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OPINION ARTICLE

Knowledge and community resilience in rangelands recovery: the case of Wadi Allaqi Biosphere Reserve, South Eastern Desert, Egypt

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Many ecosystems are actually social–ecological systems (SESs) consisting of mutually interacting natural and social subsystems. Resilience, the capacity to absorb or withstand perturbations while maintaining structure and functions, is an important feature of these systems. Indigenous or traditional knowledge is considered to be an important factor in being able to absorb change and maintain structure in the context of ecosystem dynamics. In this article, I use the framework of resilience to analyze how the Bedouin communities in Wadi Allaqi, Egypt, experienced and responded to the disturbing impact of Lake Nasser's formation in the mid-1960s. Prior to that disturbance, the Bedouin lifestyle was characterized by traditional pastoral life based on rotational grazing by their herds. Afterward, the Bedouins permanently settled along the shores to make use of the new abundant water resource. This resulted in overgrazing of the rangelands along the lakeside and the disappearance of the traditional pastoral lifestyle. However, the Bedouins later learned to use the *Najas* species in the lake, ushering in a new SES. This new system is based on tactical grazing along the shores, giving the rangelands the opportunity to recover from the temporary grazing pressure. I argue that because many degraded ecosystems are actually SESs, ecological restoration should also focus on societal-level measures.

Key words: ecological restoration, indigenous knowledge, knowledge and community resilience, Lake Nasser, social–ecological system

Implications for Practice

- Community resilience of indigenous social–ecological systems (SESs) implies self-organization and sustainability through indigenous knowledge about natural resources.
- Indigenous knowledge should not be seen as an unchangeable and stable body of knowledge, but rather as a dynamic form of knowledge that reflects changing circumstances.
- The concept of SES resilience and traditional knowledge may offer opportunities for action points related to ecological restoration.

Introduction

Ecological restoration as a strategy for ecosystem recovery has become a central component of modern conservation paradigms (Hobbs & Harris 2001; Suding 2011) and has become integrated into global and regional biodiversity policies in the last decade (Aronson & Alexander 2013). There is also a growing, global effort to integrate cultural and stakeholder knowledge into conservation strategies since many threatened ecosystems are actually social–ecological systems (SESs): a set of critical natural, socioeconomic, and cultural resources whose flow and use are regulated by a combination of ecological and social systems (Glaser et al. 2008). In the context of threatened SESs, the concept of resilience is important: the capacity of an SES to absorb or withstand perturbations and other stressors while remaining within the same regime, essentially maintaining its structure and functions (Reenberg et al. 2008). Resilience also describes the degree to which the system is capable of self-organization, learning, and adaptation (Gunderson & Holling 2002).

Indigenous or traditional knowledge is widely considered to be an important factor of SES resilience because it is a flexible knowledge system that can absorb change and maintain its SES structure in the context of ecosystem dynamics (Berkes et al. 2000; Gunderson 2003). Considering community issues at the local scale with respect to ecological degradation may therefore contribute to the effectiveness of conservation strategies and resource management (Schipper et al. 2008). Gunderson (2000) explains the role of traditional knowledge in SES resilience by noting that the dynamic nature of an SES usually requires continuous testing, learning about, and developing knowledge and

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understanding in order to cope with change and uncertainty. We may therefore also use the term "knowledge system resilience" (e.g. Reyes-García et al. 2014) to describe the adaptive role of indigenous knowledge under changing environmental circumstances.

A related concept is "community resilience," defined by the U.N. International Strategy for Disaster Reduction (UNISDR 2007) as "the ability of the community to resist, absorb, accommodate and to recover from the effects of the hazards in a timely and efficient manner, whilst preserving essential basic structures and functions." Magis (2010) argues that "members of these communities intentionally develop personal and collective capacity that they engage to respond to and influence change, to sustain and renew the communities and to develop new trajectories for the community's future" (p 402). Several studies have examined various aspects of community resilience in the context of natural disasters (Cutter et al. 2008), climate change and social resilience (Hastrup 2009), and biodiversity and resource depletion (Forbes et al. 2009). From this perspective, I hope that conservation and restoration strategies may be enriched and inspired by examples of knowledge and community resilience from indigenous communities.

To substantiate this, I present a case study of knowledge and community resilience by nomadic Bedouin tribes in Wadi Allaqi, Egypt after the construction of Lake Nasser in the mid-1960s. Based on interviews with Bedouins and literature, I reconstruct how the Bedouin SES was affected by this event and how Bedouins subsequently responded by developing new knowledge, skills, and grazing strategies. Insights about these developments may contribute to the conservation and restoration of SESs on which indigenous people are dependent. First, I sketch the study area and the methodology. Next, I describe the developments of the Bedouin SES since the creation of Lake Nasser. In the discussion, I interpret these developments with resilience concepts and draw some conclusions with respect to conservation and restoration strategies.

Study Area

Wadi Allaqi is located about 180 km south of Aswan City and is the largest wadi in the southern part of Egypt's Eastern Desert. It extends for more than 270 km along a northwest/southeast axis from its highest tributaries in the Red Sea Hills to its downstream confluence with the Nile Valley east of Lake Nasser (Fig. 1). Wadi Allaqi was declared a conservation area in 1989 and was designated as a biosphere reserve in 1993 in the UNESCO Man and the Biosphere Programme. Desert is the common ecosystem in this area, and is found mainly in midstream and upstream areas of the wadi. This part of the wadi is usually void of vegetation cover, except at the foot of the Red Sea Hills. Vegetation growth may appear in a rainy season, but may be absent for many years without rainfall. Shallow coarse deposits cover the wadi and rock cracks facilitate water's passage to the plants' roots, giving certain trees the opportunity to grow (Springuel & Belal 2003).

After the Aswan High Dam was built in the mid-1960s, Lake Nasser was formed and caused major changes in the ecology and ecosystems of Wadi Allaqi (Springuel 1991; Murphy et al. 1992). The water body behind the dam entered the mouth of the wadi and about 20 km of the downstream part of Wadi Allaqi was inundated and remained under water for several years. Nowadays, water from Lake Nasser reaches the desert through the wadi and has transformed the deltaic part of the wadi into an inlet, which is called a khor. Khor Allaqi enters the wadi over a distance of 10–50 km, depending on the water level fluctuations. In wintertime, the lake water floods the surrounding areas and reduces the available grazing resources; in summertime, the water level decreases, leaving wetlands around the shores and giving annual species the opportunity to grow.

Lake Nasser is now characterized by stagnant, clear, calcareous, and nutrient-poor water, which has led to the appearance of macrophyte submerged species, mainly *Najas* spp. (Tackholm 1974). In Khor Allaqi, three species of *Najas* have been identified (Fig. 2): *Najas horrida* A. Br. Ex Magn., *Najas marina* ssp. *armata* (Lindb. f.) Horn, and *Najas minor* All. (Tackholm 1974; El-Hadidi & Springuel 1978). According to Springuel (1987), vigorous growth of *N. marina* (ssp. *armata)* took place between 1980 and 1986, and this species is now a common weed in many South Egyptian water bodies. However, more recent studies (Yacoub 2009, 2011) have noted the dominance of *N. horrida* in Khor Allaqi, where it usually thrives as mats in shallow sheltered areas along the shores.

Methodology

Interviews were conducted with Bedouins between June 2009 and June 2010, usually in tents, at livestock watering points, or in grazing areas. The informants were from various tribes (Sedinab, Yousefab, Hamedab, Agebab, and Amorab) and two ethnic groups (Ababda and Beshari). Interviews were also taken from non-Bedouin individuals working in investment projects (mining and quarries) in Wadi Allaqi who had long-term experience with the Allaqi community. The informal discussions focused on the grazing strategies used before and after the construction of Lake Nasser and on the associated shore agriculture.

The interviews were based on questionnaires with open-ended and closed-ended questions (Appendices S1 & S2, Supporting Information). Questionnaire I focused on the Bedouins' knowledge, experience, and practice of traditional grazing systems before 1965 and shortly after the formation of Lake Nasser (from 1970 to 1980). I administered this questionnaire to Bedouins and non-Bedouins. Most of the interviewed Bedouins and all the non-Bedouins were male, ranging in age from 15 to 90 years (Table 1).

Questionnaire II addressed the Bedouins' knowledge of the *Najas* species that has been used as feed since the early 1990s. These interviews were taken from 132 Bedouins, most of whom were under the age of 15 (since the utilization of the *Najas* species as fodder is mainly the responsibility of young people). Since most of the interviewees who answered Questionnaire II were children, parental permission was obtained. The children were only asked simple questions (the first six questions in Questionnaire II) that were directly related to their daily practice

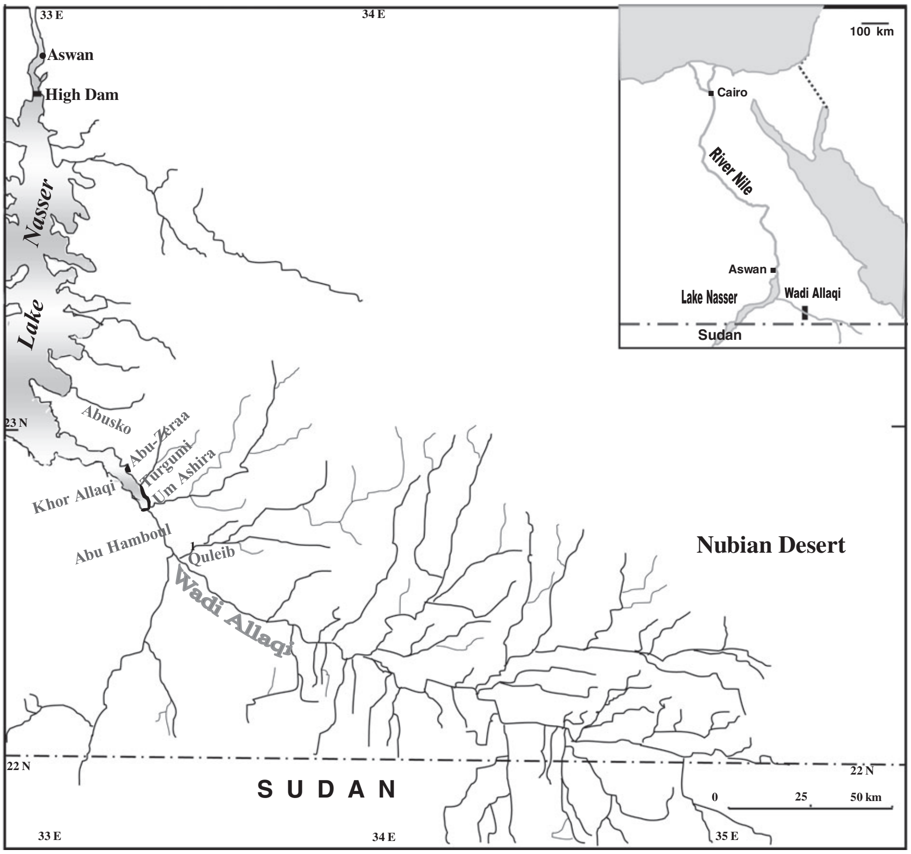

Figure 1. Map of Khor Allaqi with the study sites of downstream wadis.

Figure 2. Pictures of the three identified *Najas* spp. in the water bodies of Khor Allaqi: left, *Najas horrida* A. Br. Ex Magn.; middle, *Najas marina* ssp. *armata* (Lindb. f.) Horn; and right, *Najas minor* All.

of harvesting *Najas* and the animals' feeding conditions. The more advanced questions about the value of *Najas* as fodder, its availability, and its relationship to natural rangelands and grazing strategies were only asked to older individuals.

Because Bedouins in Wadi Allaqi usually feel suspicious and uncomfortable around writing and tape recording, the information obtained from interviews was transcribed from memory immediately afterward.

Data Analysis

The data were analyzed by scoring the set of answers to the interview questions (Table 1, Appendix S2). Subsequently, both the answers and the notes made reflecting open discussions were analyzed by applying a coding system consisting of codes related to grazing strategies, related knowledge, conditions, and challenges. The resulting set of codes was sorted and sifted, which resulted in nine main categories: water resources,

Table 1. Demographic data of the survey population.

		Questionnaire I	*Questionnaire II*
Number of respondents	All	91	132
	Bedouins	58	132
	Non-Bedouins	33	—
	Male	70	67
	Female	21	65
Age	>50	63	9
	30–50	21	18
	15–29	7	11
	11–14	—	51
	<11	—	43
Research areas in Wadi Allaqi	Roud Abu-Hamboul	48	73
	Raas El-Maiaa	21	27
	Quleib	9	23
	Turgumi	13	9

Bedouins' livestock, particular grazing systems, pasture conditions, land use strategies, mobility, resource degradation, use of *Najas* plants as fodder, and grazing knowledge (Table 2 in Appendix S2). Next, both frequency tables were used to reconstruct the narrative about how the Bedouin community in Wadi Allaqi has experienced and responded to the consequences of Lake Nasser's formation.

Results

Interviews and literature make it clear that the Bedouin way of life used to be characterized by traditional, pastoral, nomadic migratory patterns, primarily determined by the herds' needs for water and pastures. These nomadic Bedouins did not have permanent settlements, but lived in tents or other relatively easily constructed dwellings year-round. They were exposed to variations in their habitats through changing natural conditions such as aridity and drought, and were usually self-sufficient in terms of food and most nonfood necessities (Springuel et al. 2001).

Livestock was their central household economy and they had practiced grazing for thousands of years (Briggs 1991; White 1995). As the pastures were only available after occasional rainfall (once every few years), overuse of resources was a rare phenomenon. The traditional Bedouin herding strategy was an indigenous management practice based on selective grazing and controlled browsing that led to a sustainable existence in their traditional SES. Traditional Bedouin culture may thus be considered an indigenous SES because their way of life follows and interacts with natural and seasonal dynamics (Folke et al. 2010). According to the interviewees, rain and underground waters were the main and limiting water resources of rangelands in former times.

However, that changed after the formation of Lake Nasser in the 1960s and the subsequent flooding of the nearby rangelands. Lake Nasser became the main water resource. Interviewees also mentioned additional water resources through the appearance of shallow underground water resources called "Gammama." Interviews revealed that the formation of Lake Nasser not only caused major ecological changes but also changed the Bedouin way of life. The availability of a huge and rather reliable water source encouraged them to settle close to its shores to benefit from the new resource. They migrated only temporarily to other locations when resources became limited. Whereas drought was the most significant factor determining rangeland productivity before Lake Nasser, the annual water level fluctuations became the most important factor afterward. The interviewees mentioned that the annual water level variation in Lake Nasser has decreased the quality of the pastures and rangelands (e.g. forage composition). This is also confirmed by the literature, which reports changes in vegetation succession and the replacement of many plant species on the shores by species more tolerant to disturbances (Belal et al. 2009).

At the same time, the Lake Nasser Development Authority stimulated agriculture on the large new shores along the lake and irrigation canals were dug shortly after the lake was formed. The rise of agriculture also encouraged tribes of Bedouins to stay in nearby areas and utilize crop harvest residues as feed. As a consequence, traditional pastoral mobility was strongly reduced and Bedouins became more dependent on crop cycles. Most Bedouin families now live near cultivated areas. Although agriculture around Lake Nasser provides them with stable and regular nutritious resources for animal fodder, the interviews made it clear that grazing, especially by sheep and goats, is still the dominant land use in Wadi Allaqi. As in former times, the number of livestock varies from only a few animals to 150 heads per family. The wealthiest families may even have more than 300 animals.

Lake Nasser has thus had a tremendous impact on Bedouin grazing strategies. Whereas rotational grazing characterized their livelihoods in the early days after the formation of Lake Nasser, continuous, uncontrolled grazing became the dominant grazing strategy by making use of the new, abundant, and accessible grasslands on the lakeshores. However, the interviewees admitted that the forage quality in the period before Lake Nasser was better, the palatability of plants was higher, less forage was wasted, and herders had better control of feed during drought than they do with the new grazing system, which focuses on rangelands along the shoreline. Furthermore, grazing was more sustainable and profitable for them because of a greater variety of forage species in the former area of Wadi Allaqi. The reason that they nevertheless settled near the lake was mainly related to resource quantity, not quality.

In the early days, droughts did not usually create strong deleterious effects on the quantity and quality of pastures because most of the Bedouins knew on what, where, and when to graze their herds. However, according to older interviewees, the younger generations of herders have now lost much of the knowledge about water resources management, especially the knowledge related to managing grazing during water scarcity periods (e.g. preferred grazing species and locations of additional desert water resources).

During the 1970s and 1980s, the productive grazing areas became restricted to only the Allaqi downstream and upstream areas. However, overstocking strongly reduced the quality of pastures along the shores. Interviewees also mentioned soil degradation as a consequence of the new agriculture practices. Publications from the Unit of Environmental Studies and Development (UESD) at Aswan University and the Nature Conservation Sector (NCS) of the EEAA confirm that the quality of soil, overgrazing, and water level fluctuations had a strong negative impact on the rangelands around Lake Nasser (Mekki et al. 2000; Belal et al. 2009; NCS 2011).

During my interviews and discussions with Bedouin people, it became clear that climate factors also played a role. Long droughts, high temperatures, reduced underground water discharge, saltier wells, moving dune formations, and consequently reduced grazing possibilities for the animals all contributed to worsening livelihood conditions. Interviewees also mentioned ecosystem changes: the delayed flowering and thorny and smaller leaves of Acacia trees, the dominance of unwanted species like *Pulicaria crispa*, *Aerva javanica*, and *Fagonia* spp., and a decrease in the number of migratory birds. Signs of social-ecosystem degradation after the formation of Lake Nasser (e.g. the appearance and extension of low-quality feed species like *Tamarix nilotica* and *Eragrostis aegyptiaca*, and the reduction or disappearance of palatable species) have been confirmed (Mekki et al. 2000). From the interviews, it appears that these conditions had a negative impact on the Bedouins' livelihood and even forced families to leave the area and migrate to Aswan City. According to Solway and Mekki (1999), the initial positive socioeconomic effects shortly after their settlement near the lake decreased because of mismanagement and overuse of their resources.

Despite these negative developments, new resources became available because aquatic *Najas* species started to grow abundantly in the lake in the 1980s. The responses to Questionnaire II made clear that, from the 1990s onwards, Bedouins used trial and error to learn how to utilize these species for their livestock. It appeared that these plants were nutritious and an easy-to-store feed for their livestock. Knowledge about the different *Najas* species, age, and feeding time, as well as optimal mixtures with other plant species to improve its palatability, appeared to be important to successful utilization of this resource. *Najas* species are now an important source of animal feed in the Bedouin community. In summertime, when the water level in Lake Nasser is low, these aquatic plants are harvested, dried, and used as feed (Fig. 3). However, grazing on the natural rangelands remains the main household activity and most of interviewees mentioned that the best areas are still the Lake Nasser shores, because of the dominating grasses.

Figure 3. A Bedouin woman from the Sedinab tribe in Wadi Allaqi collecting *Najas* from the water.

The availability of the *Najas* fodder has affected the browsing periods and the grazing system in general. When the *Najas* harvest peaks, between April and July, herders are much less dependent on rangelands as a grazing resource; outside that period, grazing on the rangeland along the shores is still important. The older interviewees explained that the availability of *Najas* fodder has made the grazing system flexible: they stock in summertime, when *Najas* fodder is available, and use rotational grazing strategies in wintertime, when there are high water levels and low *Najas* availability. This grazing system, which is known in the literature as "tactical grazing" (Noad 2000), implies that the rangelands along the shore can recover in the period between April and August. The interviewees reported that this newly evolved grazing system had a positive impact on the productivity of the grasslands areas and that rangeland soils have become more cohesive and stable. They also stated that this grazing system led more forage species to become available.

The NCS Annual Report of Wadi Allaqi confirms the improved productivity of the grasslands areas and the fertility of the soil on the shores of Lake Nasser after 2000 (NCS 2009). For example, grasslands cover in Roud Abu-Hamboul has increased by about 7.8% compared with results reported in 1991 (NCS 1992). The expansion of grasslands to new areas in Raas El-Maiaa is another sign of grasslands recovery in Wadi Allaqi (NCS 2009). Both *Acacia radianna* and *A. ehrenbergiana* in Wadi Quleib have shown better growth performance in dry periods during low water levels of the lake. Acacia tree density and alternative fuel wood production in Wadi Quleib have increased remarkably over the last two decades (NCS 2009).

Discussion

The creation of Lake Nasser in the mid-1960s weakened the Bedouins' SES in Wadi Allaqi. It resulted in overgrazing of the rangelands along the lake and the disappearance of the Bedouins' traditional pastoral lifestyle, which was based on rotational grazing. However, the later use of the abundant *Najas* species has ushered in a new SES based on tactical grazing along the shores. Both stocking and rotational grazing strategies are being used, giving the rangelands an opportunity to recover from temporary grazing pressures.

According to Folke et al. (2010), resilience relates to three aspects of an SES: persistence, adaptability, and transformability. Persistence is a system's ability to change to remain within a stability range. Adaptability is a system's capacity to respond to changing internal processes and external drivers, to remain and follow a trajectory of development within its stability domain. Transformability is a system's capacity to create and enter into new stability domains and trajectories after a strong disturbance.

Based on these resilience categories, I interpret the Wadi Allaqi system before the creation of Lake Nasser as a system characterized by persistence and adaptability, keeping it within its stability range. However, the creation of Lake Nasser was a strong disturbance that destroyed the traditional system and damaged the desert ecosystem, causing social misery and the disappearance of the Bedouin's traditional lifestyle. Kandal et al. (2016) showed that this event also led to a strong reduction in traditional knowledge about desert plant species among younger people in Wadi Allaqi. However, since 1990, Bedouins have developed new knowledge and skills, and a grazing system partly based on the use of *Najas* species from the lake. This has had a positive impact on the grazing resources and rangeland ecology.

The SES has thus been transformed into another stability regime. Although it took many years, the Bedouin SES of Wadi Allaqi has demonstrated a capacity for knowledge and community resilience (i.e. the ability to transform itself as an SES).

The recognition of community and knowledge system resilience in the case of Wadi Allaqi may have a message for ecological restoration. Ecological restoration usually includes a wide scope of projects such as erosion control, reforestation, reintroduction of native species, removal of non-native species, and habitat and range improvement for targeted species (Bradshaw 1997). Although Wadi Allaqi cannot be called an intended restoration practice, the Bedouin community was able to contribute to the recovery of the rangeland as an SES. Ecological restoration usually focuses on ecological elements such as soils and vegetation. However, in an SES, social elements are probably equally important. SES resilience and traditional knowledge may offer opportunities for social action points of ecological restoration.

The case of Wadi Allaqi teaches us that an SES relies on flexibility and the adaptive capacity to respond to disturbances through the creation of new opportunities. Related knowledge may also contribute to ecological recovery. Of course, participation is already an important issue in restoration and conservation (Magis 2010; Ray et al. 2012), but Wadi Allaqi makes it clear that successful ecological restoration can perhaps also use, and is perhaps dependent on, the understanding of the role indigenous communities play in SESs.

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Supporting Information

The following information may be found in the online version of this article:

Appendix S1. Questionnaires.
Appendix S2. The answers of interviewees including the frequencies and code analysis.

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