TOWARD A NEW INSTITUTIONAL ANALYSIS OF SOCIAL-ECOLOGICAL SYSTEMS (NIASES): COMBINING ELINOR OSTROM'S IAD AND SES FRAMEWORKS

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1. Introduction

The late Elinor Ostrom was justly famous not only for her empirical investigations into common-property governance of common-pool resources but also for the development of analytical frameworks to facilitate cross-disciplinary research using various theories, models, and methods.[1] The Institutional Analysis and Development (IAD) framework she developed (along with colleagues from the Workshop in Political Theory and Policy Analysis) has been widely adopted by social scientists to study both discrete cases and institutional change over time (see, e.g., Ostrom and Cox 2010; Ostrom 2007a; Andersson 2006; Rudd 2004; Tang 1992); and is one of the leading frameworks in the policy sciences (Sabatier 2007). The strength of the IAD framework stems from "its systematic theoretical focus on the impact of rules and norms on individual incentives in complex ecological-economic systems, its empirically oriented focus on outcomes (including the transaction costs of management) and by its accounting for dynamic systemic interactions at multiple tiers of analysis" (Rudd 2004, p. 2010). Quite simply the IAD framework recognizes the complexity of the world around it; but provides researchers with a tool to integrate knowledge by leveraging the strengths of multiple methods. Although the framework is sufficiently general to explore a wide range of research questions unrelated to the environmental issues; it has had its greatest influence with regards to the design and analysis of environmental policies.

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[1] In Ostrom's vocabulary, the terms "frameworks," "theories," and "models" are all terms of art. "Frameworks" are the "most generalized form of theoretical analysis," providing a general set of variables that comprise a meta-language, which is used for comparative institutional analyses of various "theories" and "models" of social-ecological conditions and interactions. "Theories" (e.g., economic theory or game theory) are comprised of working assumptions and hypothesized specifications of relevant variables (provided by the framework) deemed sufficient to provide adequate explanations or diagnoses of social or social-ecological conditions. "Models" (e.g., the rational actor model or game-theory models) use more "precise assumptions about a limited set of variables and parameters to derive precise predictions about the results of combining these variables using a particular theory." See Ostrom (2011, pp. 8-9). Ostrom and Cox (2010, p. 5) suggest that "frameworks" may best be thought of as "metatheoretical conceptual map[s]."

The IAD framework was often promoted as an interdisciplinary research tool with which social and natural scientists could build knowledge concerning the sustainability of social-ecological systems. However, after many years of criticism and complaints that the that the IAD framework paid insufficient attention to the great diversity and complexity of natural systems and processes (Ostrom and Cox 2010, p. 6; Berkes and Folke 1998; Young 2002; Agrawal 2003), Ostrom and her colleagues responded by developing the Social-Ecological Systems (SES) framework (Ostrom 2007b, 2009; Ostrom, Janssen and Anderies 2007; Anderies, Janssen, and Ostrom 2004; Ostrom and Cox 2010; McGinnis and Ostrom 2014). The SES framework incorporates large, decomposable sets of social and ecological attributes that potentially affect choices and outcomes in SESs. Although not utilized as widely as the IAD framework (Epstein et al. 2013), the SES framework is very useful for understanding and diagnosing problems in complex social-ecological systems (see, e.g., Ostrom and Cox 2010) where outcomes arise as a result of the interplay of multiple attributes such as the combination of leadership, social capital and spatial management plans (Gutierrez et al. 2011). It also facilitates data coding for purposes of meta-analyses and quantitative assessments across numbers of cases (see, e.g., Ostrom and Cox, p. 9; Epstein et al. 2013).

Ostrom (2011, p. 9) intended the "broader" SES framework to fully "integrate" with and therefore subsume, the IAD framework. But the SES framework suffers from important deficiencies that have prevented it from replacing the IAD framework. Most importantly, the SES framework lacks the dynamic character of the IAD framework. Therefore, although the static SES framework may be used to identify combinations of SES attributes associated with some outcome it simply provides no basis for explaining how those attributes interacted to generate that outcome, let alone predicting or prescribing changes to social-ecological conditions over time. As a result, scholars are forced to choose between the finely-detailed but static SES framework or the dynamic but underspecified IAD framework.

The purpose of this paper is to remedy the chief problems of each of Ostrom's analytical frameworks simply by combining them. However, instead of amending (or expanding) the SES framework to subsume the IAD framework, as Ostrom initially intended, this paper proposes a converse solution, incorporating the SES variables directly into the existing IAD framework's set of "pre-existing conditions." That simple expedient enables the IAD framework to deal with higher levels of ecological and social complexity and improves the framework's utility for meta-analyses and quantitative studies, while retaining its invaluable dynamism for understanding, predicting, and possibly even prescribing institutional change over time.

The next section of this paper shows how the two frameworks might easily be combined. Although the process itself is quite simple and intuitive, the resulting framework has important benefits over either the IAD and SES frameworks alone, and allows for rigorous analysis of the social and ecological processes that contribute to SES outcomes. Section 3 shows how the combined IAD-SES framework operates in the hypothetical context of Hardin's open-access pasture. Section 4 demonstrates its utility in a real-world empirical and dynamic context of Maine's lobster fisheries (Acheson 1988, 2004, 2013). Section 5 provides further discussion and possible extensions of that analysis. And Section 6 concludes the paper with a discussion of remaining deficiencies of the

combined IAD-SES framework, which require additional work in order to establish a truly "New Institutional Analysis of Social-Ecological Systems" or "NIASES".[2]

2. The Combined IAD-SES Framework

As mentioned previously, the procedure for combining the IAD and SES framework is quite simple. Start with the basic IAD framework (Fig. 1):

[Insert Figure 1 about here.]

The only alteration in this depiction of the IAD framework, compared to Ostrom's (2011, p. 10, Fig.1; Ostrom and Cox 2010, p. 5, Fig. 1) own version, is the characterization of three sets of factors that feed into action situations that what were often labelled as "Exogenous Variables" (or sometimes "External Variables"). That label was misleading because each of those categories – biophysical conditions, community attributes, and rules-in-use – are endogenized to the framework by virtue of the feedback loop from interactions and outcomes. Consequently, we prefer the label "pre-existing conditions," which simply denotes or characterizes potentially relevant social and ecological variables immediately preceding the analysis of a focal action situation (or action situations).

Now compare the SES framework (Fig. 2):

[Insert Figure 2 about here.]

This basic SES framework (as modified by Epstein et al. 2013) presents seven first-tier categorical components of SESs affecting interactions and outcomes in focal action situations: Resource Systems (RS); Resource Units (RU); Governance Systems (GS); Actors (A); Related Social, Economic and Political Systems (S); Ecological Rules (ER); and Related Ecosystems (ECO). Each of those first-tier components are defined by a set of attributes that are further decomposable into second-, third-, and in some cases even fourth-tier variables (as in Table 1), allowing for increasingly finely-grained analyses of social and ecological conditions, which is the chief strength of the SES framework.

The action situation appears once again as a centerpiece of the SES framework ostensibly sharing the concept of focal action situations, interactions and outcomes with the IAD framework. Similarly, it incorporates feedback mechanisms to allow for dynamic analyses; but the mechanism(s) by which feedback occurs, and how the feedback affects social and ecological conditions, is opaque and would likely lead to idiosyncratic implementation. Perhaps for that reason, the SES framework has been used for static analysis, useful mainly (or only) for describing or diagnosing, albeit to a very fine level of analysis, of existing conditions (Gutierrez et al. 2011;

[2]Elinor Ostrom and Michael McGinnis initiated efforts to combine the IAD and SES frameworks as part of a "Program in Institutional Analysis of Social-Ecological Systems," or PIASES (see McGinnis and Ostrom 2010). Our replacement of "Program" with "New" reflects our belief that the word "program" lacked a clear meaning or purpose, while the word "new" signifies a framework intended to succeed the SES and IAD frameworks, while also evoking the "new institutional" movement in social sciences, which Ostrom generally embraced (along, it must be said, with much of the "old" or "classical" institutionalism) (see, e.g., McGinnis 1996, p. 740). In addition, the present approach is moving in a substantially different, and therefore "new," direction from Ostrom and McGinnis's initial efforts.

Cinner et al. 2012). In contrast to the IAD framework, it has not been used to examine how dynamic social and ecological processes can change institutional and ecological conditions over time or to predict how changes to one more institutional attributes, might alter social-ecological outcomes.

Table 1. Second- and Third-tier SES Variables

Resource Systems	Resource Units	Governance Systems	Actors	Action Situations
1) Sector 2) Boundary clarity 3) Size a) Area b) Volume 4) Infrastructure 5) Productivity 6) Equilibrium properties a) Recharge dynamics b) Recharge rate c) Number of equilibria d) Feedbacks i) Positive ii) Negative 7) Predictability 8) Storage capacity 9) Location	1) Resource unit mobility 2) Replacement rate 3) Interactions a) Strong to weak b) Predatory or symbiotic 4) Economic value 5) Size a) Large to small b) Trophic level 6) Distinctive markings 7) Distribution a) Spatial heterogeneity b) Temporal heterogeneity	1) Rules a) Operational b) Collective-choice c) Constitutional 2) Property-rights regime a) Private b) Public c) Common d) Mixed 3) Network structure a) Centrality b) Modularity c) Connectivity d) Number of levels	1) Group size 2) Socioeconomic attributes a) Economic b) Cultural 3) History of use 4) Location 5) Leadership 6) Social capital 7) Knowledge of SES 8) Resource dependence 9) Technology used	1) Process a) Monitoring i) Environmental ii) Social b) Sanctioning c) Conflict resolution d) Provision i) Informational ii) Infrastructural e) Appropriation f) Policymaking

Source: Ostrom and Cox (2010)

A closer comparison of Ostrom's two frameworks reveals that all of the SES variables already are contained, at least in theory, within the IAD framework. The SES framework's "RS," "RU," "GS," and "A" variables (and their sub-variables) are, in fact, the elements that populate the "Biophysical Conditions," "Community Attributes," and "Rules-in-Use" boxes of the IAD framework. Figure 3 obviates this point simply by substituting the first-tier SES variables (which remain decomposable into various sub-variables) for the original IAD boxes.[3]

[Insert Figure 3 about here.]

The RS and RU variables represent the IAD's old "biophysical conditions" or "nature of the good." The GS category includes the "rules-in-use' of the IAD framework, and the Actor category includes factors originally labeled "attributes of the community" as well as the decisional capabilities of actors that were, in earlier versions of the IAD framework, directly incorporated within the action situation. Nothing that was in the IAD framework has been lost, and the potential for more finely-grained analysis and more consistent coding of variables across cases has been

[3] We have intentionally excluded Ostrom's first-tier variables concerning Related Ecosystems (ECO) and Related Social, Economic, and Political Systems (S), and Ecological Rules (ER) because they have not yet been as well developed in the literature as those we have included. However, it should be clear how easy it would be to plug them into what otherwise remains to all extent and purposes the original IAD framework. In section 5, Related Ecosystems are brought into play in an extension of the framework.

improved. By the simple expedient of incorporating the SES variables directly into the existing IAD framework, we have at once resolved a major perceived deficiency of the IAD framework – lack of due attention to complex ecological variables – and a major perceived deficiency of the SES framework – lack of dynamism, restricting the framework's utility to purely diagnostic purposes, with no ability to predict or explain either distinct institutional or co-produced social-ecological changes over time. Now, as part of the dynamic IAD framework, it is clearer how social interactions/decisions lead to outcomes that affect those SES variables.

3. A Hypothetical Application of the Combined IAD-SES Framework: Hardin's Pasture

Cole, Epstein, and McGinnis (2014) revised Ostrom's application of the SES framework to Hardin's Herder Problem (a.k.a., "the tragedy of the commons"). The purpose was to demonstrate that Hardin's "tragedy" arises from a far more complex institutional structure than either Ostrom or Hardin suggested. It is not just about the open-access pasture but a larger Governance System that combines various property rules and allocation mechanisms that together create incentives for herders to overuse the pasture. Specifically, in addition to the open-access (*res communes omnium*) pasture, Hardin's tragic situation involves privately owned (*res privatæ*) cattle, unowned but appropriable (*res nullius*) grass, markets in which cattle are bought and sold pursuant to enforceable contracts, and other background institutions. The tragedy did not result from the *absence* of institutions but rather a mismatched set of institutions governing three interacting resources that generated the destructive incentives.

Figure 4 locates all variables in this revised SES application within the new combined IAD-SES framework. This combined IAD-SES formulation of the Herder Problem adds two main values to the revised SES analysis. First it incorporates the dynamic element of the IAD framework by explicitly linking the outputs and outcomes of action situations over one snapshot to the set of social and ecological conditions (i.e. Resource Systems, Resource Units, Governance Systems, and Actors) in place for subsequent interactions. Second, it draws attention to the IAD framework's "Evaluative Criteria" which allows for critical (social as well as individual) reflection on the social-ecological interactions and outcomes, wherein actors may deliberately consider changing institutions or the values upon which they are assessed, in subsequent collection-choice action situations, in order to alter incentives and potentially improve future outcomes. The "Evaluative Criteria" remains an underdeveloped element of the IAD framework, which we plan to flesh out in subsequent work on the NIASES project.

[Insert Figure 4 about here.]

4. A Dynamic Application of the Combined IAD-SES Framework: Acheson's Maine Lobster Fishery

This application of the combined IAD-SES framework to Hardin's "tragedy" demonstrates the value of digging deeper into the institutional structure of SES processes; the value of a framework ultimately rests in its ability to describe and/or diagnose real-world phenomena. To demonstrate its empirical utility, we apply the combined IAD-SES framework to the famous case of Maine's

lobster fishery, as described in series of publications, including Acheson (1988, 1997, 2004, 2013); Acheson and Wilson (1996); and Wilson, Acheson, and Johnson (2013).

Resource unit variables. Lobsters are mobile resources. Younger lobsters are fairly sedentary, and are typically caught within a two-mile radius of where they are born. Older lobsters can range more widely and generally inhabit deeper waters, but exhibit seasonal migrations from deeper waters in the winter to shallower waters in the summer. Female lobsters reproduce within relatively small geographic areas, but carry their egg broods for 9-11 months; and they have an unusually long reproductive life. Lobsters are vulnerable to predators by other marine species, including groundfish (RU3), especially in the early stages of their life cycle.

Resource system variables. Natural system boundaries (RS1) tend to be fairly distinct for lobsters as a result of their life history characteristics that confine activities to a fairly narrow geographical range. This facilitates the use of territoriality in the governance system, although in some cases the area is large enough to create assignment, monitoring, and sanctioning problems. The success of conservation efforts depends significantly on the ability of local lobster fishers to exclude outsiders. Fortunately, most lobster fishing areas are near the shore, which facilitates exclusion, monitoring, and sanctioning.

Actor variables. Lobster fishers share many demographic characteristics in addition to their location, including similar income-levels and social status. Many of them also are second- or third-generation lobster fishers. It is generally an occupation without a great deal of entry or exit, particularly since the 1940s, when harbor gangs and licensing systems acted as a barrier to entry. Although lobster fishers compete with one another for resource units, and at time groups have experienced considerable conflict amongst themselves, user attributes have generally favored cooperation with regards to the design and implementation of conservation policies.

Governance system variables. The rules used to manage Maine's lobster fishery have changed significantly on numerous occasions since the commercial fishery was founded around the 1840s. We divide the governance system into five historical eras: 1840-1860; 1860-1895; 1896-1940; 1941-1977; and 1977-1995. The first represents an era of "open access;" the second represents an era of increasing pressure on the resource and the initial, competitive and unsuccessful, efforts at management using state legislative mechanisms; the third represents an era of continuing governance failure; the fourth, an era of successful self-management, eventually nested within supportive state and federal rules; and the fifth, essentially a continuation of the fourth, with only minor changes. Our dynamic application of the combined IAD-SES framework to the Maine lobster fishery tracks these phases. The dynamism of framework is not represented by a feedback loop in each figure; rather it is captured in the transition from one figure to the next, as the "outcomes" from one (preceding) phase affect the "initial conditions" in the next phase.

Phase 1: 1840-1860. Originally, as might be expected, the lobster fishery was treated as "open-access." In other words, no governance system directly restricted access or use of the fishery; and this was likely efficient. Lobsters were mainly sold locally and in small enough numbers that little pressure was placed on the resource. The combined IAD-SES depiction of Phase 1 is straightforward.

[Insert Figure 5 about here.]

Phase 2: 1860-1895. Canning operations developed by the 1860s, exponentially increasing the size of the market for Maine lobsters, allowing them to be sold over vastly greater distances. Live lobster traders were not *directly* competing with canners. The canners tended to target smaller lobsters as they were more efficiently canned; while live lobster traders favored larger lobsters. But their combined efforts led to declining harvests and a general recognition that something needed to be done to manage the fishery. The canners initially succeeded in lobbying for rules prohibiting the taking of egg-carrying ("berry") lobsters; minimum size restrictions applied only when canners were busy with other products. However, the canners' success proved short-lived, in part for reasons of geography. Lobster traders were concentrated in vote-rich population centers, while canners were located in just two, lightly populated counties. Over time, lobster traders leveraged their electoral advantages in the Maine legislature, successfully pushing for legislation that applied minimum-size rules throughout the year, which effectively put the canners out of business. Although by 1898 landings had fallen by about two million pounds, lobster fishers had begun to build a sense of shared interest and social capital from their experience with successful self-organization.

[Insert Figure 6 about here.]

Phase 3: 1896-1940. This period is generally characterized as one of governance failure with declining catches and high levels of non-compliance. In fact, the period experienced a fairly unique combination of declining catches and declining economic value that put a number of fishers out of business (although the total number of license holders did increase again by 1940). The Maine fisheries commission began to play an active role in the regulation of fishing activities, most notably under the entrepreneurial leadership of Commissioner Crie in the 1930's. Along with lobster fishers, Crie lobbied the federal government to ban lobster imports from Canada, and to advertise local lobster products. Although these efforts largely failed, they may have garnered the Commissioner support for new controversial measures within the State of Maine. A double gauge law, which established a minimum and maximum size for captured lobster was introduced and adopted in 1933. Acheson (1977) suggests that the entrepreneurial activities of the Commissioner likely titled the balance in favor of regulation in an industry that was pretty evenly split. Finally, the phase is also characterized by increasing consolidation of harbor or lobster "gangs," comprised of local fishers who set traps in near-shore areas, from which they attempted to exclude outsiders. Although these gangs continued to compete with one another for the same stock of lobster, they came from the same communities and interacted on a daily basis, which allowed them to develop mutual trust, along with a shared interest in protecting their fishing locations from outsiders. Ultimately, they self-organized to mutually enforce informal boundary rules using a variety of mechanisms that included cutting the lines of traps set by outsiders. As a consequence, the decline in lobster populations was curtailed.

[Insert Figure 7 about here.]

Phase 4: 1940-1977. Between 1940 and 1977, Maine's lobster fishery experienced a great recovery with landings increasing from about seven million pounds to eighteen million pounds; and licensed fishers increasing from 3717 to 8827. Despite the increased pressure, the combination of the

double gauge law, informal boundary rules and the addition of a v-notch law to the prohibition against egg-bearing females appears to have worked to adequately protect the breeding stock while allowing for considerably increased harvests. The V-notch rule was passed in 1947 and specified that fishers could mark an egg-bearing female with a V-shaped cut on the tail (which amounts to a humanly-created attribute of certain resource units), and that that lobster would subsequently be prohibited from sale until the notch disappeared. This allowed lobster fishers to return reproductive females, but also when caught by other fishermen provided an indirect indication of the trustworthiness of their peers. The harbor gangs became a more prominent feature of the fishery and enforced not only their territories but also conservation rules, which generated high levels of rule compliance. Finally in 1977, the Federal government and regional fisheries management organizations first entered the scene as a result of the passage of a Federal Act that aimed to reduce pressure on US fisheries from foreign fleets.

[Insert Figure 8 about here.]

Between 1977 and 1995, the most recent time period for which we have historical data, the fundamental structure of the fishery remained intact, with just a few tweaks to the system, mainly at higher levels of government, supporting local self-management.

[Insert Figure 9 about here.]

5. Discussion and Further Extensions

This application shows how combining the SES framework with the IAD framework effectively leverages the dynamism of the latter to improve the utility of the former for treating changing social and ecological circumstances over time. The detailed listing of key characteristics of this resource system in different time periods highlights those factors most important in marking the transition from one phase to the next.

However, this framework does not solve the problems of selecting relevant time periods and SES variables, which remains more of an art than a science. As Cole, Epstein, and McGinnis (2014) argue, the key is to select those SES variables that together are necessary and sufficient to explain the outcomes we see. With respect to choosing the relevant time periods for dynamic analysis, it seems a matter of looking for those periods during which significant institutional or ecological changes occur, to which evident outcomes or effects might be reasonably attributed.

This framework can also be used to support cross-case analysis. For example, it could be used to diagnose other resources that share the same marine ecosystem as the lobster, including sea urchins and groundfish, which can, in addition to institutional changes and exogenous shocks, affect lobster stocks and the success of lobster fishery management institutions. For example, Steneck and Wahle (2013) suggest that the success of the Maine lobster fishery – combining large harvests with increasing size of lobsters harvested – may have as much or more to do with declining groundfish populations that prey on lobsters than with institutional measures taken by local lobster fishers and higher-level governance units. Thus, a failure of local collective-action to protect one fishery may have contributed to the success of local collective-action to protect another. They

caution that the lobster population may itself be vulnerable to a rapid collapse, if its own food sources reach exhaustion levels.

In a similar vein, Wilson, Acheson, and Johnson (2013) investigate why community-based management of lobster fisheries has been so successful, whereas similar efforts to manage sea urchins and groundfish have so far yielded very disappointing results. The reason cannot lie in the differing social or economic characteristics of the respective communities, they argue, as all fisheries draw from the same stock of Maine residents. However, by focusing on interactions among the respective groups of resource users they are able to identify one critical difference that partially structures the incentives actors face in other, related action situations. Whereas lobster fishers routinely engage in extensive patterns of communication and information sharing, the other fisher groups do not. Wilson Acheson and Johnson further demonstrate that variations in information sharing are likely the result of the differing nature of the resources being harvested. In short, characteristics of the biophysical setting provided more or less compelling incentives for them to share information, and in doing so they were able to build the social ties and institutional practices needed to maintain the long-term viability of that fishery, in the case of lobsters, or not, in the other fisheries.

Even this brief discussion of Wilson, Acheson, Johnson's (2013) analysis suffices to make one significant point, namely, that different combinations of focal action situations may turn out to be most critical in longitudinal analyses of a single case versus cross-case comparisons. As noted above, Wilson, Acheson, and Johnson (2013) pay particular attention to information-sharing and self-organizing activities, neither of which was included in the figures we used to summarize the five phases of the Maine lobster fishery system. We did include the formation of lobster gangs as a critical step in phase 3, but we did not find it necessary to investigate in any detail the processes through which these informal organizations were built. The conditions that facilitated this form of self-organization became much more noticeable when making comparisons to cases with different conditions.

6. Conclusion

The main contribution of this paper is to show that combining the IAD and SES frameworks allows for deeper analyses of dynamic changes in social-ecological circumstances by making direct connections between institutional changes and social-ecological outcomes. By so doing, the Combined IAD-SES framework creates the potential not only for diagnosis and evaluation but *prediction* of social and ecological consequences of similar institutional changes in similar circumstances. Of course, selecting the correct variables – those that are both necessary and sufficient to understand outcomes and effects – remains both tricky and overwhelmingly important (see Cole, Epstein, and McGinnis 2014), as does selecting the time periods for analysis.

Much more work remains to be done before this combined IAD-SES framework can fulfill its potential as the foundation for a truly New Institutional Analysis of Social Ecological Systems (NIASES). For example, none of our figures on the Maine lobster fishery explored the "Evaluative Criteria" that might have played a significant role in outcome evaluation and/or the innovation of new management approaches (at various levels of governance). Moreover, where our analysis has presumed more or less direct feedbacks from institutional changes to SES variables, it is likely that

outcomes are highly variable in the way they affect social-ecological systems. And, as noted in the previous section, application of the combined IAD-SES framework (or any other analytical framework for that matter) is greatly complicated by ecological-system interactions that remain an active concern for many inter-disciplinary research teams.

Finally, it might well be argued that our treatment of the Maine lobster fishery has not been truly "dynamic," but more in the nature of a "comparative statics" analysis of two (not necessarily stable) equilibria, before and after alteration of some significant variable in the social-ecological system (see, e.g., Nachbar 2008).[4] Nevertheless, the combined IAD-SES framework is a significant advance on the *status quo ex ante*, which has been non-comparative statics analysis of social-ecological systems. Any truly dynamic (in real time) framework may end up being so complicated and unwieldy as to be virtually unusable. We have attempted to show that even relatively simple modifications to the IAD and SES frameworks can support significant moves forward.

The next step toward NIASES is to further refine and rationalize SES variables and more carefully develop elements of the IAD, including "evaluative criteria" and the relations between formal legal rules and "rules-in-use." Development of evaluative criteria is a crucial next move if only because it is the only element in the framework with potential normative implications, i.e., to tell actors what *should* be done to sustain social-ecological systems over time.

References

Acheson, James M. 1988. *The Lobster Gangs of Maine*. Lebanon, NH: University Press of New England.

Acheson, James M. 1997. "The Politics of Managing the Maine Lobster Industry: 1860 to the

_____. 2004. *Capturing the Commons: Devising Institutions to Manage the Maine Lobster Industry*. Lebanon, NH: University Press of New England.

_____. 2013. "Co-management in the Maine Lobster Industry: A Study in Factional Politics." *Conservation & Society*. 11(1):60-71.

Acheson, James M., and Roy Gardner. 2004. "Strategies, Conflict, and the Emergence of Territoriality: The Case of the Maine Lobster Industry." *American Anthropologist* 106 (2): 296–307.

_____. 2005. "Spatial Strategies and Territoriality in the Maine Lobster Industry." *Rationality and Society* 17 (3): 309–41.

_____. 2011a. "The Evolution of the Maine Lobster V-Notch Practice: Cooperation in a Prisoner's Dilemma Game," *Ecology and Society* 16(1): 41.

[4] Virtually by definition, if nothing changes after the alteration of a particular institutional variable, then that variable, at least by itself, would not be deemed "significant."

_____. 2011b. “Modeling Disaster: The Failure of the Management of the New England Groundfish Industry,” *North American Journal of Fisheries Management* 31:1005-1018.

Acheson, James M., and James A. Wilson. 1996. "Order out of Chaos: The Case for Parametric Fisheries Management." *American Anthropologist* 98 (3):579-94.

Agrawal, Arun. 2003. “Sustainable governance of common-pool resources: context, methods, and politics. *Annual Review of Anthropology* 32: 234-262.

Anderies, John M., Marco A. Janssen, and Elinor Ostrom. 2004. “A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective,” *Ecology and Society*. 9: 18 [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art18.

Andersson, Krister. 2006. “Understanding decentralized forest governance: an application of the institutional analysis and development framework.” *Sustainability: Science, Practice, & Policy* 2: 25-35.

Berkes, Fikret and Carl Folke, eds. 1998. *Linking Social and Ecological Systems: Management Practices for Social Mechanisms for Building Resilience.* Cambridge, UK: Cambridge University Press.

Cinner, Joshua E., Tim R. McClanahan, M. Aaron MacNeil, Nicholas A. J. Graham, Tim M. Daw, Ahmad Mukminin, David A. Feary, Ando L. Rabearisoa, Andrew Wamukota, Narriman Jiddawi, Stuart J. Campbell, Andrew H. Baird, Fraser A. Januchowski-Hartley, Salum Hamed, Rachael Lahari, Tau Morove, and John Kuange. 2012. Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences* 109 (14): 5219-5222.

Cole, Daniel H., Graham Epstein, and Michael D. McGinnis. 2014. “Digging Deeper into Hardin’s Pasture: The Complex Institutional Structure of the ‘Tragedy of the Commons.’” *Journal of Institutional Economics* 10:353-369.

Epstein, Graham, Jessica M. Vogt, Sarah K. Mincey, Michael Cox, and Burney Fischer. 2013. “Missing ecology: integrating ecological perspectives with the social-ecological system framework.” *International Journal of the Commons*. 7(2): 432-453.

Gutierrez, Nicolas L., Ray Hilborn, and Omar Defeo. 2011. Leadership, social capital and incentives promote successful fisheries. *Nature* 470 (7334): 386-389.

McGinnis, Michael D. 1996. “Elinor Ostrom: A Career in Institutional Analysis.” *PS: Political Science & Politics.* 29:737-741.

McGinnis, Michael D and Elinor Ostrom. 2010. “IAD and SES Dynamic Flows: Introducing the Program in Institutional Analysis of Social-Ecological Systems (PIASES) Framework.” Unpublished conference paper, available on the Digital Library of the Commons:

http://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/9250/McGinnis%20%26%20Ostrom_IAD%20and%20SES%20Dynamic%20Flows%204.pdf?sequence=1.

McGinnis, Michael D., and E. Ostrom. 2014. "Social-ecological system framework: initial changes and continuing challenges." *Ecology and Society* 19 (2): 30.

Nachbar, John. 2008. "Comparative Statics." *The New Palgrave Dictionary of Economics*. Second Edition. Eds. Steven N. Durlauf and Lawrence E. Blume. Palgrave Macmillan, 2008. The New Palgrave Dictionary of Economics Online. Palgrave Macmillan. 23 August 2014 <http://www.dictionaryofeconomics.com/article?id=pde2008_C000256> doi:10.1057/9780230226203.0275>.

Ostrom, Elinor. 2007a. "Institutional rational choice: an assessment of the institutional analysis and development framework. In: *Theories of the Policy Process,* 2d ed., ed., P.A. Sabatier, pp. 21-64. Boulder, CO: Westview Press.

_____. 2007b. "A diagnostic approach for going beyond panaceas." *Proceedings of the National Academy of Sciences* 104(39): 15181-15187.

_____. 2009. "A general framework for analyzing sustainability of social-ecological systems." *Science* 325: 419-422.

_____. 2011. "Background on the Institutional Analysis and Development Framework." *Policy Studies Journal* 39: 7-27.

Ostrom, Elinor and Michael Cox. 2010. "Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis." *Environmental Conservation* 37: 451-463.

Ostrom, Elinor, Marco Janssen, and John M. Anderies. 2007. "Going beyond panaceas." *Proceedings of the National Academy of Sciences* 104(39): 15176-15178.

Ragin, Charles C. 2000. *Fuzzy-set social science*. University of Chicago Press.

Rudd, Murray A. 2004. "An institutional framework for designing and monitoring ecosystem-based fisheries management policy experiments." *Ecological Economics* 48: 109-124.

Sabatier, Paul A. 2007. "The Need for Better Theories." In *Theories of the Policy Process, 2nd Edition*, ed. Paul A. Sabatier. Boulder, CO: Westview Press. 3-17.

Scopel, Darren A, Walter J Golet, and Winsor H Watson Iii. 2009. Home range dynamics of the American lobster, Homarus americanus. *Marine and Freshwater Behaviour and Physiology* 42 (1): 63-80.

Steneck, Robert S., and Richard A. Wahle. 2013. "American Lobster Dynamics in a Brave New Ocean," *Can. J. Fish. Aquat. Sci.* 70: 1612-1624.

Steneck, Robert S, Amanda Leland, Douglas C McNaught, and John Vavrinec. 2013. Ecosystem flips, locks, and feedbacks: the lasting effects of fisheries on Maine's kelp forest ecosystem. *Bulletin of Marine Science* 89 (1): 31-55.

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

Wilson, James A., James M. Acheson, and Teresa R. Johnson. "The cost of useful knowledge and collective action in three fisheries." *Ecological Economics* 96 (2013): 165-172.

Young, Oran. 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. Cambridge, MA: MIT Press.

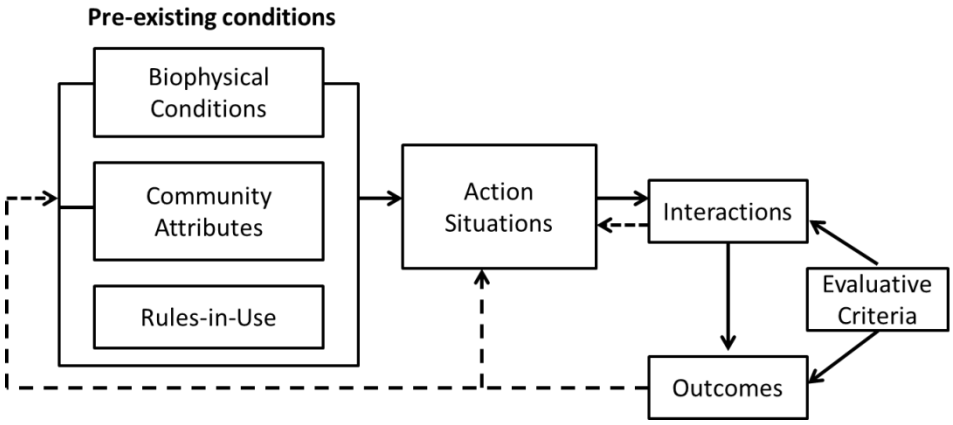

Figure 1. Basic Components of the IAD Framework
Source: Adapted from E. Ostrom (2010, p. 646)

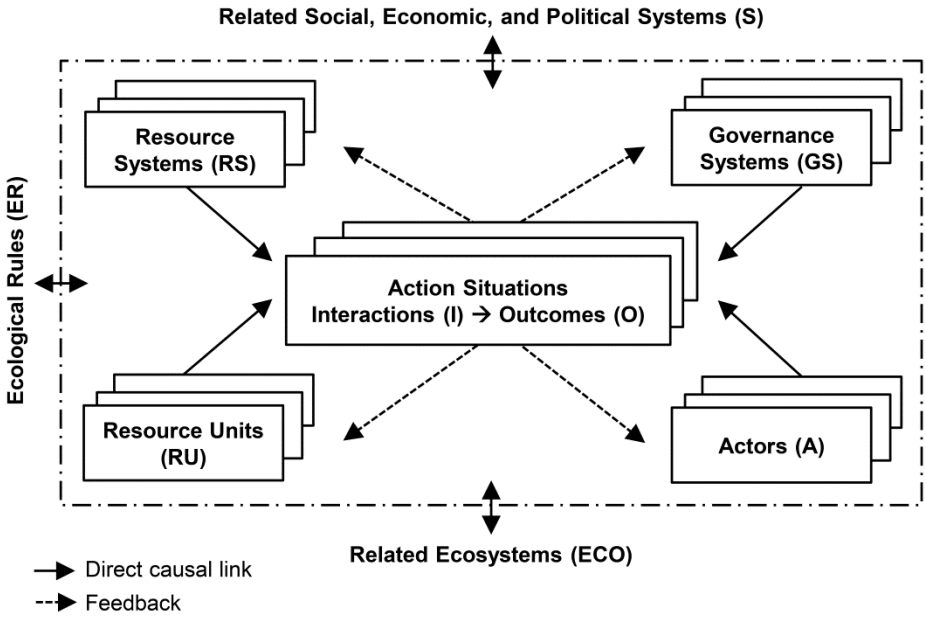

Figure 2. The SES Framework

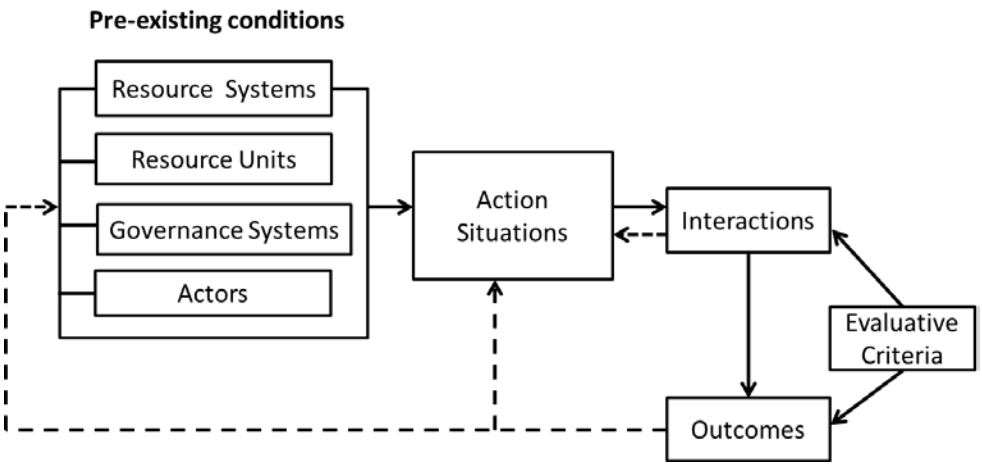

Figure 3. The Combined IAD-SES Framework

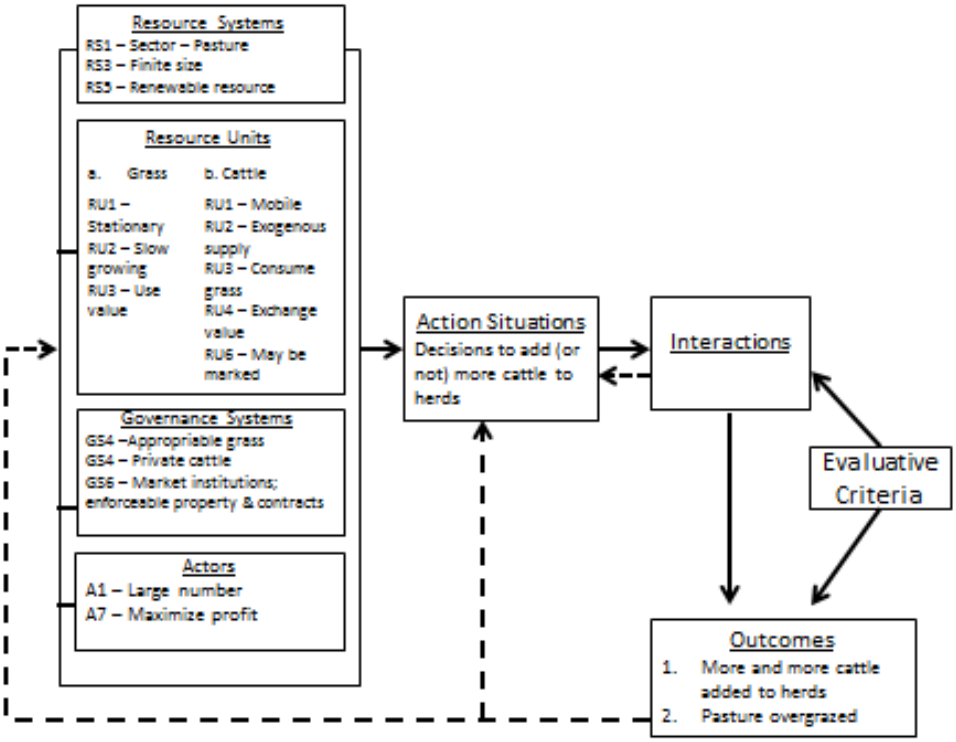

Figure 4. Combined IAD-SES Application to Hardin's Pasture

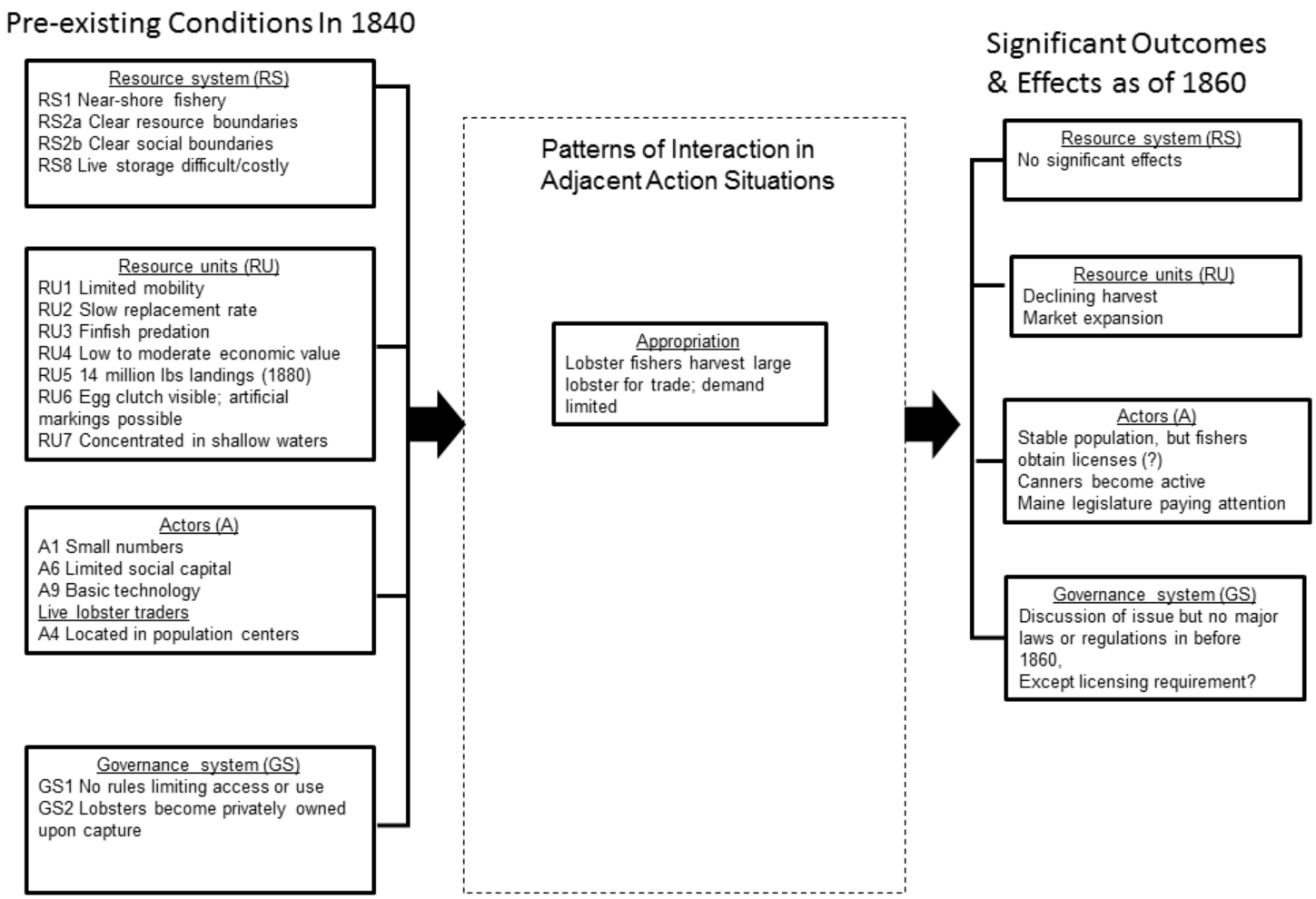

Figure 5. Combined IAD-SES Application to Maine Lobster Fishery, Phase 1: 1840-1860

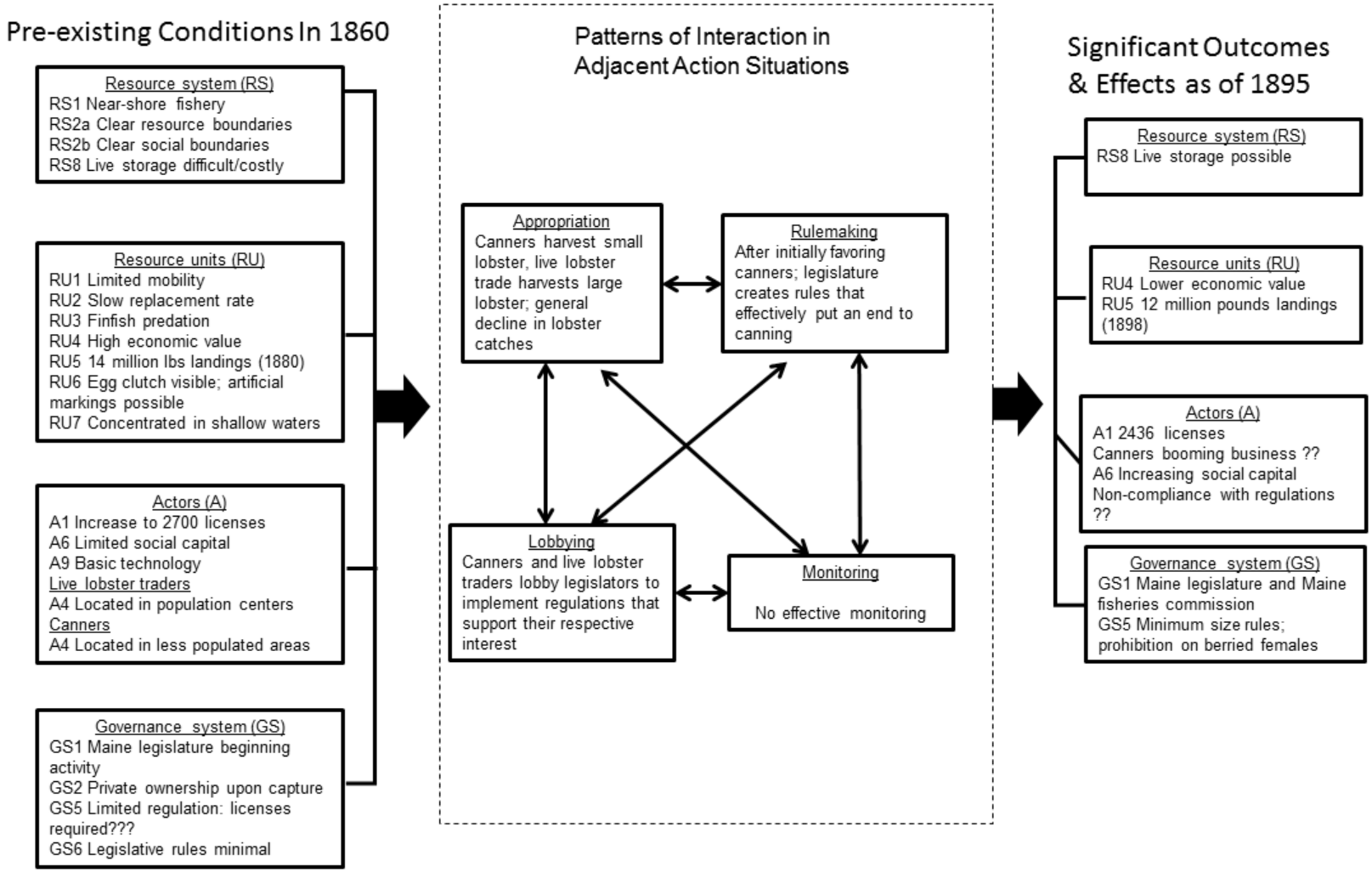

Figure 6. Maine Lobster Fishery, Phase 2: 1860-1895

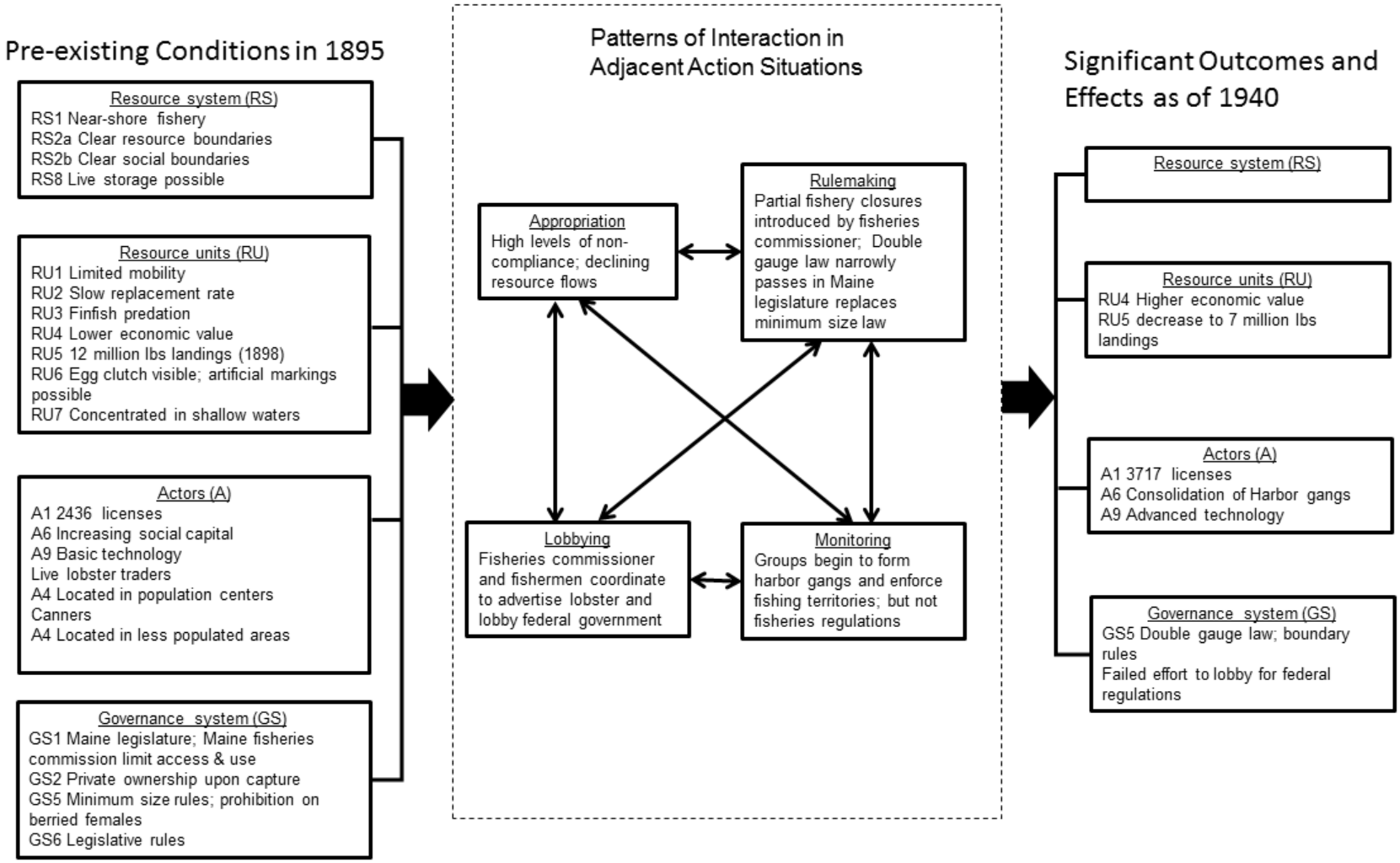

Figure 7. Maine Lobster Fishery, Phase 3: 1895-1940

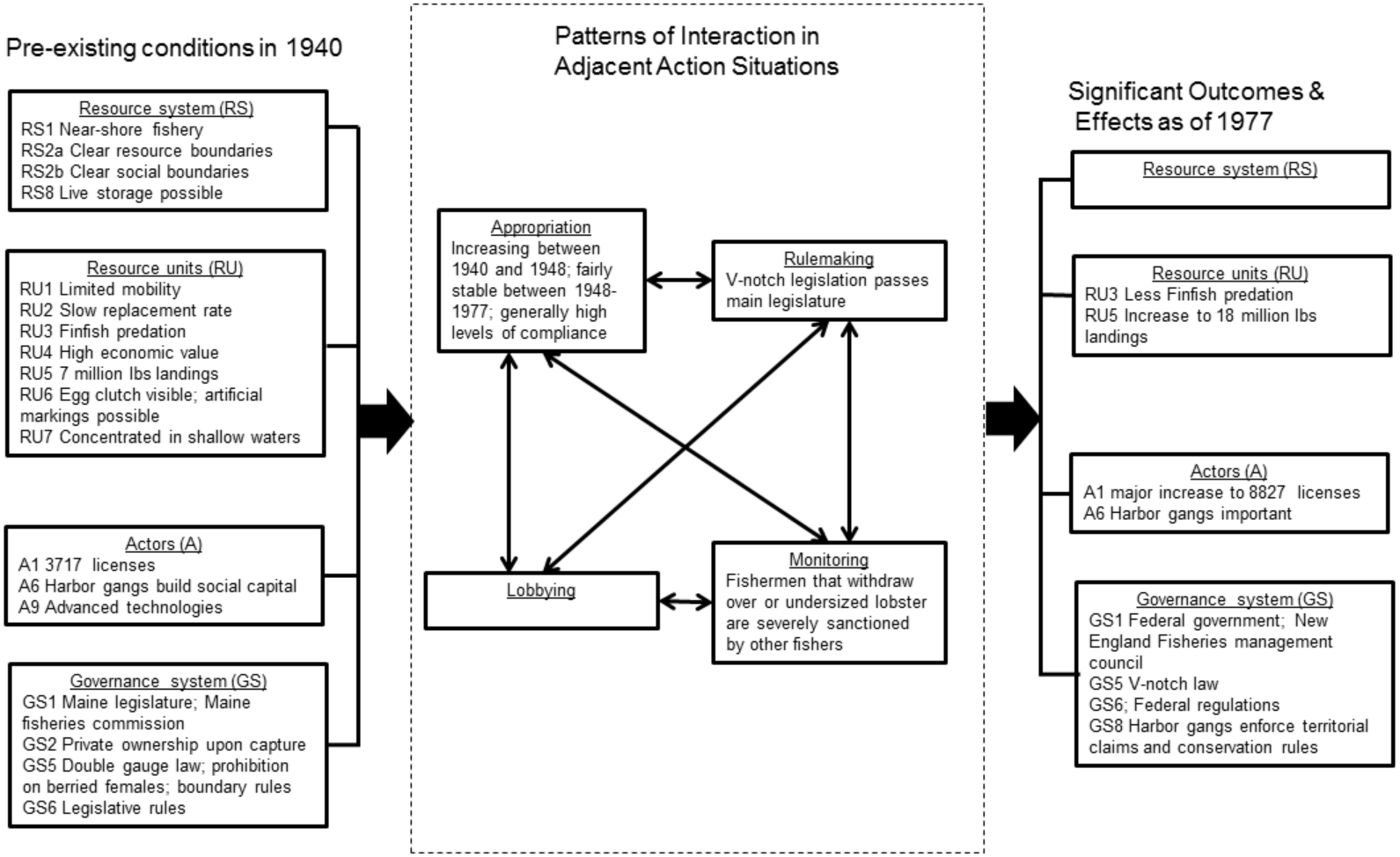

Figure 8. Maine Lobster Fishery, Phase 4: 1940-1977

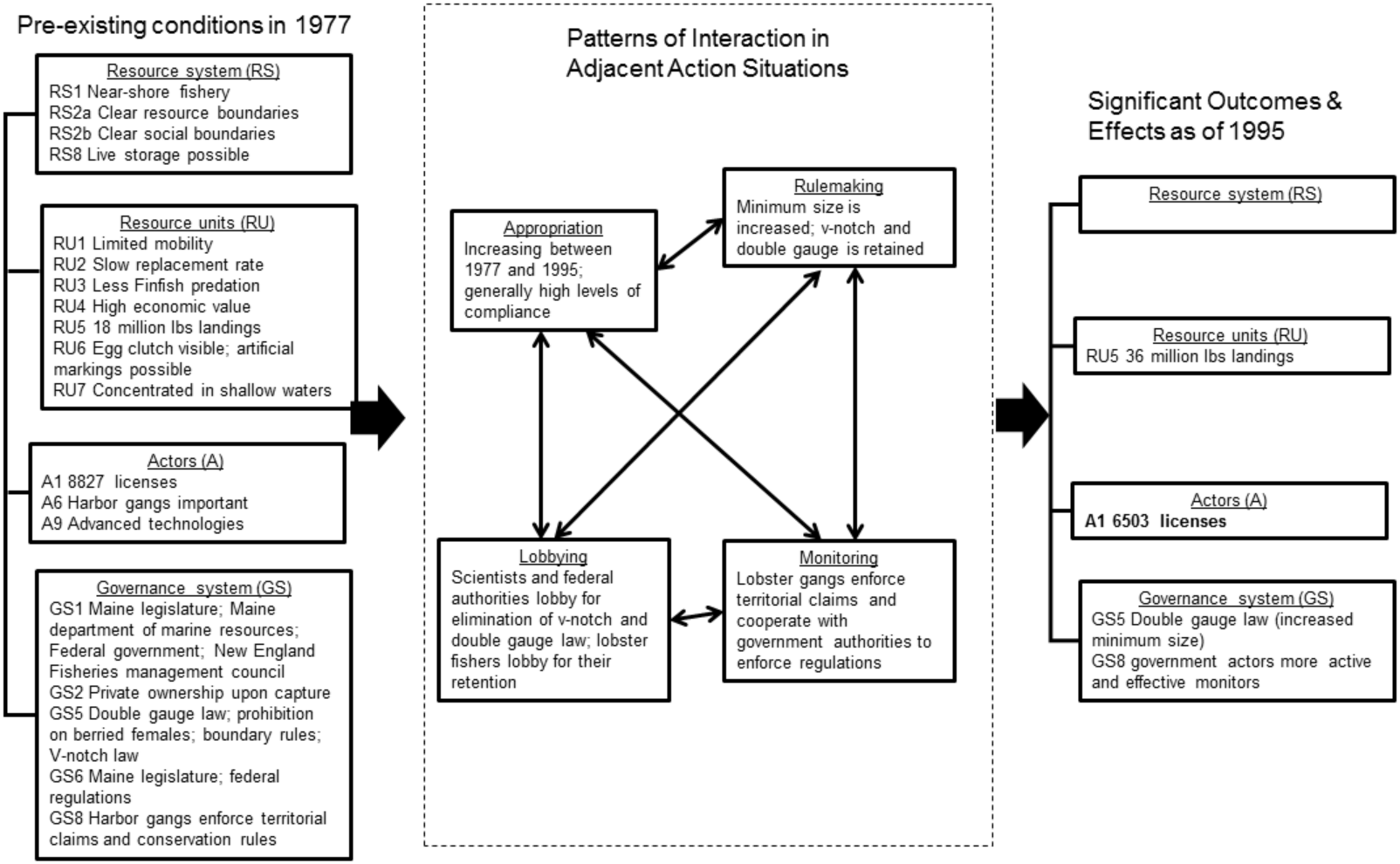

Figure 9. Maine Lobster Fishery, Phase 5: 1977-1995.