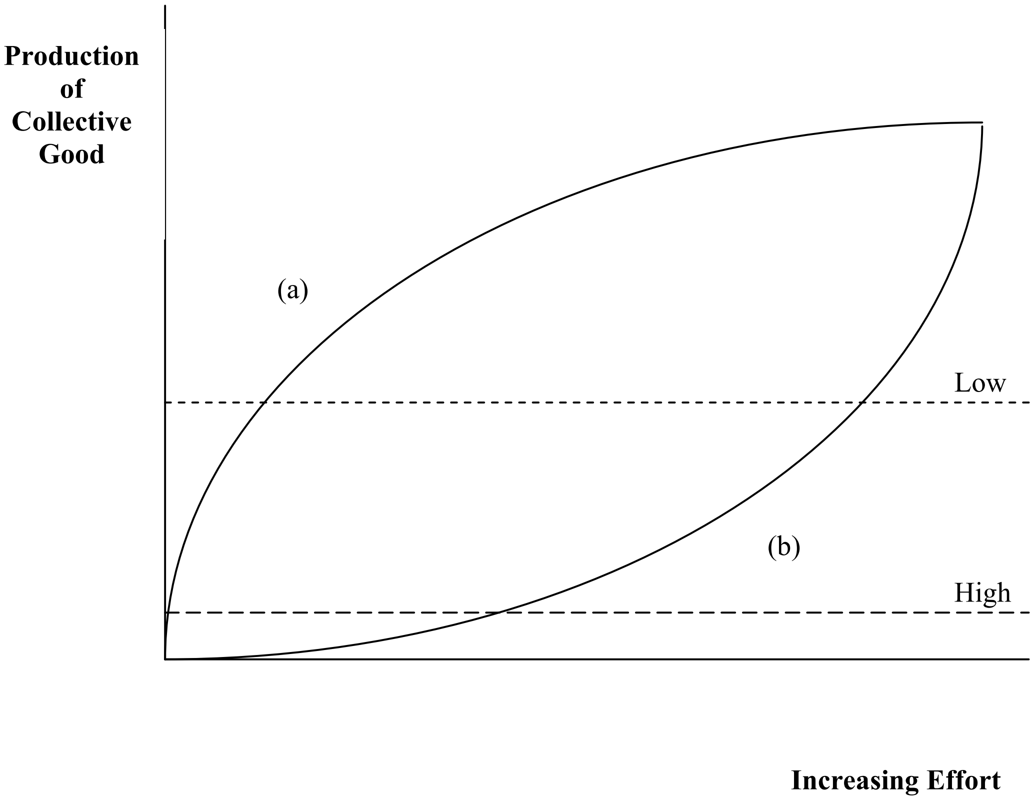

Table 1. Cases used in the study (adapted from Schlager 1994, and Tang 1994).

Country	**Local Name**	**Resource Type**	**Sources**
Australia	Lakes Entrance	Fishery	Sturgess et al. 1982
Australia	Lakes Entrance	Fishery	Sturgess et al. 1982
Australia	Port Phillip Bay	Fishery	Sturgess et al. 1982
Australia	Port Phillip Bay	Fishery	Sturgess et al. 1982
Australia	Port Phillip Bay	Fishery	Sturgess et al. 1982
Australia	Port Phillip Bay	Fishery	Sturgess et al. 1982
Belize	Caye Caulker	Fishery	Sutherland 1986
Brazil	Arembepe	Fishery	Kottak 1966
Brazil	Coqueiral	Fishery	Forman 1966, 1970
Brazil	San Pedro	Fishery	E. Gordon 1981
Brazil	Valenca	Fishery	Cordell 1972, 1974, 1978b, 1983, 1984
Brazil	Valenca	Fishery	Cordell 1972, 1974, 1978b, 1983, 1984
Brazil	Valenca	Fishery	Cordell 1972, 1974, 1978b, 1983, 1984
Canada	Baccalaos Cove	Fishery	Powers 1984
Canada	Cat Harbour	Fishery	Faris 1972
Canada	Fermeuse	Fishery	K. Martin 1973, 1979
Canada	James Bay	Fishery	Berkes 1977, 1987
Canada	Petty Harbour	Fishery	Shortall 1973
Canada	Port Lameron - Pagesville Finfish	Fishery	A. F. Davis 1975, A. Davis 1984
Canada	Port Lameron - Pagesville Lobster	Fishery	A. F. Davis 1975, A. Davis 1984
Greece	Messolonghi-Etolico	Fishery	Kotsonias 1984
India	Jambudwip	Fishery	Raychaudhuri 1968, 1980
Jamaica	Farquhar Beach	Fishery	Davenport 1956
Japan	Ebibara	Fishery	Brameld 1968
Korea	Kagoda	Fishery	Han 1972
Malaysia	Kampong Mee	Fishery	E. Anderson and Anderson 1977
Malaysia	Perupok	Fishery	Firth 1966
Mexico	Andres Quinta Roo Lobster	Fishery	D. Miller 1982
Mexico	Andres Quintana Roo Scalefish	Fishery	D. Miller 1982
Mexico	Ascension Bay Lobster	Fishery	D. Miller 1982, 1989
Nicaragua	Tasbapauni	Fishery	Nietschmann 1972, 1973
Sri Lanka	Gahavalla	Fishery	Alexander 1982
Sri Lanka	Gahavalla	Fishery	Alexander 1982
Sri Lanka	Gahavalla	Fishery	Alexander 1982
Thailand	Rusembilan Kembong	Fishery	T. Fraser 1960, 1966
Turkey	Alanya	Fishery	Berkes 1986
Turkey	Ayvalik-Haylazli	Fishery	Berkes 1986
Turkey	Tasucu Bay	Fishery	Berkes 1986
USA	Mount Desert Island	Fishery	Breton 1973
Venezula	Chiguana	Fishery	Grossinger 1975
Bangladesh	Nabagram	Irrigation	Coward and Badaruddin 1979
India	Area Two Tailend Watercourse	Irrigation	Botrall 1981
India	Dhabi Minor	Irrigation	Reidinger 1974, 1980, Vander Velde 1971, 1980

India	Kottapalle	Irrigation	Wade 1988a, 1992
India	Sananeri	Irrigation	Meinzen-Dick 1984, Gustafson and Reidinger 1971
Indonesia	Area Three Watercourse	Irrigation	Bottrall 1981
Indonesia	Bondar Parhudagar	Irrigation	Lando 1979
Indonesia	Saebah	Irrigation	Hafid and Hayami 1979
Indonesia	Silean Banua	Irrigation	Lando 1979
Indonesia	Bali Subak A	Irrigation	Geertz 1967
Indonesia	Takkapala	Irrigation	Hafid and Hayami 1979
Iran	Deh Salm	Irrigation	Spooner 1971, 1972, 1974
Iran	Nayband	Irrigation	Spooner 1971, 1972, 1974
Iraq	El Mujarilin	Irrigation	Fernea 1970
Laos	Nam Tan	Irrigation	Coward 1980b
Mexico	Diaz Ordaz Tramo	Irrigation	Downing 1974
Nepal	Char Hazar	Irrigation	Fowler 1986
Nepal	Chhahare Khola	Irrigation	Water and Engineering Commission 1987
Nepal	Lothar	Irrigation	Pradhan1988, Laitos et al. 1986, Nirola et al. 1987
Nepal	Naya Dhara	Irrigation	Water and Engineering Commission 1987
Nepal	Raj Kulo	Irrigation	E. Martin and Yoder 1983a, 1983b, 1986
Nepal	Thulo Kulo	Irrigation	E. Martin and Yoder 1983a, 1983b, 1986
Pakistan	Area One Watercourse	Irrigation	Bottrall 1981
Pakistan	Dakh	Irrigation	Mirza 1975
Pakistan	Gondalpur	Irrigation	Merrey and Wolf 1986
Pakistan	Punjab	Irrigation	Lowdermilk, Clyma, and Early 1975
Peru	Hanan Sayoc	Irrigation	Mitchell 1976, 1977
Peru	Lurin Sayoc 1	Irrigation	Mitchell 1976, 1977
Peru	Lurin Sayoc 2	Irrigation	Mitchell 1976, 1977
Philippines	Agcuyo	Irrigation	de los Reyes 1980a
Philippines	Cadchog	Irrigation	de los Reyes 1980a
Philippines	Calaoaan	Irrigation	de los Reyes 1980a
Philippines	Laoag-Vintar	Irrigation	Ongkingco (1973)
Philippines	Mauraro	Irrigation	de los Reyes 1980a
Philippines	Nazareno-Gamutan	Irrigation	Ongkingco (1973)
Philippines	Oaig-Daya	Irrigation	de los Reyes 1980a
Philippines	Pinagbayanan	Irrigation	F. Cruz 1975
Philippines	Sabangan Bato	Irrigation	de los Reyes 1980
Philippines	San Antonio	Irrigation	de los Reyes et al. 1980
Philippines	San Antonio	Irrigation	de los Reyes et al. 1980
Philippines	Silag-Butir	Irrigation	de los Reyes 1980a
Philippines	Tanowong Bwasao	Irrigation	Bacdayan 1980
Philippines	Tanowong	Irrigation	Bacdayan 1980
Philippines	Zanjera Danum Sitio	Irrigation	Coward 1979
Switzerland	Felderin	Irrigation	Netting 1974, 1981
Taiwan	Area Four	Irrigation	Bottrall 1981
Tanzania	Kheri	Irrigation	Gray 1963
Thailand	Amphoe Choke Chai	Irrigation	Gillespie 1975
Thailand	Chiangmai	Irrigation	Potter 1976

Thailand	Kaset Samakee	Irrigation	Gillespie 1975
Thailand	Na Pae	Irrigation	Tan-kim-yong 1983

Table 2. Variables used in analyses. Detailed description of the methods for constructing variables can be found in the text. Code in parentheses refers to location in original operational level (OL) or subgroup (SG) coding form, and question number therein.

Principal Dependent Variables: Measures of Success

Abundance - Abundance relative to demand at end of period (OL C1a-b)

Quality – Quality of resource units appropriated at the end of the period (OL C6)

Closure –Closed access to the resource at the end of the period (OL C14b)

RuleFollow – Do users obey rules-in-use in average years (SG F11)

Sanction - Likelihood of rule-breaking being sanctioned (OL F4-6)

Maintenance – Maintenance of appropriation resources at the end of the period (OL C11a)

Alternative Dependent Variables

Formal Sanction – Likelihood of formal sanctions (OL F6)

Informal Sanction – Average likelihood of social or informal physical sanctions (OLF4-5)

MaintenanceD – Maintenance of distribution resources at the end of the period (OL 11b)

MaintenanceP – Maintenance of production resources at the end of the period (OL 11c)

Independent Variables: Economic Indicators

AVASSET – Mean proportion of users that own land or capital (SG C12)

RNGASSET – Largest difference in subgroup scores on proportion owning assets (SG C12)

AVINCOME – Mean annual family income level taken across subgroups (SG C9)

RNGINCOM – Largest difference in subgroup scores on average family income (SG C9)

HIVARINC – Highest within subgroup variation in average annual family income (SG C10)

Independent Variables: Measures of Dependence

SIMDEPEN – Difference in dependence on resources across subgroups. (OL H3a-f C4)

HIDEPEN - Highest subgroup dependence on the resource for family income

SUBNOT – Lowest subgroup score on amount of time spent in alternative activities (SG C7)

ALTSUP – Lowest subgroup score on alternative supplies available (SG C 13)

Independent Variables: SocioCultural Indicators

TRUST - Level of trust among all appropriators at the end of the period (OL C12)

CULTVWR – Largest difference between subgroups in cultural view of the resource (OL F1h)

AVEHET – Mean of differences in ethnicity, gender, clan, race, caste, religious, language, and other differences that affect communication (OL F1a-i)

HIHET – Highest difference in ethnicity, gender, clan, race, caste, religious, language, and other differences that affect communication (OL F1a-i)

Other variables

RICHDEPE – Are there subgroups, or individuals, of above average wealth with above average dependence on resource.

Table 3. Spearman's rank correlations (2-tailed) of main outcomes with economic indicators. Test are repeated with (a) the aggregated data set, (b) with only fisheries cases and (c) with only irrigation cases. (*) indicates correlation at the 0.05 level, (**) indicates correlation at the 0.01 level.

		Abundance	Quality	RuleFoll	Sanction	Closure	Maintain
(a) Fisheries and Irrigation							
AVASSETS	Correlation Coefficient	-0.118	0.185	0.092	-0.042	-0.074	
	Sig. (2-tailed)	0.345	0.147	0.471	0.763	0.67	
	N	66	63	64	54	36	
RNGASSET	Correlation Coefficient	0.127	-.270(*)	0.025	0.189	-.372(*)	
	Sig. (2-tailed)	0.316	0.035	0.848	0.179	0.03	
	N	64	61	62	52	34	
AVINCOME	Correlation Coefficient	-0.247	-.329(**)	-0.071	0.012	0.326	
	Sig. (2-tailed)	0.051	0.008	0.579	0.929	0.09	
	N	63	63	63	55	28	
RNGINC	Correlation Coefficient	0.126	-0.22	0	.284(*)	-0.193	
	Sig. (2-tailed)	0.318	0.079	0.997	0.033	0.307	
	N	65	65	65	57	30	
HIVARINC	Correlation Coefficient	-.313(*)	-0.075	-.335(*)	-0.264	-0.179	
	Sig. (2-tailed)	0.024	0.596	0.016	0.076	0.372	
	N	52	52	51	46	27	
(b) Fisheries							
AVASSETS	Correlation Coefficient	-0.18	-0.058	0.281	0.033	0.087	
	Sig. (2-tailed)	0.323	0.756	0.126	0.874	0.643	
	N	32	31	31	25	31	
RNGASSET	Correlation Coefficient	-0.067	-.471(**)	-0.076	.441(*)	-.375(*)	
	Sig. (2-tailed)	0.725	0.01	0.694	0.035	0.045	
	N	30	29	29	23	29	
AVINCOME	Correlation Coefficient	-0.087	-0.095	0	-.546(*)	0.269	
	Sig. (2-tailed)	0.687	0.666	1	0.019	0.215	
	N	24	23	24	18	23	
RNGINC	Correlation Coefficient	-0.254	-.535(**)	-0.222	.515(*)	-0.125	
	Sig. (2-tailed)	0.211	0.006	0.276	0.02	0.552	
	N	26	25	26	20	25	

HIVARINC	Correlation Coefficient	-0.051	-0.11	-0.401	-0.172	-0.28	
	Sig. (2-tailed)	0.819	0.616	0.058	0.468	0.196	
	N	23	23	23	20	23	

(c) Irrigation

AVASSETS	Correlation Coefficient	-0.197	0.162	-0.02	-0.105	0.577	0.027
	Sig. (2-tailed)	0.264	0.375	0.913	0.587	0.308	0.878
	N	34	32	33	29	5	34
RNGASSET	Correlation Coefficient	0.299	0	0.113	-0.073	.	0.305
	Sig. (2-tailed)	0.086	1	0.533	0.705	.	0.08
	N	34	32	33	29	5	34
AVINCOME	Correlation Coefficient	-0.116	-0.093	-0.14	0.076	0.612	0.081
	Sig. (2-tailed)	0.482	0.57	0.394	0.656	0.272	0.621
	N	39	40	39	37	5	40
RNGINC	Correlation Coefficient	.342(*)	0	0.146	0.154	.	0.262
	Sig. (2-tailed)	0.033	1	0.376	0.364	.	0.103
	N	39	40	39	37	5	40
HIVARINC	Correlation Coefficient	-.487(**)	0.166	-0.343	-.409(*)	0.236	-.466(*)
	Sig. (2-tailed)	0.007	0.389	0.074	0.038	0.764	0.011
	N	29	29	28	26	4	29

Table 4. Mann-Whitney U test (2-tailed) was used to test whether better outcomes obtained in cases where there were wealthy individuals who were dependent on the resource versus all other cases. The test was done for each of the five main outcomes using the grouping variable, **RICHDEPEND**. Test are repeated with (a) the aggregated data set, (b) with only fisheries cases and (c) with only irrigation cases. (*) indicates correlation at the 0.05 level.

	Abundance	Quality	RuleFoll	Sanction	Closure	Maintain
(a) Fisheries and Irrigation						
Mann-Whitney U	422.5	315.5 (*)	458	361	56	n/a
Z	-0.618	-2.356	-0.103	-0.291	-1.707	
Asymp. Sig. (2-tailed)	0.537	0.018	0.918	0.771	0.088	
(b) Fisheries						
Mann-Whitney U	56.5	45	53	25.5	28.5 (*)	n/a
Z	-0.593	-0.92	-0.812	-1.309	-2.091	
Asymp. Sig. (2-tailed)	0.553	0.357	0.417	0.19	0.037	
(c) Irrigation						
Mann-Whitney U	141	136 (*)	162	170.5	1	178.5
Z	-1.152	-2.118	-0.542	-0.016	-1.333	-0.31
Asymp. Sig. (2-tailed)	0.249	0.034	0.588	0.988	0.182	0.757

Table 5. Spearman's rank correlations (2-tailed) of main outcomes with indicators of dependence on resource. Test are repeated with (a) the aggregated data set, (b) with only fisheries cases and (c) with only irrigation cases. (*) indicates correlation at the 0.05 level, (**) indicates correlation at the 0.01 level.

		Abundance	Quality	RuleFoll	Sanction	Closure	Maintain
(a) Fisheries and Irrigation							
SIMDEPEN	Correlation Coefficient	0.128	.250(*)	0.06	0.2	-.533(**)	
	Sig. (2-tailed)	0.242	0.022	0.606	0.1	0	
	N	86	84	77	69	42	
HIDEPEN	Correlation Coefficient	0.133	0.03	-0.056	-0.152	0.055	
	Sig. (2-tailed)	0.255	0.8	0.642	0.223	0.747	
	N	75	75	72	66	37	
LOSUBNOT	Correlation Coefficient	-0.146	.351(*)	.337(*)	0.227	0.067	
	Sig. (2-tailed)	0.286	0.011	0.015	0.138	0.701	
	N	55	52	52	44	35	
LOALTSUP	Correlation Coefficient	-0.027	0.165	0.184	0.033	-.567(**)	
	Sig. (2-tailed)	0.821	0.172	0.136	0.801	0.001	
	N	75	70	67	60	33	
(b) Fisheries							
SIMDEPEN	Correlation Coefficient	-0.1	.336(*)	-0.043	.	-.552(**)	
	Sig. (2-tailed)	0.554	0.045	0.82	.	0	
	N	37	36	30	24	36	
HIDEPEN	Correlation Coefficient	0.209	0.118	0.054	-0.368	0.16	
	Sig. (2-tailed)	0.251	0.526	0.775	0.077	0.39	
	N	32	31	31	24	31	
LOSUBNOT	Correlation Coefficient	-0.168	0.144	.388(*)	0.348	0.23	
	Sig. (2-tailed)	0.342	0.441	0.028	0.088	0.214	
	N	34	31	32	25	31	
LOALTSUP	Correlation Coefficient	0.033	0.097	0.26	0.076	-.598(**)	
	Sig. (2-tailed)	0.86	0.629	0.191	0.749	0.001	
	N	31	27	27	20	27	

(c) Irrigation

SIMDEPEN	Correlation Coefficient	0.221	0	0.155	0.252	.	0.196
	Sig. (2-tailed)	0.127	1	0.297	0.095	.	0.172
	N	49	48	47	45	6	50
HIDEPEN	Correlation Coefficient	0.015	-0.187	-0.172	-0.019	-0.402	-0.079
	Sig. (2-tailed)	0.923	0.225	0.283	0.904	0.429	0.611
	N	43	44	41	42	6	44
LOSUBNOT	Correlation Coefficient	0.242	0.288	0.385	0.219	0.816	0.128
	Sig. (2-tailed)	0.29	0.206	0.093	0.367	0.184	0.582
	N	21	21	20	19	4	21
LOALTSUP	Correlation Coefficient	-0.052	0.125	0.146	0.086	0.402	0.149
	Sig. (2-tailed)	0.738	0.424	0.369	0.599	0.429	0.34
	N	44	43	40	40	6	43

Table 6. Spearman's rank correlations (2-tailed) of main outcomes with sociocultural variables, and levels of trust. Test are repeated with (a) the aggregated data set, (b) with only fisheries cases and (c) with only irrigation cases. (*) indicates correlation at the 0.05 level, (**) indicates correlation at the 0.01 level.

		Abundance	Quality	RuleFoll	Sanction	Closure	Maintain
(a) Fisheries and Irrigation							
TRUST	Correlation Coefficient	0.1	0.142	.614(**)	.252(*)	-0.247	
	Sig. (2-tailed)	0.379	0.216	0	0.045	0.12	
	N	80	78	73	64	41	
CULTVWR	Correlation Coefficient	.255(*)	.326(**)	-.243(*)	-0.099	-0.231	
	Sig. (2-tailed)	0.029	0.005	0.04	0.434	0.204	
	N	74	72	72	64	32	
AVEHET	Correlation Coefficient	-0.129	-.299(**)	0.048	0.043	.497(**)	
	Sig. (2-tailed)	0.248	0.007	0.69	0.734	0.001	
HIHET	Correlation Coefficient	0.216	0.042	-.242(*)	-0.2	0.093	
	Sig. (2-tailed)	0.051	0.71	0.039	0.11	0.575	
	N	82	80	73	65	39	
(b) Fisheries							
TRUST	Correlation Coefficient	-0.128	0.187	.424(*)	0.023	-0.215	
	Sig. (2-tailed)	0.451	0.276	0.019	0.915	0.208	
	N	37	36	30	23	36	
CULTVWR	Correlation Coefficient	-0.208	-.539(**)	-0.279	.467(*)	0.126	
	Sig. (2-tailed)	0.288	0.004	0.151	0.028	0.522	
	N	28	27	28	22	28	
AVEHET	Correlation Coefficient	0.257	-0.121	0.103	-0.031	.368(*)	
	Sig. (2-tailed)	0.131	0.488	0.596	0.89	0.03	
	N	36	35	29	23	35	
HIHET	Correlation Coefficient	.375(*)	-0.026	0.042	-0.065	0.154	
	Sig. (2-tailed)	0.024	0.882	0.827	0.768	0.378	
	N	36	35	29	23	35	

(c) Irrigation

TRUST	Correlation Coefficient	0.227	-0.066	.678(**)	.392(*)	-0.148	.513(**)
	Sig. (2-tailed)	0.143	0.677	0	0.011	0.812	0
	N	43	42	43	41	5	44
CULTVWR	Correlation Coefficient	0.063	-.302(*)	-0.272	0.188	.	-0.134
	Sig. (2-tailed)	0.676	0.043	0.074	0.233	.	0.368
	N	46	45	44	42	4	47
AVEHET	Correlation Coefficient	-0.178	-0.169	0.009	-0.031	-0.333	-0.114
	Sig. (2-tailed)	0.237	0.267	0.956	0.847	0.667	0.444
	N	46	45	44	42	4	47
HIHET	Correlation Coefficient	-0.114	-.396(**)	-.460(**)	-0.139	.	-.337(*)
	Sig. (2-tailed)	0.451	0.007	0.002	0.382	.	0.021
	N	46	45	44	42	4	47