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Attentive maintenance models of social-ecological pastoral systems

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Key words: Resilience; Social-Ecological; Adaptive; Sustainability; Complex

Abstract

Pastoral societies have developed sophisticated institutions for managing persistent, sustainable social-ecological systems in nonequilibrium environments. These institutions operate at different geographic scales in different years, depending on the climate. This paper generalizes a methodology for modelling groups of related pastoral institutions as complex adaptive systems. The methodology then draws on hierarchy theory to detect inter-system relationships that are characteristic of social-ecological panarchies. I applied this methodology in southeast Amdo, Tibet (part of western China), an area with highly differentiated cultural and linguistic pastoral institutions. The methodology generated three interdependent models, which I termed "Attentive Maintenance Models" and which each describes complex adaptive systems at a distinct social-ecological scale: livestock herd composition, livestock herd movements, and dairy product flows. Each attentive maintenance model further reveals 1) degrees of freedom for influencing pastoral systems at that scale and 2) which institutions play similar roles to one another in enabling systems at that scale to persist. Historical qualitative data, sourced through semi-structured interviews, supports my theory that completely removing any one type of institution in an attentive maintenance model (e.g. those linked to ecological cycles, stochastic social events, or personal sentiments) precipitates system collapse across all scales. Since attentive maintenance models reveal the degrees of freedom for helping a system adapt as well as which of its types of institutions are most vulnerable for a lack of redundancy, I recommend using this methodology to assess the adaptive capacity, resilience, and vulnerability of pastoral social-ecological systems prior to forecasted types of political and climatic change. This framework reveals opportunities to reinforce resilience, adaptive capacity, sustainability, and risk management in existing pastoral systems through the development of educational resources about pastoral system function and the protection of functionally redundant institutions.

Introduction

In southeast Amdo, Tibet in western China, overlapping southern Gansu Province and northern Sichuan Province and at an elevation between roughly 3000 and 4000 meters, nomads historically managed the compositions of herds and flocks, the locations of herds and flocks, and the production and distribution of dairy products (Burnett, in press). They were attentive to ecological, social, and sentimental cues to manage these resources in particular ways: ecological cues such as physical, phenological, and physiological changes encouraged partial resource turnover; social cues such as ceremonies, celebrations, and chance

meetings encouraged partial resource recombination; and sentimental cues stemming from gratitude or long-term habits and relationships encouraged partial resource persistence (Burnett, in press). The combination of these types of resource management guided nomads in adapting their pastoral resources to the ever-changing environment.

Ellis and Swift (1988) theorized that pastoral ecosystems are often non-equilibrial: "strongly controlled by external forces rather than, or in addition to, internal biotic factors" (Ellis and Swift 1988:453). Yet, despite pastoral systems' sensitivity to external influences, Ellis and Swift observed in the region they studied—Ngisonyoka Turkana in northern Kenya—that "[the] ecosystem and its pastoral inhabitants are relatively stable" (Ellis and Swift 1988:453). Fernandez-Gimenez and Le Febre (2006) described how pastoral institutions—"the formal and informal rules, norms, and repeated patterns of interaction among people that guide individuals' behaviour with respect to the environment and other people" (Fernandez-Gimenez and Le Febre 2006:342)—support strategies of "flexibility, mobility, diversity, reserves and reciprocity" (Fernandez-Gimenez and Le Febre 2006:342) that enable pastoralists to persist in "patchy and unpredictable low-productivity environments" (Fernandez-Gimenez and Le Febre 2006:341). Burnett (2024a) demonstrated that such pastoral institutions in southeast Amdo, Tibet in western China are interdependent in a highly structured way, and Burnett (in press) modelled the structure of the interrelationships between pastoral institutions there, then used the resulting model to trace historical disturbances' effects on social-ecological resources—the resources that pastoralists traditionally had managed in response to ecological, social, and sentimental cues.

This paper generalizes Burnett's methodology of i) identifying social-ecological resources in a pastoral system, ii) identifying the pastoral institutions responsible for maintaining those social-ecological resources, iii) modelling the management of social-ecological resources using Attentive Maintenance Models (AMMs), and iv) embedding those AMMs into a Panarchical Model comprising nested sets of complex adaptive systems (Holling 2001; Gunderson and Holling 2002; Burnett 2024a; Burnett, in press). It then demonstrates that using Panarchical Models and AMMs can help people manage risk by predicting the combined effects of different policies and environmental changes on the resilience, adaptive capacity, and sustainability of a pastoral system.

Methodology for Modelling Pastoral Systems Using Attentive Maintenance Models

The first step in developing AMMs to include in a Panarchical Model of a pastoral system is to identify the system's social-ecological resources, as follows (Burnett 2024a; Burnett, in press):

1. Record, then translate into a written language, semi-structured interviews with people in their native dialects talking about the natural resources they depend on.
2. With each successive interview, adapt the topics/questions to better align with what past interviewees seemed excited or enthusiastic to talk about, talked about at greater length, or chose to talk about (especially when their responses did not directly answer the questions you had thought you were asking). If there is a strong division of labour in the management of natural resources between the different demographics of people that you interview, then the topics and questions you focus on will need to be fine-tuned independently for each demographic.
3. From the transcripts, compile a list of all the actions that people described having taken alongside whatever particular observations they had made that precipitated those actions. Some examples from southeast Amdo include: "winter → slaughter yaks and sheep for food," "livestock not happy → move the livestock," "meet somebody with a good yak → try to exchange livestock for it," "livestock fare poorly somewhere → avoid that location during that season in the future," and "feel for your past livestock and have excess butter → offer religious butter lamps" (Burnett, in press).

4. Divide the resulting list into three separate parts, one each for observations related to: physical, physiological, and phenological cycles; social happenings or events; and internal personal sentiments.
5. Identify things, concrete or abstract, that are directly affected by actions taken in all three parts of the list. The things will likely be describable in two parts: i) an ecological resource and ii) what is being managed about that ecological resource (e.g. "livestock" and "herd composition," "livestock herds" and "location," and "dairy products" and "flows of production and distribution"). These things are likely to be critical social-ecological resources within the system that you are studying.

For each social-ecological resource identified, an AMM can then be constructed that describes important ways that pastoralists manage the related ecological resource. An AMM is constructed using the following steps:

1. Subset the list that you compiled of sequences of observations and actions to include only those that directly affect the social-ecological resource for which you are making the current model.
2. Place the three parts of the subsetted list side-by-side: place the sequences associated with ecological observations in the left-hand column, sequences triggered by social events or observations in the middle column, and sequences related to sentiment, accrual, or persistence in the right-hand column.
3. Rephrase each sequence's action component as a decision that affects the available set of a single ecological resource (e.g. livestock in a herd or flock, pastures to move to, or dairy product recipients).
4. Use arrows to represent observations and draw boxes to represent consequent decisions that are made.
5. To simplify the diagram, multiple arrows may be pointed to a single box wherever different observations can lead to the same decision state. The final AMM should resemble Figures 1 and 2.

In Figure 1, observations (arrows) lead to decisions (boxes) about Set A of an ecological resource. Observation-decision sequences in the left column are triggered regularly by ecological observations. Sequences in the middle column are triggered stochastically by social observations. Sequences in the right column are triggered by sentiment. An emergent attribute of Set A becomes a social-ecological resource that adapts based on the interplay of decisions being made at these three different frequencies.

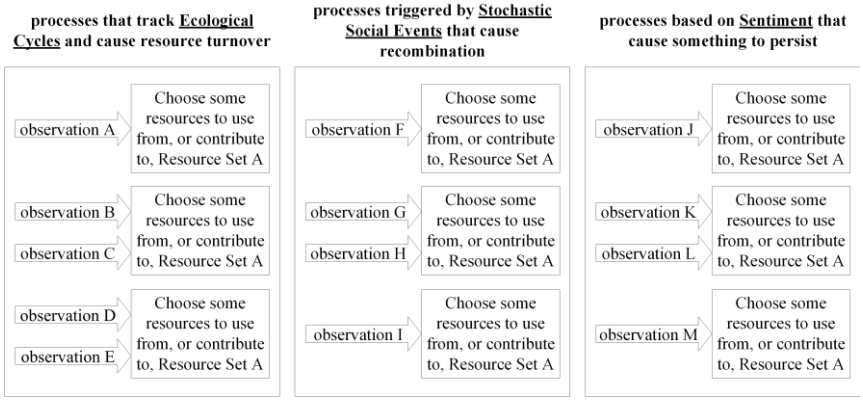

Figure 1: Schema of an Attentive Maintenance Model (Burnett 2024b)

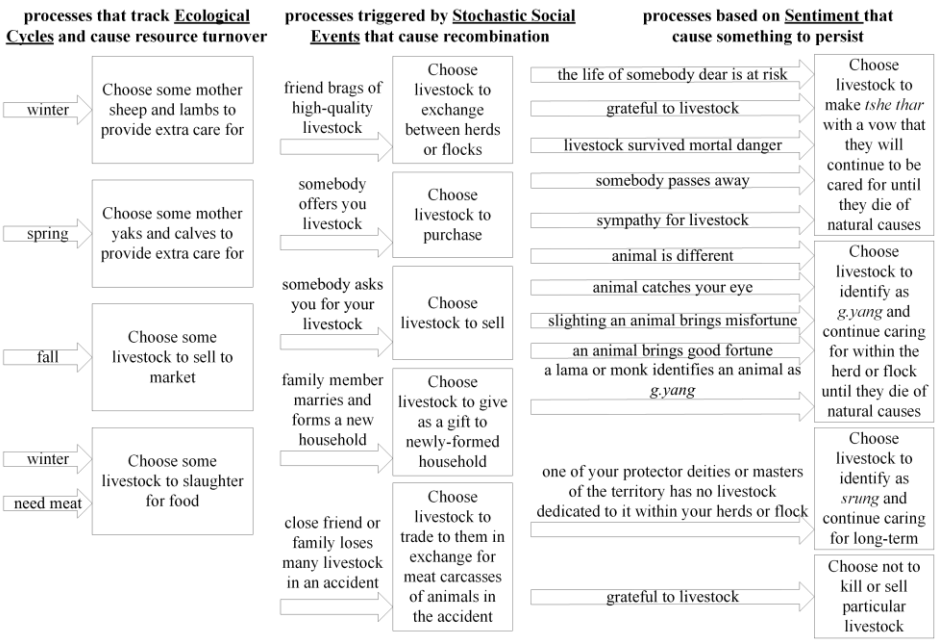

Figure 2: Livestock Herd Composition Attentive Maintenance Model (Burnett 2024b)

Ecological, social, and sentimental observations prompt nomads to make decisions affecting the fates of individual livestock in southeast Amdo. These three different types of observations occur at different frequencies, and they prompt different types of decisions. Collectively, they cause livestock herd compositions to adapt to the ever-changing environment.

Modelling the Interdependence of Different Social-Ecological Resources in a Pastoral System

Different social-ecological resources in a pastoral system are managed in accordance with different AMMs, but they are also hierarchically interdependent (Burnett 2024a; Burnett, in press; cf. Holling 2001, Gunderson and Holling 2002). For example, in southeast Amdo, each household can manage its own herd's composition, but then to feed that herd the household must begin to move through rangeland. As households meet each other while moving through the common rangeland, they pool their labour to increase dairy production (Burnett, in press). These relationships are hierarchical because many herds must exist before they will develop patterns of sharing forage with one another, and many families must be keeping their herds and tents close to other families before noticeable increases in dairy production and distribution will arise due to shared labour. Each larger social-ecological resource management pattern is therefore sustained by many functionally redundant management patterns of a smaller-scale social-ecological resource: large regional flows of dairy are sustained by many sets of households internally sharing milking labour, and cooperation within each of those sets of households is sustained by the movement patterns of the many households' yak herds (see Figure 3).

The more types of hierarchically interdependent social-ecological resources exist in a pastoral system, the more resilient that pastoral system will be (Burnett 2024a). As different households exchange labour,

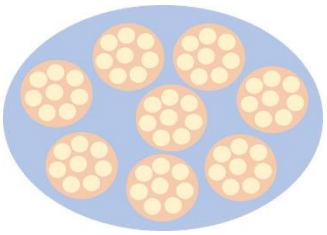

Figure 3: Hierarchical Structure of Panarchy (Burnett 2024b)

In Figure 3, using the example of southeast Amdo, each innermost yellow oval represents a herd of yaks maintained by one household, each intermediate orange oval represents the patterned movements of many herds of yaks, and the outermost blue oval represents the production and distribution of dairy products coming from the many sets of many households moving with their herds of yaks. Larger ovals are sustained by many functionally redundant smaller ovals and also provide a network of resource exchange for the smaller ovals that increases their adaptive capacity and resilience to disturbance.

livestock, and knowledge with one another in response to ecological, social, and sentimental cues (respectively), those exchanges enhance their guiding of the adaptation of their social-ecological resources, and they improve the odds that those social-ecological resources can recover from disturbances. Since the management of each different social-ecological resource generates a new social network, hierarchies that have more scales of social-ecological resources provide people with more social networks. The resultant increase in structured connectedness enhances pastoral system resilience (Walker and Salt 2012) by increasing in-network opportunities for people to share labour, livestock, and knowledge with one another. Figure 3 illustrates panarchy's nested hierarchical structure, which underlies the resilience in addition to the sustainability of pastoral systems.

Implications

The role that social-ecological resources play in structuring the social resource networks of pastoral systems has largely been overlooked in scientific literature. Studies of rangeland management and pastoral cultures usually measure ecological resources and social resources separately. Since ecological resources and social resources both fluctuate for pastoral societies, pastoralists create internal resource stability by developing dependable patterns of pastoral institution use that mediate their relationships with society and ecology. In this paper, I have shown how to detect those stabilizing patterns and communicate them using AMMs and a Panarchical Model, as in Figure 4. These models can be used for environmental education, to vet proposed policies, and to plan for climate change. They are useful because they clarify when seemingly irrelevant customs are critical to the resilience and sustainability of a pastoral system in practice and they reveal vulnerable institution types.

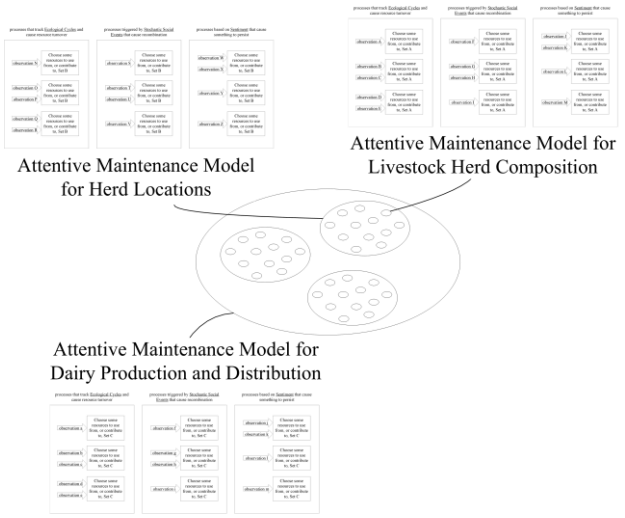

Figure 4: Scales of Panarchy and Attentive Maintenance (Burnett 2024b)

Attentive Maintenance Models can be used to describe the management of social-ecological resources at different scales within a panarchy. The three types of nested social-ecological resources in this sample Panarchical Model are managed in accordance with three respective Attentive Maintenance Models.

Every column in the AMMs of a pastoral panarchy is critical to pastoral resilience. Removing any one of them causes the loss of social networks at that scale and all larger scales of the pastoral panarchy, reducing the resilience of the pastoral system. In southeast Amdo, private leasing of rangelands once used in common now prevents pastoralists from moving their yak herds in response to social, ecological, or sentimental changes, amounting to the removal of three columns of attentive maintenance. Dairy production is no longer sustained by the social-ecological pattern of yak herd movements, which once led households to share milking labour. The larger two scales of social networks and resilience in the pastoral panarchy are thus fading, but assessment with a Panarchical Model reveals both the mechanisms underlying these changes and the potential to reverse them (Burnett, in press). Risk in a pastoral system can be mitigated by the restoration and support of all columns of attentive maintenance; in combination, the columns help a system adapt to its changing context, even when the columns' internal sequences change.

Acknowledgements
UC Berkeley and the NSF GRFP (Grant No. DGE 1752814) financially supported this research. Lynn Huntsinger, James Bartolome, Nathan Sayre, the author's mentors and research partners in the field, and one anonymous reviewer facilitated the improvement of this research with their insightful comments and support.

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