The Pika and the Watershed

by

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ABSTRACT

As much as 40% of the world's human population relies on rivers which originate on the Qinghai-Tibetan Plateau (QTP) (Xu et al. 2009, Immerzeel et al. 2010). However, the high alpine grasslands where these rivers emanate are at a crossroads. Fed by seasonal monsoon rains and glacial runoff, these rivers' frequent flooding contributes to massive losses of life and property downstream (Varis et al. 2012). Additionally, upstream grasslands, which regulate the flow of these rivers, are considered to be deteriorating (Harris 2010). This thesis examines the regional vulnerability of these rivers and highlights the impacts of several policy responses, finding that both climate change and grassland degradation pose significant challenges to Asia's water security. Additionally, I suggest that many of the responses elicited by policy makers to meet these challenges have failed. One of these policies has been the poisoning of a small, endemic, burrowing mammal and keystone species, the plateau pika (*Ochotona curzoniae*) (Smith and Foggin 1999). Contrary to their putative classification as a pest (Fan et al. 1999), I show that the plateau pika is instead an ecosystem engineer that actively increases the infiltration rate of water on the QTP with concomitant benefits to both local ecosystems and downstream hydrological processes.

DEDICATION

To my friends, family, and mentors.

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First, I wish to offer special thanks to my friends and family. To my wife: Angie, thank you for teaching me to follow my dreams and loving me through the process. To my family: thank you for pushing me when I needed to be pushed, but supporting me when I was vulnerable. To my friends: without you, this research simply would never have happened.

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Chapter 1. Introduction

The Qinghai-Tibetan Plateau (QTP)(Figure 1) is one of the most enigmatic places in the world. With an average elevation of 4,000m, a distinct cultural heritage, and an isolated history, the QTP has interested scholars for its cultural value, political importance, and physical location. However, in recent decades the importance of the QTP has been viewed in a new light. As much as 40% of the world's human population directly relies on water resources which descend from the QTP (Xu et al. 2009, Immerzeel et al. 2010) which leads many to call it "Asia's water tower." With this in mind there has been a concerted effort, lead primarily by the Chinese government, to understand the ecology of this critical headwater's region and to quantify its effects downstream.

However, this recognition of the QTP as a critical headwaters region has not occurred in a vacuum. Rather, as the importance of this ecosystem is becoming clearer, an unprecedented modernization process has begun on the QTP which includes movement away from traditional land use practices (Figure 2) as well as the poisoning of an endemic small mammal (Miller 1995; Yan et al. 2005; Sheehy et al. 2006; Foggin 2008; Yeh and Gaerrang 2010; Foggin and Torrance-Foggin 2011). Yet, while these modernization projects are massive in scale, a full examination of their impact is lacking. This lack of definitive research hampers decision makers as they attempt to both protect the QTP's ecology while providing social services to its people.

The following thesis focuses on the interplay of these issues. Chapter two is a summary which focuses on identifying the vulnerabilities in the water systems which descend from the QTP. Special attention is paid in this chapter to the current social and environmental changes which are currently taking place across the QTP as they directly impact the livelihoods of millions of people living downstream. Conversely Chapter three focuses on the impacts of one specific policy, plateau pika (*Ochotona curzoniae*) (Figure 3) poisoning, its impact on the biodiversity of the QTP, and the water systems of Asia.

With the water security of millions at stake, these are critical and timely issues. In order for policy makers to make informed decisions as to what is best not only for the QTP and its people, but also those living downstream, it is of the upmost importance that we come to understand the interplay between the ecology of the QTP, its people, and their lifestyle.

Chapter 2. Asia's Water Tower: Tibet and the Rivers of Asia

Introduction

As much as 40% of the world's human population relies on watersheds which originate on the Qinghai-Tibetan Plateau (QTP) (Xu et al. 2009, Immerzeel et al. 2010) (Figure 1). These rivers, which provide for the livelihoods of people living downstream, can also be incredibly destructive. Fed by seasonal monsoon rains and glacial melt, their frequent flooding may lead to massive losses of life and property downstream (Varis et al. 2012). Therefore it should be no surprise that the Chinese have taken to calling the Tibetan plateau a "water tower" while nicknaming the Huang He (Yellow River), "China's sorrow."

These rivers are the lifeblood of Asia. However, many contemporary analyses suggest that the high alpine wetlands and grasslands where these rivers originate are becoming increasingly degraded (Zhou et al. 2004, Harris 2010) and that most corrective activities have ranged from unsuccessful to counter-productive (Pech et al. 2007, Harris 2008, 2010). These grasslands and the people who depend upon them are at a crossroads. If degradation continues and these grasslands lose their capacity to naturally regulate downstream flow, the losses could be cataclysmic (Xu et al. 2009). This chapter aims to examine the current state of watersheds descending from the QTP, as well as to address grassland degradation and its causes. In conclusion I will present various pathways forward which should enhance the capability of restoring Asia's water tower while also mobilizing local people toward community-based action directed to ensure the sustainability of the grasslands upon which they depend.

A Changing Climate

One of the primary threats to Asia's rivers is a changing climate (Shrestha et al. 2008, Wang et al. 2009, Xu et al. 2009, Immerzeel et al. 2010, Mool et al. 2011, Varis et al. 2012). The flow of these rivers is directly impacted by two climatic variables: glacial melt and precipitation. The following sections aim to discuss the impacts of these changes in climate on the river systems of Asia.

Glacial Melt

While glacial melt plays a critical, though variable, role in the flow of all rivers which descend from the QTP, the melt of Himalayan Glaciers remains one of the most contested issues in climate science. While most the evidence suggests that Himalayan glaciers are melting, the rate of melt is inconsistent among glaciers. The melt rates of the Himalayan glaciers seem to be regionally specific and unpredictable (Immerzeel et al. 2010). Most current data point to an increase in glacial melt rate leading to glaciers being completely absent from the Himalayas within the century (Xu et al. 2009).

These complexities are further compounded by the fact that not all rivers depend on glacial melt equally. Water derived from glacial melt makes up from 5% to greater than 45% of river discharge (Xu et al. 2009), with melt being most important to the rivers that dominate the Indian subcontinent, and least important to the rivers of China and Southeast Asia (Immerzeel et al. 2010). The Indus River seems particularly at risk to glacially-mediated flow inconsistencies, with glacial melt making up nearly 100% of its early spring discharge, while the Yellow River seems nearly unreliant on water derived from glacial flow (Immerzeel et al. 2010). This variability suggests that the brunt of global warming’s impact will not be felt equally across the QTP, but rather will be primarily absorbed by the Indian subcontinent, while largely leaving China and Southeast Asia unscathed.

Monsoonal Flow

Current scientific thought underwrites the assertion that the Asian monsoon will likely be characterized by an increase in precipitation and a subsequent increase in spatial variability (Kripalani et al. 2003). These predicted changes will have a strong impact on the water systems of the Indian subcontinent, where up to 80% of annual precipitation is directly dependent on monsoon strength, though notable changes in precipitation will also be visible across the QTP (Kripalani et al. 2003). While the relative interaction between changes in monsoonal flow and melting glaciers will be discussed later in this paper, it is important to note that the small input of glacial melt into the total discharge of rivers in China creates scenarios in which flow of Chinese rivers are wholly reliant on precipitation generated by summer monsoon rains (Immerzeel et al. 2010).

Interactions Between Glacial Melt and Precipitation

Two processes, glacial melt and monsoonal strength, are inextricably bound together. The first and likely most important connection between these two events is their temporal scale, with the peak of both events occurring between June and September. This creates a circumstance in which the maximum river discharge caused by both events happens at relatively close intervals, leading to a major cause of vulnerability - flooding in the short-to-medium term (Immerzeel et al. 2010). Yet, as glaciers continue to recede, and eventually disappear, this short term increase in peak flow will give way to water shortages across these watersheds, especially on the glacier-dependent Indian subcontinent.

However, there is likely a secondary, but not unimportant connection between monsoonal flow and glacial recession. It is widely agreed that increases in global temperature will result in an increase in the frequency and intensity of the meteorological anomaly - the El Niño Southern

Oscillation (ENSO). These ENSO patterns are directly related to low snow cover in the northern hemisphere (Kripalani et al. 2003). Thus, marked by a decrease in snow cover and an increase in glacial melt, glaciers will be effectively “burnt at both ends,” resulting in glacial decreases not only due to increased melt, but also due to decreased accumulation. This lack of snowfall, and thus glacial growth, will likely cause a temporal reduction of the short term “flooding” period, speeding up the overall process of glacial recession and resulting in a relatively shorter period for decision makers across the region to make appropriate adaptation plans for the critical resource of water for livelihoods downstream.

These factors, through their interaction, primarily control the climatological inputs to the hydrologic regime of Asia’s headwaters. Through the temporal interaction of glacial melt and monsoonal rains, massive amounts of freshwater are released from the Himalaya to downstream communities and ecosystems every year. However, climate instability is bringing these processes into question. Understanding that increases in global temperature will likely increase both monsoonal moisture and (in the short term) glacial run-off, the current inputs to the water systems of Asia are at risk to significantly change from expected flow cycles.

Grassland Degradation: The Ecosystem Connection

The flow of rivers which descend from the QTP cannot be characterized by climatological phenomena alone. While precipitation and glacial melt in the headwaters region accounts for as much as 40% of the annual flow and 100% of dry period flow in these rivers with the rest of river flow originating from downstream precipitation (Xu et al. 2009, Immerzeel et al. 2010), the scientific community has largely ignored the quality of these ecosystems in hydrological research. However, there can be no question that decreased grassland quality across the QTP will result in increased runoff downstream (Xu et al. 2009). Considering the faltering state of these grasslands, this oversight seems glaring. Further, there is a lack of research which directly quantifies the extent and causes of rangeland degradation across the QTP in Western literature (Harris 2008, 2010); however, definitive research is ongoing in Qinghai Province, led by a team of researchers from Arizona State University, the University of Montana, and the University of Colorado at Boulder. The following paragraphs will present available evidence for both the extent and causes of rangeland degradation and resulting policy responses across the plateau.

Extent of Degradation

The most limiting factor facing policy makers in the QTP region is the lack of a clear definition of degradation (Harris 2010). This lack of a definition has led to widely varying estimates as to both the extent and severity of grassland degradation, with some estimating that as much as 90% of China’s grasslands are degraded in some way (State Council 2002). However, as with many other grassland ecosystems, the metrics used to make estimates of grassland degradation across the QTP are highly subjective, are not generally peer reviewed, and are made by workers whose training is sub-optimal (Harris 2010). Therefore, while many “statistics” used to support the conclusion of an increase in rangeland degradation exist, the lack of a definition of degradation may lead to subjective results calling the resulting statistics into question.

That is not to say that the rangelands across the QTP are not becoming degraded. In fact, while many studies disagree on the extent of degradation, nearly all current research shows that the alpine grasslands have been degraded to some extent (Li et al. 2010b). With this in mind it is important to analyze the possible causes of degradation in these critical headwaters regions. As noted above, while causes for degradation have not been definitively tested at this time, recent work by Harris (2008, 2010) and Zhou (2005) suggests that the most plausible explanations fall into four categories: climate, social policy, over grazing, and “rodent” damage.

Causes of Degradation: Climate, Social Policy, Over Grazing, and “Rodents”

Theories connecting rangeland degradation and climate change have developed along several lines of inquiry. The first is that grassland degradation is caused by changes in precipitation. However, while long-term climate models point to changes in precipitation across the QTP, these changes in precipitation have yet to be observed on an appropriate scale (Harris 2008, 2010, Shrestha et al. 2008). Some local areas have seen changes in precipitation; however, degradation is occurring at broader spatial scales suggesting that precipitation alone cannot account for decreases in grassland quality. This observation does not suggest that climate is a completely unrelated factor. Increasing evidence suggests that permafrost depth and quantity is declining across the plateau leading some to claim that this decrease in permafrost has upset the current hydrologic regime leading to a decrease in grassland productivity (Wang et al. 2000). Specific evidence for this connection between permafrost loss and decreases in grassland quality is lacking, with more research needed before any definitive links are made. Conversely, specific evidence is emerging which directly connects a warming climate with the changing phenology of the region. As pointed out by Yu et al. (2010) many plants across the QTP are dependent on the extreme cold of winter to trigger their growth cycle for the following year. However, as the climate continues to warm it appears that necessary cold periods are not occurring, thus leading to delays in summer growth. This explanation for grassland degradation is also incomplete. It is not likely that all the plants across the QTP share this same cold dependent cycle, calling into question the role played by warming in regard to widespread rangeland degradation.

In total these factors leave the impact of climate as muddled. Over the long term, precipitation is expected to change, yet evidence for any current changes in precipitation is lacking (Harris 2010). Permafrost will likely continue to melt, however the impact of permafrost loss is not understood in the context of the QTP. The summer phenology of vegetation on the QTP may be delayed by increasing temperatures, yet these delays may open up opportunities for other, plants not as reliant on temperature to trigger their growth cycle. While climate change likely plays some role in the decreasing productivity of these grasslands, it seems unlikely that it alone can be wholly responsible.

Some western scientists (e.g. Miller 1995, Sheehy et al. 2006, Foggin 2008, Foggin and Torrance-Foggin 2011) blame grassland degradation on Chinese social policies that impact the nomadic lifestyle of Tibetans. Currently there are two major policies designed to change traditional pastoralism across the QTP: the total removal of livestock from the land, and the movement from communal to individual land ownership. The pastoral history of the QTP is complicated at best. Due to the harshness of the climate and patchiness of resources, people living on the QTP have long taken to completing extensive seasonal migrations with their livestock, moving herds over vast elevation gradients and spatial scales to take advantage of prime grazing conditions (Miller 1995). Prior to 1958 most livestock (primarily yak and sheep) were owned by individual families, but pasture lands were managed at the community level. In 1958 livestock were collectivized into a commune system. In 1985 livestock ownership was decollectivized, with livestock divided proportionally by family size. By 1985 most winter pastures were again divided by family (although this policy was not fully implemented until 1996), whereupon management responsibilities were shifted from the community to the individual family (Miller 1995; Sheehy et al. 2006; Yeh and Gaerrang 2010). This change in policy, which has been critically examined by many scientists and observers (Miller 1995; Yan et al. 2005; Sheehy et al. 2006; Foggin 2008; Yeh and Gaerrang 2010; Foggin and Torrance-Foggin 2011) as fundamentally changing the Tibetan lifestyle, is couched in the ideas of neo-liberalism. After the failings of the commune system there has been an attempt to form a “socialized market economy with Chinese characteristics” across all of China (Wu 2008). During this time of incredible social change, grassland degradation was beginning to appear across the QTP. This observation lead many Chinese policy makers to view the communally managed grasslands as suffering a tragedy of the commons (Foggin 2008). As such, policy makers moved land management to the individual family with the intent that individuals would care more for a land that is “theirs.” This policy included the introduction of fencing, building of winter houses, and breakup of pastures into smaller units. Current research suggests that this policy has not been successful at mitigating grassland degradation (Foggin 2008, Harris 2010), and may have in fact exacerbated the underlying issues causing degradation (Yan et al. 2005, Foggin 2008). Fencing in particular seems to be an ineffective policy designed to increase grassland quality. Pastoralism is defined by a patchiness of resources (Sheehy et al. 2006). Using traditional methods, Tibetan pastoralists successfully navigated and managed these patchy resources for millennia (Miller 1995). This patchiness necessitates flexibility from those using the land. Fencing limits this flexibility, forcing nomads to graze lands which they deem marginal as they cannot cross into a neighbor’s property (Yan et al. 2005). This policy thus raises the functional grazing density on these marginal lands compared to a fenceless-system despite the fact that livestock densities may not have changed over the entire landscape.

This phenomenon may have contributed to the third possible cause of rangeland degradation: overgrazing. Herd size has significantly increased since 1949 (Harris 2010). This increase, combined with the aforementioned increases in grazing densities on marginal lands caused by fencing, has lead Chinese policy makers to institute a portfolio of policies aimed to remove pastoralists and livestock from their lands, relocating them in towns (Figure 2). With names such as “Rangeland to Grasslands” and “Ecological Migration,” these policies focus on herders and herd size as the vector of rangeland degradation with the solution being the total, and sometimes permanent, removal of livestock (Foggin 2008, Yeh and Gaerrang 2010). However, this policy too seems flawed. The underlying assumption of these policies is that a total removal of livestock would be beneficial for grassland health. However, these policies neglect the impact that Tibetan pastoralism has had on the QTP ecosystem. The yak and sheep which Tibetans herd are preferential grazers. As livestock is removed from the ecosystem, grasses and sedges which they would have consumed out-compete other plants, reducing the overall biodiversity of the area. It has been suggested that this chain reaction may exacerbate degradation (Miller 1995, Sheehy et al. 2006). Additionally, even if the total removal of livestock were beneficial to grassland health, little evidence suggests that these policies achieve this goal. In many cases pastoralists who are forced to move into settlements merely sell their livestock to pastoralists who remain on rangelands, thus failing at the primary goal of decreasing grazing pressure (Yan et al. 2005). Lastly, these policies do not come without a cost. With few skills, little-to-no income, and no prospects for employment, poverty rates are high among recently relocated nomads, while education and public health measures are low (Foggin and Torrance-Foggin 2011).

This is not to suggest, however, that overstocking is not a problem across the QTP, but rather that the policies meant to alter these outcomes have been ineffective. Stocking numbers have increased in recent years (Harris 2010), and this may be a significant factor in the increasing degradation of the QTP. Solutions designed to decrease stocking numbers will likely not come from the application of market forces (which overemphasize short-term gains over long-term growth), but rather by policies which embrace the flexibility needed for herders to be successful in such a harsh environment (Foggin and Torrance-Foggin 2011).

The final explanation for grassland degradation is damage caused by "rodents." Though not a rodent, nor the only small, burrowing mammal on the QTP, many policy makers blame grassland degradation on the high population density of a small, endemic lagomorph, the plateau pika (*Ochotona curzonia*e) (Fan et al. 1999; Smith and Foggin 1999; Harris 2010; Delibes-Mateos et al. 2011). This has led to widespread efforts to extirpate the pika, with nearly $1 billion U.S. spent and 300,000 km^2 poisoned between 2006 and 2010 (Ma 2006). In areas where the pika has been locally extirpated, large decreases in biodiversity have been observed, leading scientists to give the plateau pika the moniker of "keystone species" (Smith and Foggin 1999, Lai and Smith 2003, Smith et al. 2006, Delibes-Mateos et al. 2011). These crashes in biodiversity have not phased Chinese policy makers who have continued large scale poisoning campaigns despite warnings from the scientific community. However, even without taking concerns about biodiversity in to consideration, it seems unlikely that pikas could be responsible for grassland degradation. Pikas only appear at high densities in areas which have already been degraded (Delibes-Mateos et al. 2011); further, as an endemic species, the pika has subsisted sustainably on the grasslands of the QTP for millennia while grassland degradation has only been noted recently. As such, it seems more likely that pikas are a barometer for degradation, rather than its root cause.

The reality is that none of these causes for degradation can fully explain the deterioration of the grasslands of the QTP. Instead, it is far more likely that each of these factors plays an interacting role in a complex socio-ecological system wherein they are bound. While the pathway may not be clear, the outcome is: the headwaters of the QTP are both degraded and degrading at an ever increasing rate (Harris 2010).

A Way Forward

The factors outlined above paint a bleak picture for the future of the QTP's watersheds. In the upcoming years Asia will be forced to deal with increased, spatially patchy monsoonal rains, glacial melt, and degraded headwaters ecosystems. Many of these factors are outside of the control of policy makers. Regardless of cuts in carbon emissions (which are unlikely), global temperatures are expected to rise. Barring any scientific or policy break through, degradation will continue across the QTP, further increasing erosion and run-off (Li et al. 2010a, 2010b). These are the realities of a changing world.

Additionally, most of the countries which will be directly impacted by changes in the downstream flow of rivers originating on the QTP have little-to-no control over the quality of their headwaters landscape. International cooperation, within and across political alliances, will be critical for people who live outside of China's borders but inside its watersheds. Therefore, as flows become more seasonal and less reliable, it will be critical that China embraces its position as a headwaters partner whole-heartedly. Unfortunately this international cooperation is not happening.

The best example of this lack of cooperation is the governance along the Mekong River. Originating in Qinghai province, the Mekong travels through China before entering into Southeast Asia where it winds through Myanmar, Laos, Thailand, Cambodia, and Vietnam. To say this river is the life-blood of these countries is an understatement. Characterized by flood cycles, this river and its tributaries provide the vast majority of protein to what is one of the world's more impoverished regions and is central in the cultural identities of people living downstream (Grumbine et al. 2012). Recognizing that this river's flow is critical to such a vast number of people, the governments of the Lower Mekong Basin (LMB) (Thailand, Loas, Cambodia, and Vietnam) banded together to form the Mekong River Commission (MRC) in 1995 with the passage of the Mekong River Agreement (Grumbine and Xu 2011, Grumbine et al. 2012). This agreement joined the governments of the LMB into co-management of the river, its resources, and flow regime. However, the MRC framework presents one critical flaw: the lack of cooperation with upstream partners. After beginning on the QTP, the Mekong flows through Myanmar before descending into the LMB, yet neither China nor Myanmar are full members of the MRC. As 30% of dry period flow begins in these upstream ecosystems, this lack of partnership has severely limited the effectiveness of the MRC.

This limited partnership has allowed for different management strategies to take hold on the upper and lower reaches of the Mekong. Along the upper sections of the river (i.e. China, Myanmar) the river travels through deep canyons and areas with an exceptionally limited population. China and Myanmar have moved to dam these narrow regions of quickly descending waters in an attempt to harness large amounts of cheap, sustainable energy. However, the demands of the LMB are quite different. Here the river flows in a slow, spread-out path, and floods frequently. These flood waters provide irrigation for rice production, spread vast amounts of silt from upstream, and fill lakes such as Tonle Sap which provide the vast amount of GDP and food for LMB countries (Grumbine et al. 2012). With this reliance on flooding in mind (and with more than a little international pressure) the countries of the LMB have temporarily stalled construction on downstream dams, though many dams are still in the planning phase (Vaidyanathan 2011). With the increased growth of damming projects upstream, particularly in China, it is easy to question the amount of influence the MRC will ultimately have on the flow of the Mekong. Though these countries are far more reliant on the Mekong for food and GDP than their upstream neighbors, they can only manage the water which enters their borders. As such, it is critical that the MRC, Myanmar, and Chinese governments create an institution to manage these rivers in a single coherent policy. Without this policy change, and if continued dam production continues in upstream countries, it is not an exaggeration to suggest that the subsistence of Southeast Asia is at risk. This model of governance, if achieved, could lay the groundwork of management strategies for the QTP’s other rivers. Exemplified by the 2010 flooding of the Indus, the need for coherent water management on the Indian subcontinent seems clear. Again however, the countries of the lower basins of these rivers cannot manage their flow alone. The decisions made by China will be especially important for the countries of the Indian sub-continent as their rivers are the most reliant on glacial melt (and therefore upstream management decisions) for flow.

Yet China's needs should not be forgotten. As a country which is both growing at an exceptional rate and the world's largest contributor of carbon-dioxide, China needs clean energy. While biodiversity losses along dams can be catastrophic, so are the losses predicted to occur due to climate change and from fossil-fuel mining itself. The argument here is not that China should stop constructions of dams all together, or that damming is a particularly bad option when faced with the energy constraints of rural China, but rather to suggest that a dialog towards meeting the needs of both upstream and downstream countries is necessary, and at this time such a dialog is not occurring.

Conclusion

With as much as 40% of the world's population relying on the QTP for water, the Plateau has earned its nick-name of Asia's "water-tower." However, this water-tower and the grasslands upon which these rivers depend are at a crossroads. Impending climate change will introduce variability into the monsoon cycle and accelerate the recession of Himalayan glaciers. Grassland degradation is seemingly accelerating with unknown causes. And yet, the pressures on these ecosystems must be balanced against the people who depend on them both up and downstream. These are not small problems, and thus small solutions will not solve them. Rather, securing Asia’s water-tower will take both top-down and bottom-up approachs.

On the scale of the QTP itself, it seems clear that the current policies of sedentarizing nomads and removing livestock are not successful at restoring grassland health. Rather, these nomads, with their tacit knowledge of rangeland management, are critical stewards of the land whose livestock play a role in maintaining its community composition. As such, their ability to maintain their traditional lifestyle is critical. However, these people cannot be eco-martyrs, forced to live a lifestyle without economic or social development in the name of protecting the grasslands and the water of downstream people. Rather, we should look to scaleable solutions for growth which emphasize community engagement with pastoralist input. NGOs such as Plateau Perspectives are leading the way in this effort, proving that it is possible to provide education and health care to nomad communities without requiring nomads to give up their pastoralist lifestyle (Foggin and Torrance-Foggin 2011). These models of community involvement should be further explored, and, if successful, implemented at broader scales.

If these methods meet expectations and rangeland degradation is stymied, the international management of these watersheds will benefit. However, protecting the grasslands of the QTP will not be enough. The building of international institutions which can focus on the fair an equal management of these waters is necessary. Without these institutions the water security of much of Southeast Asia and the Indian Sub-continent is in question. As described in this paper the watersheds of the QTP are at a turning point. It is critical that the Chinese government, the scientific community, and local people turn their eyes towards the future to adapt to these problems before they become full-fledged crises.

Chapter 3. The Pika and the Watershed

Introduction

With as many as 40% of the world's human population living in its downstream watersheds, the Tibetan plateau is "Asia's Water Tower" (Xu et al. 2009, Immerzeel et al. 2010). Fed by glacial runoff and monsoon rains, the downstream flooding of these rivers has led to massive losses of life and property (Varis et al. 2012), causing the Chinese to nickname the Huang He "China's sorrow" and to build one of the largest structures on earth (Three Gorges Dam) in an attempt to tame the Yangtze. However, the upstream grasslands of the Tibetan plateau, which regulate the flow of these rivers, are becoming increasingly degraded (Zhou et al. 2004). One agent of change has been the over-grazing of livestock (yak, sheep, horses), which in turn has resulted in elevated population densities of a native small mammal, the plateau pika (*Ochotona curzoniae*) (Shi 1983, Fan et al. 1999). Seeing pikas on degraded grassland has led local authorities to classify them as pests and poison them in an attempt to restore grassland health. This poisoning has gone on for six decades, has not improved rangeland health, and is massive in scale with over 208,000 km^2 poisoned in Qinghai Province prior to 1990 (Fan et al. 1999) and over 300,000 km^2 targeted for poisoning from 2007 to 2010 (Ma 2006).

An alternative view is that rather than being a pest the plateau pika is a keystone species for biodiversity (Smith and Foggin 1999, Lai and Smith 2003, Badingqiuying 2008, Delibes-Mateos et al. 2011). The high plateau meadows support few trees, so most endemic plateau birds (Tibetan snowfinch *Montifringilla adamsi*, white-winged snowfinch *M. nivalis*, plain-backed snowfinch *M. blanfordi*, small snowfinch *M. davidiana*, rufous-necked snowfinch *M. ruficollis*, white-rumped snowfinch *M. tacazanowskii*, Hume's groundpecker *Pseudopodoces humilis*) breed almost exclusively in pika burrows (Lai and Smith 2003). When pikas are poisoned their burrows collapse and these species disappear (Lai and Smith 2003). Plant species richness is also higher in pika colonies compared with poisoned sites (Bagchi et al. 2006, Hogan 2010). Additionally, pikas are the main source of food of nearly every carnivore on the plateau (mammals: mountain weasel *Mustela altaica*, steppe polecat *M. eversmanii*, Tibetan fox *Vulpes ferrilata,* red fox *V. vulpes*, Pallas's cat *Felis manul*, wolf *Canis lupis*, brown bear *Ursus arctos*; birds: upland buzzard *Buteo hemilasius*, saker falcon *Falco* cherrug, northern black-eared kite *Milvus lineatus*, little owl *Athene noctua*) (Schaller 1998, Smith and Foggin 1999, Badingqiuying 2008). As the carnivore guild suffers in areas where pikas have been poisoned there have been concomitant knock on effects. For example, with pikas making up as much as 90% of the diet of local brown bears, bear attacks on property have increased as pikas are eliminated

(Worthy and Foggin 2008). Taken as a whole the campaigns to poison plateau pikas has resulted in a dramatic loss of biodiversity on the plateau.

The pika is also an ecosystem engineer (Hogan 2010, Delibes-Mateos et al. 2011). Pikas live in burrows in social family territories (Smith and Wang 1991, Dobson et al. 2000) with burrow densities reaching as high as 1000/hectare. With a geographic range spreading across the Tibetan Plateau the pika's habitat averages 4,000m in elevation, is classified as arid or semi-arid, and is characterized by spatially varying rainfall totals. In headwaters systems where the pika is dominant, upstream precipitation can account for as much as 40% of annual flow and 100% of dry season flow in downstream rivers (Xu et al. 2009, Immerzeel et al. 2010), with the vast majority of precipitation occurring during summer monsoon months. This short window combined with the importance of upstream precipitation contributes to large fluctuations in river flow with some rivers entering persistent flood and drought cycles. Thus, the runoff rates and groundwater retention in these upstream ecosystems have exceptional impacts on downstream communities.

I hypothesized that through their burrowing activity pika colonies act to decrease the bulk density of soil thus increasing the infiltration rate of water during monsoon storms. The subsequent benefits to groundwater recharge and overland run-off may be critical factors in flood prevention.

Methods

Infiltration rate of water was measured at three treatment types, defined as: 1) Adjacent to an active pika burrow (On Burrow) (Figure 4); 2) Between two (or more) active pika burrows, but at a distance of at least 1 m from an active burrow (On Colony)(Figure 5); and 3) Areas where pikas had been thoroughly eradicated due to poisoning campaigns and absent for more than two years (where burrows have collapsed; Off Site)(Figure 6). Measurements of infiltration rate of water were taken using a double-ring infiltrometer (Turf-Tec International: http://turf-tec.com/IN7lit.html) with an inner ring diameter of 15.24 cm and an outer ring diameter of 30.48 cm, and accompanying Mariotte Tubes (Figure 7). Infiltrometer placement at each site was randomly determined by the researchers throwing a piece of yak dung over one's shoulder in a randomly determined direction. The apparatus was then situated adjacent to the closest active burrow (On Burrow treatment) or the closest site meeting the specifications of treatments 2 (On Colony) and 3 (Off Site), respectively. All placements were approximately level as the thick sod mat inhibited driving the apparatus more than 1-2 cm deep, and leakage could only be prevented on nearly flat surfaces. To assure consistency of measurement the constant head method was used, and testing sites were brought to, or near, saturation by allowing a minimum of 20 cm of water to infiltrate into the soil before measurements were taken (Wu et al. 1997, Bodhinayake and Si 2004). To assure precision, infiltration rates were measured and averaged over two or three, fifteen minute periods.

The double ring inftiltrometer was chosen because this design of infiltrometer provides the most accurate, cost effective, and portable way to measure the infiltration rate of water into soils (in contrast to single-ring infiltrometers that vastly overestimate actual infiltration rates). While double-ring infiltrometers are known to overestimate the actual infiltration rate slightly, this error is small (Wu et al. 1997, Bodhinayake and Si 2004). Additionally, as the study will compared areas using the same equipment, this slight overestimate will not jeopardize our results in any way.

This experiment took place at five sites broadly spread across Qinghai Province in the Sanjiangyuan (“Three Great Rivers”) region which serves as the headwaters for the Yellow, Yangtze, and Mekong Rivers (Figure 1). Data were collected from the 16 May to 15 July 2010 and 18 May to 23 June 2011. Special consideration was given to site selection. Off site treatments were only areas which had supported pika colonies before poisoning campaigns and were as near as possible to currently established pika populations. To eliminate compounding factors, only areas with relatively level slopes were selected. Further, as shown by Hogan (2010), if burrow entrances are excluded there is no significant variation in ground cover between on colony and off site treatments, thus eliminating possible interactions between ground cover and infiltration rates (see Figures 4-6).

Results

The infiltration rate of water varied significantly across treatments (Figure 2, Blocking-Factor ANOVA (two tailed): $F_{2,8}=16.992$; $\alpha=0.001$). Off colony sites consistently presented the lowest infiltration rate. Intermediate infiltration rates were observed at sites on colony but away from burrows, and sites immediately next to burrow openings showed the highest infiltration rates (see Figure 2 for Tukey-Kramer comparisons).

Discussion

These data confirm that through its burrows the plateau pika acts as an ecological engineer, increasing the infiltration rate of in areas occupied by pikas. Conversely the demonstrably lower rates of infiltration in pika free (poisoned) areas indicates more rapid run-off during summer monsoon storms. While not directly quantified by this research, the additive impacts of a vastly increased infiltration rate across the range of the plateau pika (nearly the entire QTP) on both groundwater retention and runoff control are likely large. These data are especially powerful when the lack of compounding processes are considered. As pikas do not significantly decrease ground cover on the landscape scale (Hogan 2010) or impact slope angle, these changes in infiltration rates should be directly represented in overland runoff.

These data suggest that the poisoning of plateau pikas is a failed policy. Not only does the policy lead to critical losses of biodiversity, but by ignoring the benefits pikas provide as ecosystem engineers it may lead to negative consequences, such as increased potential for flooding in downstream watersheds. Further, poisoning does not lead to improved grassland health, making pika poisoning worse than a zero sum game. Therefore the only policy recommendation resulting from this research is for the immediate cessation of pika poisoning.

Figure 1. A map of the Qinghai Tibetan Plateau highlighting some major rivers. From Harris 2010.

Figure 2. A housing community for relocated Tibetan pastoralists.

Figure 3. A family group of plateau pikas (*Ochotona curzonaie*).

Figure 4. A picture showing “On Burrow” treatment. Infiltrometer was placed centered in disturbed area.

Figure 5. Picture showing “On Colony” treatment. Infiltrometer placed randomly at least 1m from an active pika burrow (see text).

Figure 6. Picture of pika free grassland with Max Wilson in foreground. Infiltrometer was placed randomly (see text). Note: due to livestock, vegetation mass appears equivalent to on-colony sites.

Figure 7. Double ring infiltrometer with a plateau pika in the foreground.

Figure 8. Map of the study are on the Qinghai-Tibetan Plateau. Study areas, shown in red (from left to right: Nangqian, Chendou, Zhenqin, Dawu, Sendou), were broadly spread across the alpine meadows of eastern Qinghai Province (average elevation = 4,000 m), encompassing the drainage systems of the Mekong (Nagqian), Yangtze (Chendou, Zhenqin) and Yellow (Sendou, Dawu) rivers.

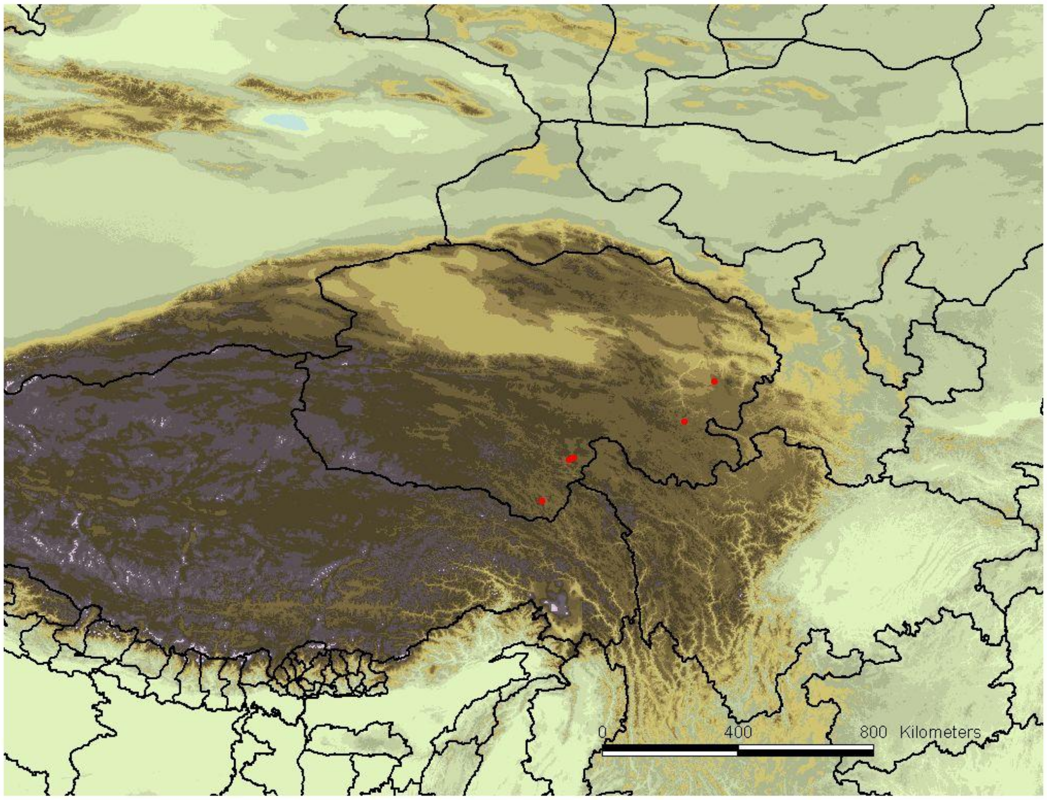
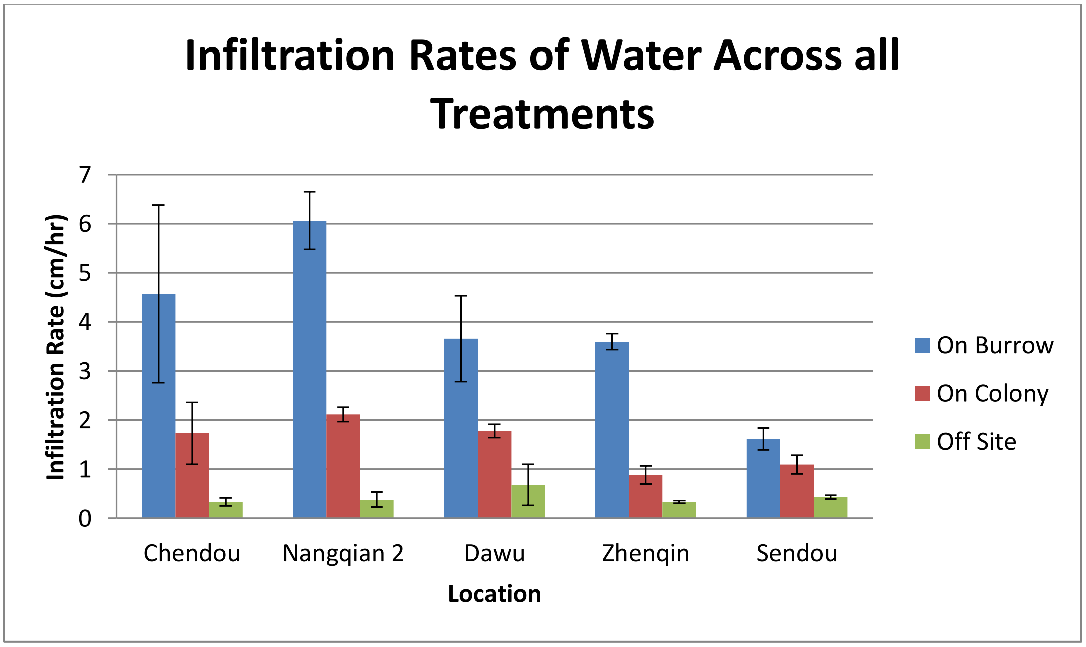


Figure 8. Average infiltration rate of water by treatment and location. Error bars represent 1 standard error of the mean. Blocking-Factor ANOVA was used to test for significant variation in mean infiltration rate of all three treatments across localities. Treatments included measurements On Burrow (adjacent to an active pika burrow), On Colony (at least 1 m from active burrows, but within an active pika colony), and Off Site (at a location where pikas had been poisoned an old burrows had collapsed). Total sample size for the project is 54 with sample sizes varying from nine (three per treatment) to fifteen (five per treatment) by locality. Blocking-Factor ANOVA (two tailed): $F_{2,8}$=16.992; P=0.001. Tukey-Kramer comparisons between sites: Off Site v. On Burrow - P<0.001; Off Site v. On colony - P<0.004; On colony v. On burrow - P<0.001.



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