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Religious tradition of conservation associated with greater abundance of a keystone tree species in rural Western Rajasthan, India

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ABSTRACT

Land-use and land-cover change in the Thar Desert region of Rajasthan threatens the persistence of many ecologically and economically important species. The Bishnoi people of Rajasthan have religiously protected a keystone tree species, *Prosopis cineraria*, locally known as the Khejeri tree, for over five centuries. We conducted the first comparative study that tests the widely held assumption that Bishnoi presence is positively associated with *P. cineraria* abundance in nineteen villages in rural Rajasthan. We also evaluated the influence of land area type, human and livestock population, and income on measured Khejeri tree abundance. Villages with Bishnoi had significantly more *P. cineraria* and had significantly higher incomes than villages without Bishnoi despite no significant differences in land area, human population, or livestock population between village classes. We found no direct associations between Khejeri tree abundance and village demographics suggesting *P. cineraria* abundance is a function of environmental and socio-economic factors. Within this context we discuss the role of Bishnoi protection of Khejeri trees in maintaining important ecosystem functions and supporting human prosperity.

1. Introduction

The role of local ecological knowledge (LEK) in addressing issues of species conservation is increasingly recognized among conservation scientists and practitioners (Agrawal and Gibson, 1999; Chalmers and Fabricius, 2007; Ford and Martinez, 2000; Steele and Shackleton, 2010). Traditionally human inhabitants of regions of conservation concern have not been included in the planning and decision making process, particularly in the developing world (Steele and Shackleton, 2010; Stevenson, 1996). Studies have shown that inclusion of local people and their knowledge of the environments they inhabit can have measurable benefits to conservation outcomes (Brooks et al., 2006; Bryce et al., 2010). Local populations are often in a favorable position to implement, enforce, and maintain conservation agendas when compared to non-local researchers and/or regional authorities (Ancrenaz et al., 2007; van Eeden et al., 2006).

The Thar Desert region in India's largest state, Rajasthan, faces considerable environmental challenges brought about by human activity (Francis and Gadgil, 2009; Khan et al., 2004; Niyogi et al., 2010). Land-use and land-cover change has led to noticeable and significant changes to local ecology and livelihoods (Ram and Chauhan, 2009; Tewari and Arya, 2005). Over the last fifty years efforts to increase agricultural productivity through massive irrigation infrastructure (Maitra, 1987) has begun to change the ecological dynamics of this desert region. While humans stand to benefit economically from these efforts (Government of India, 2010) other species that share the landscape are under increased pressure to adapt (Government of India, 2006; Hall et al., 2012). Moreover, the change brought about by increased irrigation has seen the proliferation of an invasive plant species that threatens to impede the agricultural goals of human populations (Government of India, 2006). At the center of Rajasthan's rural ecology and economy is a tree species that is widely used by human and wildlife species. *Prosopis cineraria*, locally known as the Khejeri tree, supports agricultural productivity through soil retention and nutrient cycling, is an essential source of fuel wood for rural households, provides food to livestock from leaves and fruit of branches lopped off by humans, and provides nesting habitat for a wide variety of bird species including critically endangered vultures (Goyal et al., 1988; Hall et al., 2012; Pasiecznik et al., 2001; Sharma and Dakshini, 1998). Increases in human and livestock populations and the subsequent increased harvesting of Khejeri branches (Government of India, 2006) combined with the proliferation of the aforementioned invasive *Prosopis juliflora* threaten to displace *P.*

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cineraria from its native landscape (Government of India, 2006; Sharma and Dakshini, 1998).

The Bishnoi, a particular caste group that inhabits Northwest India, have been practicing a religion since the late 1400 s that requires they protect and preserve Khejeri trees even at the cost of their lives (Jain, 2011). Khejeri are considered particularly sacred to the Bishnoi ever since the founder of their religion recognized *P. cineraria* as essential to the survival of people in a region plagued by frequent drought and famine (Brockmann and Pichler, 2004; Jain, 2011). Khejeri's ability to thrive in arid regions and support human livelihood is likely why it was singled out by the Bishnoi as important for conservation (Brockmann and Pichler, 2004; Jain, 2011). Since then the Bishnoi have earned a reputation among other castes, local managers, and scientists as effective and important environmental advocates and conservation practitioners (one particularly dramatic example being a protest in 1730 of the cutting of Khejeri ordered by Maharaja Abhay Singh that resulted in the death of 363 Bishnoi that refused to let go of trees as the Maharaja's men cut them down (Brockmann and Pichler, 2004; Jain, 2011)). Despite their reputation and assumed positive influence on the environment no studies have systematically investigated whether or not the Bishnoi have a positive influence on or are positively associated with Khejeri abundance. The fact that the Bishnoi may effectively conserve important species as a matter of cultural practice dovetails with other species conservation efforts and is worth investigating.

Here we report our results from a comparative study that pursued two lines of inquiry related to Bishnoi and Khejeri trees. First, we tested the prediction that Bishnoi presence and Khejeri tree abundance were positively associated in village areas. Second, we determined which village characteristics thought to influence Khejeri tree abundance was associated with our observed abundance figures. The overall goal of this work was to begin to test the veracity of a positive Bishnoi effect on a keystone species and orient any associations within the changing ecological context of the region.

2. Methods

2.1. Study area

Our study area included villages within 50 km of Jodhpur (26°18′N, 73°08′E) bordering the Thar Desert (Fig. 1). The semi-arid landscape is dominated by farmland primarily punctuated with *P. cineraria*. The climate of northwestern India is hot and dry. Temperatures can reach highs of 50 °C in May and June and lows of ~1 °C during January and February. Annual rainfall averages 360 mm with 90% occurring during the monsoon season (July–September). Rajasthan's primary industry is agriculture and most rural populations practice some form of agropastoralism (Fisher, 1997; Tewari and Arya, 2005). Monsoon rains are essential for crops, drinking water, and feeding livestock and therefore local people face considerable economic and subsistence challenges during drought (Fisher, 1997; Tewari and Arya, 2005).

Fieldwork was conducted in 19 villages covering approximately 312 km^2 that were chosen based on logistical feasibility and preexisting research infrastructure facilitated by a local non-governmental organization (NGO) the School of Desert Sciences (SDS). SDS is a social and ecological development NGO that focuses on improving the lives of rural peoples through a variety of education and research programs. For the past fifteen years SDS has conducted various wildlife and socio-economic surveys in the region and are known to most villagers within the study area. This type of relationship was essential to carrying out our study, as travel to and across village lands would not have been permitted without some type of pre-existing relationship with researchers.

All villages in the study area were organized in the roughly the same way, with a centralized housing area and agricultural and community (e.g. fallow/grazing land, water catchment area) lands located on the periphery. Village boundaries are established by land ownership (land owned by members of different villages) or delineated by roads. Each village shared a border with at least one other study village. The caste composition of villages was heterogeneous ranging from two to seventeen distinct castes groups (i.e. Bishnoi, Jain, Rajput, and Megwal caste groups living in one village). The percentage of Bishnoi in eight of the nineteen villages also varied, ranging from 13% to 78% (Hall, unpublished data).

2.2. Study species

P. cineraria, locally known as the Khejeri tree, occurs in northwest India and across the Thar Desert region (Pasiecznik et al., 2001; Sharma et al., 2010). Khejeri trees have thin leaves, thorny branches, and yellow flowers. They are well adapted to arid environments and thrive on cultivated land (Pasiecznik et al., 2001). Trees in the study area were as tall as 10 m, but the majority were less than 7 m and had very similar girth. Khejeri trees are central to the ecology and economy of rural Rajasthan (Fisher, 1997; Pasiecznik et al., 2001). Human populations use Khejeri for fuel wood, building material, fencing, and fodder for livestock. Several studies have shown that Khejeri also support agriculture through soil retention and nutrient cycling (Sharma and Dakshini, 1998; Yadav et al., 2008). Wildlife species also use Khejeri trees for shelter, nesting habitat, and a source of food (Chhangani, 2005; Goyal et al., 1988). In our study area, Khejeri trees grew almost exclusively on village farmland presumably because of the known agricultural benefits they provide.

2.3. Khejeri tree transects

We sampled Khejeri trees on farmlands within a 1 km radius (covering a maximum of 3.14 km^2) of the reported village center in each of the nineteen villages in our study area. Each transect began 500 m from the village center (mostly housing areas devoid of any trees) in each cardinal and sub cardinal direction. We counted all Khejeri trees within 10 m of the 500 m transect line. Numbers of other tree species on farmland in both Bishnoi and non-Bishnoi areas were too scarce to analyze in a meaningful way and thus we did not record their numbers. Because the proportion of farmland within 1 km of village centers varied between villages the total number of transects run in each village varied from five to eight. Five transects was the minimum number we were able to run in each village due to logistical constraints. As such we account for the difference in total transects per village in our analysis.

2.4. Village demographic data

We collected village demographic data from four sources; the 2001 Rajasthan census (Sharma, 2011), district officials (called *patwaris*) who keep written demographic information of villages, demographic data collected by the School of Desert Sciences during their various projects in 2007, and semi-structured interviews (Bernard, 2001) we conducted for this study. Each interview consisted of a group of 3–18 adult male (18 years or older) residents who voluntarily gathered to be interviewed (cultural constraints limited the participation of women). Interviews lasted from half an hour to one and a half hours. Collecting information from multiple sources allowed us to verify reported information for the demographic characteristics we were interested in. We chose to focus

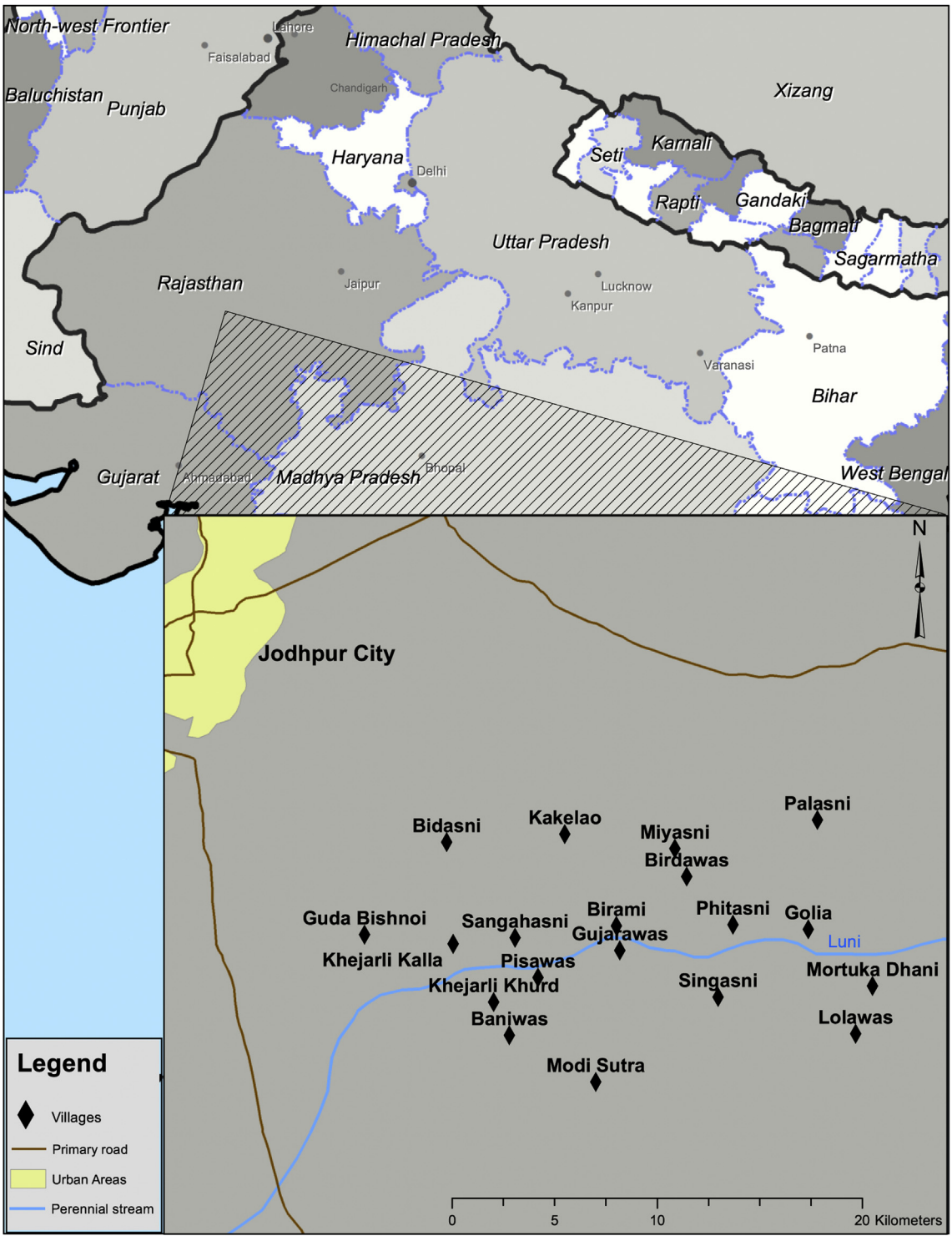

Fig. 1. Map of village study area in Rajasthan.

on four metrics that were likely to be associated with Khejeri tree abundance, based on previous research (Fisher, 1997; Goyal et al., 1988; Lal, 1991; Sharma, 2011): human population, livestock population, farmland area, and average annual village income (AAI). Rainfall, a likely important factor for Khejeri tree abundance, is not recorded at the village level and thus was not included in our comparative study. Given the size of our study area 312 km^2 and available district level rainfall data we do no expect that rainfall differed substantially between villages. In addition to the four categories of demographic information we also recorded the tree species deemed most important as reported by interviewees during semi-structured interviews. The purpose of this information was to capture villager perception of the relative importance of Khejeri trees among other species present in village areas.

Table 1
Average abundance of village demographics for both village types. Standard deviation in parenthesis.

	Kherjeri tree abundance		Human population	Total livestock	Farmland area (ha)	Average annual income (AAI)	
	Standard abundance	Per transect abundance				Indian rupees	US dollars
Village w/Bishnoi	72.43 (29.79)[a]	12.86 (4.44)[a]	3700.43 (5285.70)	3242 (2386.18)	2151.03 (1587.20)	41,349.43 (19,324.37)[a]	$826.98 ($386.49)[a]
Villages w/o Bishnoi	51.09 (19.32)	9.42 (3.18)	1703.09 (2104.01)	2710 (3567.74)	991.77 (704.11)	26,870.00 (6794.93)	$537.40 ($135.90)

[a] Indicates values that are significantly greater than values in Villages without Bishnoi.

2.5. Data analysis

The villages in our study area were separated into two categories, villages with a Bishnoi population and villages without a Bishnoi population. We calculated an average of each demographic characteristic – Khejeri tree abundance, human and livestock population, farmland area, and average annual income (AAI) – for the two village types from the totals collected for each village (i.e. the average annual income of villages with Bishnoi was calculated from the sum total of AAI in each village with Bishnoi divided by eight).

Because the total number of Khejeri transects differed between villages we chose to analyze two metrics of Khejeri tree abundance; the total number of trees counted in the minimum number of transects run for all villages (five) and the average number of trees counted per total transect effort (i.e. 60 trees counted in 6 transects for village A for an average of 10 trees per transect). We designate the former Khejeri abundance value *Standard Abundance* and the later *Per Transect Abundance*. Annual income numbers were collected during semi-structured interviews at the caste level and divided by the number of castes in the given villages for the average annual income of the village. We used Mann–Whitney *U*-Test to compare the averages of each demographic value between village types.

In order to determine what village demographics were associated with both metrics of Khejeri tree abundance we used analysis of covariance (ANCOVA). Demographic data was log transformed and two separate ANCOVA's were run, one for each type of Khejeri tree abundance. For both tests our input variables were human population, livestock population, farmland area, average annual income, and the presence or absence of Bishnoi. All statistical test were performed using SPSS (v.21.0).

3. Results

3.1. Village demographics

On average we found approximately twenty more Khejeri trees in villages with Bishnoi versus villages without Bishnoi (three more trees per transect) (Table 1). This difference was statistically significant (*Standard Abundance* $p = 0.020$, *Per Transect Abundance* $p = 0.026$). Average annual income also differed significantly between the two village classes as families in villages with Bishnoi populations reportedly earned $289.58 (14,479□) more per year on average ($p = 0.033$). There was no significant difference in the remaining village demographics (*Human Population* $p = 0.657$, *Livestock Population* $p = 0.545$, *Farmland Area* $p = 0.310$) between village classes (Table 2). In semi-structured interviews Khejeri trees were reported as the most important tree species in fifteen of the nineteen (79%) total villages (Table 2). Two villages from each village type did not name Khejeri trees as the most important tree species. In one case interviewees from Khejarli Khurd named all tree species as important (Table 2).

Table 2
Transect and demographic data for each village in the study. Villages are separated by type, villages with Bishnoi (8) and villages without Bishnoi (11).

Village w/Bishnoi	Kherjeri tree abundance		Human population	Total livestock	Farmland area (ha)	Average annual income (AAI)		Most important tree	Bish pop	Bish pop %
	Standard abundance	Per transect abundance				Indian rupees	US dollars			
Bidasni	131	20.57	574	235	518	37,500.00	$750.00	*Prosopis cineraria*	448	78.05%
Birami	29	5.40	2251	5851	2181.2	26,200.00	$524.00	Acacia nilotica	834	37.05%
Golia	61	12.20	576	715	729.8	26,300.00	$526.00	*Prosopis cineraria*	207	35.94%
Guda-Bishnoi	76	15.20	16207	6610	4446	83,700.00	$1674.00	*Prosopis cineraria*	8024	49.51%
Kakelao	96	17.17	2919	3330	4162	34,700.00	$694.00	*Prosopis cineraria*	1240	42.48%
Khejarli Kallan	80	13.86	2129	3220	1990.6	35,821.00	$716.42	*Prosopis cineraria*	875	41.10%
Khejarli Kurd	69	11.57	695	2265	1047.6	29,600.00	$592.00	All species	88	12.66%
Sangahasni	96	14.63	1126	703	500	53,125.00	$1062.50	*Prosopis cineraria*	270	23.98%

Villages w/o Bishnoi	Kherjeri tree abundance		Human population	Total livestock	Farmland area (ha)	Average annual income (AAI)		Most important tree
	Standard abundance	Per transect abundance				Indian rupees	US dollars	
Baniwas	33	5.00	1159	2164	791	25,000.00	$500.00	*Prosopis cineraria*
Birdawas	31	6.20	1253	1251	987	31,500.00	$630.00	*Prosopis cineraria*
Gujarawas	40	8.00	412	395	660	25,833.00	$516.66	*Prosopis cineraria*
Lolawas	28	5.60	1547	1770	717.28	34,714.00	$694.28	*Prosopis cineraria*
Miyasani	53	10.17	1369	4909	831.2	15,000.00	$300.00	*Prosopis cineraria*
Modi Sutara	58	11.60	1887	638	657	28,375.00	$567.50	*Azadirachta indica*
Mortuka	78	14.33	1210	2315	1292	35,222.00	$704.44	*Prosopis cineraria*
Palasni	53	10.60	7904	12800	2989.12	28,176.00	$563.52	*Prosopis cineraria*
Phitasani	88	14.00	700	585	322	23,917.00	$478.34	*Prosopis cineraria*
Pisawas	40	8.00	646	1633	916.9	32,083.00	$641.66	*Prosopis cineraria*
Singahasni	60	10.14	647	1350	746	15,750.00	$315.00	*Azadirachta indica*

3.2. ANCOVA analysis

ANCOVA results show that none of the selected village demographics were significantly associated with either standard Khejeri tree abundance or per transect abundance (Table 3). In both cases however, the presence of Bishnoi was the least non-significant factor ($p = 0.098$, *Standard Abundance*; $p = 0.170$, *Per Transect Abundance*).

4. Discussion

Our results show a clear and significant difference in the number of *P. cineraria* sampled in villages with Bishnoi versus villages without Bishnoi. Though this is a widely held assumption by local people and some environmental practitioners this is the first study, to our knowledge, that demonstrates a positive association between Bishnoi and Khejeri trees. In the majority of interviews conducted in villages within our study area interviewees named Khejeri as the most important of all tree species in the region. The fact that Khejeri abundance differs between village classes despite the percentage among the two village classes that named Khejeri as most important was roughly the same (75% in villages with Bishnoi vs. 82% in villages without Bishnoi) suggests that people within these villages may use Khejeri in different ways. In other words people in villages with Bishnoi may highly value Khejeri trees and preserve them while people in villages without Bishnoi may highly value Khejeri trees and harvest them to use more directly. We found no significant differences in farmland area, livestock population, or human population between village classes that might explain the significant difference in Khejeri tree abundance. This fact supports the idea that differential abundance is a product of human/Khejeri interaction and not simply a matter of villages with Bishnoi having more farmland to support more Khejeri trees or villages without Bishnoi having more livestock and people and thus having a greater need to harvest more Khejeri trees. Average annual income did differ significantly between village classes, but was not significantly associated with Khejeri tree abundance. The economic dynamics of rural economies are inherently complex in this region (Jones, 2008; Robbins et al., 2009) and while our results show no direct association with income and Khejeri tree abundance we cannot rule out the impact of income on how local people choose to use a natural resource. The exact causal relationship between Bishnoi presence, income, and Khejeri tree abundance requires more investigation.

4.1. Ecological implications

The benefits of Khejeri tree preservation extend beyond the potential economic benefits they may afford human populations. Because many species also utilize Khejeri trees the overall ecosystem function of the region is impacted by difference in its abundance and condition. In the case of critically endangered vultures that nest in Khejeri trees (Hall et al., 2012) the abundance of nesting habitat and consequently the abundance of vultures can impact human populations. Vultures are particularly important in rural Rajasthan because they consume dead livestock that would otherwise decompose in the open air. Recently, many native and migratory vulture species have experienced dramatic declines in population due to a variety of human activities compounded by the effects of global climatic change (Hall et al., 2012; Prakash et al., 2003). Steps have been taking to restore populations of these birds through a captive breeding program that will eventually reintroduce birds to the landscape (Vulture Rescue, 2013). Reintroduced populations may find it difficult to survive however, if an increasing portion of land is occupied by growing human and livestock populations and the spread of the invasive *P. juliflora*, which grows as a shrub rather than a tree and obscures open habitat needed for take off and landing. The results of this study show that areas with Bishnoi, which have comparatively more Khejeri trees, may provide comparatively better nesting habitat for reintroduced vulture populations, an essential component of any successful species reintroduction (Hall et al., 2012). Moreover, nesting habitat in Bishnoi areas are more likely to be maintained as the Bishnoi are less likely to change their policy of the lopping and felling of trees given their long history of protesting such acts (Jain, 2011). Such a partnership between the Bishnoi and conservation efforts to restore vulture populations through the preservation of Khejeri trees remains unexplored but has obvious potential benefits.

The proliferation of the invasive species *P. juliflora* also presents an ecological problem for humans and wildlife. *P. juliflora* was first introduced into Rajasthan by the British colonial government in the early part of the twentieth century to provide timber and fuel wood and rapidly populated the landscape (Pasiecznik et al., 2001). Wildlife habitat and traditional water catchment landscapes have become overgrown with *P. juliflora* in subsequent decades (Pasiecznik et al., 2001; *personal observation*). Efforts to control the spread of this invasive species are not always successful given the labor and economic investment required to remove plants once they've been established (these efforts often require a backhoe to remove taproots [*personal observation*]). *P. juliflora* is considered a superior competitor to other slower growing native species (Pasiecznik et al., 2001) and with the increasing availability of water in Rajasthan facilitated by the Indira Gandhi Canal many expect *P. juliflora* numbers to increase in rural areas (Government of India, 2006; Pasiecznik et al., 2001). While this increase would provide more fuel wood and potential fodder for villagers it would also increase competition for agricultural land and native habitat for wildlife. The Bishnoi people's particular affinity for native Khejeri trees may play an important role in the persistence in this native species, one that instead of directly competing for land with human populations has been shown to be compatible with the human livelihoods.

The mechanism by which the Bishnoi protect Khejeri trees is not well understood by researchers. The Bishnoi have a reputation for deterring poachers of antelope (another species they consider sacred) through political and direct physical confrontation (Jain, 2011), but no such examples aside from the protest in 1730 have been recorded in academic literature. Given the Bishnoi's reputation and social status in village areas – they belong to the middle class caste category *Other Backwards Castes* (OBC (Brockmann and Pichler, 2004; Fisher, 1997)) – we suspect others avoid harvesting trees from their lands because the Bishnoi have earned the social capital through their historical sacrifices and because the Bishnoi

Table 3
Results of analysis of covariance (ANCOVA) to determine if village demographics were significantly associated with either Khejeri tree abundance categories, *Standard Abundance* and *Per Transect Abundance*.

Effect	*F*	df	*p*
Standard abundance			
Bishnoi presence	3.173	1	0.098
Livestock population	1.195	1	0.294
Human population	0.709	1	0.415
Average annual income (AAI)	0.081	1	0.780
Farmland area	0.005	1	0.943
Per transect abundance			
Bishnoi presence	2.106	1	0.170
Livestock population	1.958	1	0.185
Human population	0.964	1	0.344
Average annual income (AAI)	0.135	1	0.719
Farmland area	0.101	1	0.756

have the economic and social status as OBC to maintain this authority. The principles associated with private property ownership (i.e. one may not harvest trees that do not belong to them) also likely plays a role. Further research into these exact relationships and how the Bishnoi may directly prevent Khereji tree harvesting is needed.

Ultimately the successful preservation of native environments and important ecosystem functions in rural Western Rajasthan may be a function of where the values of such preservation are already in practice and are not likely to change. How the Bishnoi continue to respond to the landscape and ecological changes taking place remains to be seen, but there is little evidence that they will change these practices that appear to positively impact keystone species persistence. The benefit of exploring the cultural traditions of local people in conservation may be that these cultural traditions, as is the case for the Bishnoi, manifest solutions that benefit both humans and non-human species.

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