Ecological Modelling 305 (2015) 54–63

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Simple movement rules result in ideal free distribution of mobile pastoralists

Mark Moritz[a,b,*], Ian M. Hamilton[c,d], Andrew J. Yoak[c,d], Paul Scholte[e], Jeff Cronley[f], Paul Maddock[a], Hongyang Pi[f]

[a] Department of Anthropology, The Ohio State University, Columbus, OH 43210, USA
[b] Netherlands Institute for Advanced Studies (NIAS), Wassenaar, Netherlands
[c] Department of Evolution, Ecology and Organismal Biology, The Ohio State University, Columbus, OH 43210, USA
[d] Department of Mathematics, The Ohio State University, Columbus, OH 43210, USA
[e] German Technical Development Organization GIZ, Yaoundé, Cameroon
[f] Research for Undergraduates: Adventures in Mathematical Biology and Its Applications (RUMBA), Columbus, OH 43210, USA

ARTICLE INFO

Article history:
Received 8 October 2014
Received in revised form 17 March 2015
Accepted 22 March 2015
Available online 9 April 2015

Keywords:
Complex adaptive systems
Common-pool resources
Emergent Commons
Pastoralism
Ideal free distribution
Agent-based model

ABSTRACT

While open access to common-pool resources has been equated with a tragedy of the commons, we have found that mobile pastoralists in the Logone Floodplain in Cameroon are sustain ably managing open access to common-pool grazing resources. We have described this pastoral system as a self-organizing complex adaptive system (CAS) in which mobile pastoralists distribute themselves over common-pool grazing resources without central or collective decision-making. We have found evidence of management of open access in the form of an ideal free distribution (IFD). Here we discuss the results of an agent-based model (ABM) simulation and show how pastoralists are able to achieve an IFD with relatively simple movement rules. We describe this system as an Emergent Commons (EC).

1. Introduction

The discussion about our impact on ecosystems has been profoundly shaped by Hardin's tragedy of the commons (1968). Hardin's thesis that common-pool resources cannot be managed sustainably, unless governed by the state or transformed into private property, has been challenged by many (Feeny et al., 1990; Ostrom, 1990; Ostrom et al., 2002). One of the main critiques has been that Hardin confused commons with open access or unmanaged common-pool resources, and that commons can be managed sustainably (Berkes et al., 1989; Ostrom, 1990). The current consensus is that commons can be sustainably managed but that open access to common-pool resources will lead to a tragedy.

While open access to common-pool resources has been equated with a tragedy of the commons (Hardin, 1968; Ostrom, 1990), we have found that this is not the case for mobile pastoralists in the Logone Floodplain in the Far North Region of Cameroon. On the contrary, we have described pastoralists' management of open access to common-pool grazing resources as a self-organizing complex adaptive system (CAS) in which mobile pastoralists distribute themselves over the available common-pool grazing resources without conflicts (Moritz et al., 2013). In our longitudinal study of pastoral mobility we have found evidence of management of open access in the form of an ideal free distribution (IFD) in which there was a positive correlation between the total resources and total numbers of cattle across camp zones (Moritz et al., 2014a, 2014b). In this system of open access all pastoralists have the same rights to use grazing lands, regardless of ethnicity, nationality, seniority, or socioeconomic status. Pastoralists emphatically argue that access is free and open for everyone (Moritz et al., 2013).

We argue that this management system of open access is best described as an Emergent Commons (EC). First, management is an *emergent* property of this self-organizing system in which there is no central and/or collective decision-making; instead the management system emerges from individual decision-making and coordination among users. Second, pastoralists view these grazing resources as commons to which they have *common rights*. We argue that these EC are best understood as a CAS, "in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information

* Corresponding author at: Department of Anthropology, The Ohio State University, 174 West 18th Avenue, Columbus, OH 43210-1106, USA. Tel.: +1 614 247 7426; fax: +1 614 292 4155.
E-mail address: moritz.42@osu.edu (M. Moritz).

http://dx.doi.org/10.1016/j.ecolmodel.2015.03.010
0304-3800/

processing, and adaptation via learning or evolution" (Mitchell, 2009). Varied examples of CAS include ant colonies (Gordon, 2010), the human mind (Taylor, 2001), ecosystems (Holling, 1973), and irrigation systems in Bali (Lansing, 2006).

An excellent example of a social-ecological system that works as a complex adaptive system comes from the work of Lansing (2006), who has described how Balinese rice cultivators coordinate water use for irrigated rice cultivation in order to maximize production while simultaneously controlling pests by allocating water to some subaks (community rice fields), while leaving others fallow. The management system emerges without central decision-making as subaks coordinate water use from the bottom up via the network of water temples associated with the subaks. Critical in this CAS are the ecological processes and interdependencies, an irrigation infrastructure that is mirrored by a network of water temples, and a shared ethos that allows Balinese farmers to coordinate their activities.

There are a number of similarities between the Balinese system and the pastoral system in the Logone Floodplain: dynamic feedbacks between pastoralists and pastures, an information-processing network, and a shared ethos among pastoralists. However, one of the main differences is that the floodplain is an open system – there are no social or ecological boundaries – as pastoralists move continuously in response to spatiotemporal changes in the distribution of common-pool grazing resources inside and outside the floodplain.

We have argued elsewhere that this self-organizing system results in sustainable use of common-pool grazing resources in the Logone Floodplain and used the concept of the ideal free distribution (IFD) as an indicator of this management system (Moritz et al., 2013). The IFD model predicts how animals should distribute themselves over resource patches or habitats (Fretwell and Lucas, 1969; Sutherland, 1996). The two main assumptions of the model are: individuals have perfect knowledge about the resource quality and quantity of each patch (ideal assumption); and individuals are free to move to any patch (free assumption). In our ABM we tracked the distribution of agents and resources. We examined whether and to what extent these movement rules would result in an IFD of agents over the available resources. If resources deplete slowly, individuals will first move to the patches with highest resources (or quality). However, as more and more individuals occupy those patches, resources on the occupied patches decline. At some point, the current quality of the occupied patches will equal that of at least one unoccupied patch. When this is so, some individuals will move to that previously unoccupied patch. There are several predictions that arise from this model. First is that occupied habitats have higher resource density than do unoccupied habitats at any point in time, because high resource habitats are occupied first. Second, the variance in standing resource quality of occupied habitats should be lower than the variance in resource quality of unoccupied habitats, because foragers will tend to deplete all occupied habitats to the same quality, while, in unoccupied habitats, current resource quality is unaffected by depletion. Finally, there should be a positive correlation between total resources in a habitat and total number of foragers in a habitat. Under a model incorporating only depletion, resource quality per unit area should be equal in all occupied habitats; however, if habitats vary in area, larger habitats should include more individuals (Fretwell and Lucas, 1969; Flaxman and deRoos, 2006). We found evidence in support of these predictions in our empirical studies of mobile pastoralists in the Logone floodplain (Moritz et al., 2014a, 2014b).

The question is how exactly the IFD emerges in this self-organizing system. We think that it emerges from a dynamic process in which open access, habitual movements, participation in an information-sharing network, and pastoralists' independent decision making are important factors and examined that hypothesis using an agent-based model. Here we discuss the results of a numerical simulation of the floodplain system, which shows that pastoralists are able to achieve an IFD similar to that predicted by gradual resource depletion that we observed on the floodplain with relatively simple movement rules.

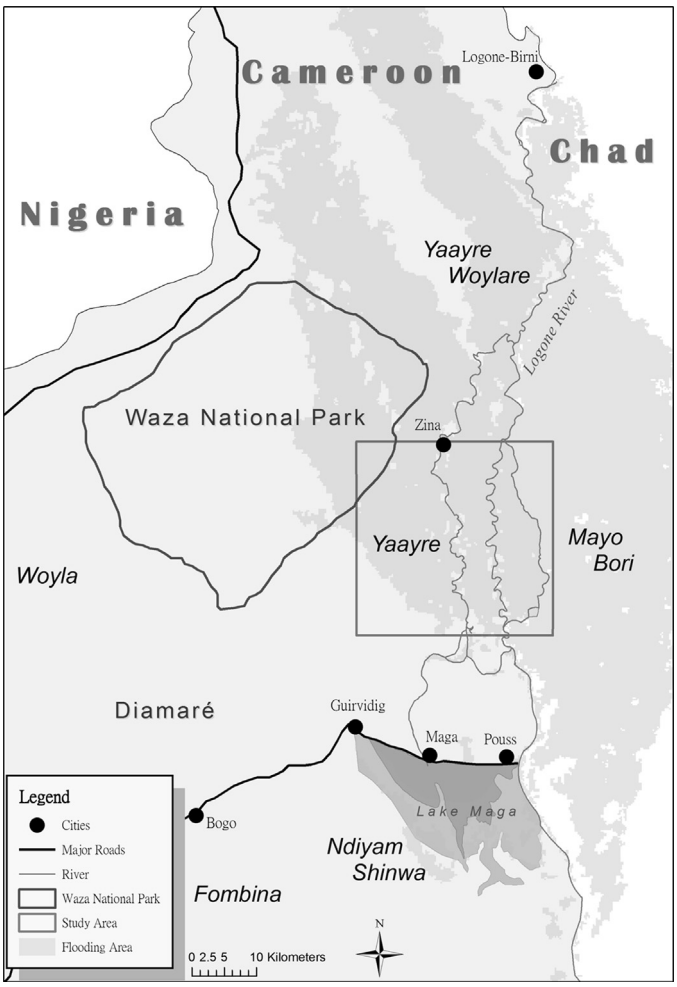

Fig. 1. The study area in the Far North Region of Cameroon.

First, we provide a detailed description of the social-ecological system of mobile pastoralists in the Logone Floodplain, emphasizing the important dynamics of this complex social-ecological system that we captured in our agent-based model.

2. Description of the social-ecological system

Landscape: Our study area is an approximately 1000-km^2 section of the Logone Floodplain with well-defined boundaries of the Waza National Park in the west, the Logone River in the east, the irrigated rice fields of SEMRY in the south, and the village of Zina in the north (see Fig. 1). The study area overlaps with the pilot zone of the Waza Logone Project (1990–2003), which started reflooding of the pilot zone by opening an old waterway in an embankment along the Logone River in 1994 (Scholte, 2005). The Logone Floodplain is located in the Far North Region of Cameroon, which is characterized by two phytogeographic zones: Sudanian in the southern grades and Sahelian in the Logone floodplain. Although the Sahelian zone is characterized by lower rainfall, the seasonal flooding of the Logone River makes this zone one of the most important dry season grazing lands in the Chad Basin. Thousands