Dartmouth in Namibia

Dartmouth College, Environmental Studies Program, Hanover NH USA

October-November 2013

Foreward

The papers that follow were authored by the students in the 2013 Dartmouth College Environmental Studies Program in Namibia. Dartmouth College is a liberal arts university in Hanover, New Hampshire USA. The students were tasked with engaging productively in the socio-ecological system that has at its core the !Nara plant, the Khuiseb Topnaar and their subsistence and commercial harvest of !Nara, and the Gobabeb Research and Training Center that conducts research on !Nara and is situated along the Khuiseb River. These four papers are some of the products of that engagement.

The students were, Joseph Bonnell-Hall, Hemayat Chowdhury, Tsomo Cuomaoji, Meegan Daigler, Samantha Dowdell, Will Hirschfeld, Aislinn McLaughlin, Chris Megrue, Andrew Milligan, Krystyna Oszkinis, Samantha Parker, Nick Pavlis, Claire Pendergrast, Matt Stanton, Katie Williamson, and Reed Wommack.

There were many people who made this work possible – too many to mention individually. But we would like to acknowledge Chief Kooitjie and his staff, and the many members of the Topnaar community that gave generously of their time and knowledge. We also wish to thank Gillian Maggs-Kolling, Mrs. Irish, Sebedeus Swartbooi, Esther Nashipolo Uushona (Gwash) and the rest of the Gobabeb staff and interns, Julian Fennessy and Stephanie, Molly and Luca Fennessy, Tom Kraft, Celia Chen and Maya Bolger-Chen, Wild Dog Safaris, Desert Hills, Bill Roebuck, and Kim Wind.

Doug Bolger
Director, Dartmouth in Namibia

The Economics of !Nara

Claire B. Pendergrast[1]

Nicholas D. Pavlis[1]

William J. Hirschfeld[1]

[1]Dartmouth College, Hanover, New Hampshire, U.S.A.

Abstract

The Topnaar people of Namibia have been harvesting and utilizing the !nara plant for centuries as a cultural tradition and livelihood strategy. Towards the end of the twentieth century, Topnaar began to seek benefits from the resource beyond subsistence use, but also through commercial sale of !nara products outside the Topnaar community. In this briefing we examine the current state of the !nara market system, using a value chain approach to identify leverage points for strategic intervention to improve market efficiency and increase economic benefits throughout the market system. We then propose a multi-phase business model that addresses key barriers to !nara's commercial viability with the aim of improving harvester organization and collaboration, quality and price of raw material, and communication between producers and processors. While such a model holds great potential, we recognize that its utility and feasibility is limited by knowledge gaps of current system dynamics; we therefore suggest opportunities for further research efforts.

Introduction

Namibia's indigenous natural plant resources offer many opportunities to the country's rural poor; sustainable INP harvest and trade offer opportunities for poverty alleviation, food security, interaction with developed markets and diversification of livelihoods. In Namibia, where twenty percent of rural populations are considered "extremely poor" and inadequate rainfall restricts subsistence farming potential, livelihood diversification to generate supplementary income is vital to human security (MCA). Namibian INP initiatives support the organization of INP harvesters into producer groups or associations equipped to manage resource utilization, maximize economic benefit for the community, and ensure sustainable harvesting practices are followed.

The INP Sub---Activity coordinated by the Natural Resources Institute, University of Greenwich, and, supported by MCA---Namibia (MCA---N), has conducted extensive assessments of Namibia's diverse indigenous plant resources in order to evaluate how development funds and support could be leveraged to facilitate community ownership, improved capacity and achieving long---term sustainable economic benefits from INP commercialization.

The INP Sub---Activity supports species were selected based on

- community organizational capacity to manage INP resources
- abundance and quality of INP resource available for sustainable harvest
- market demand for INP product

While !nara was initially included on MCA---N's list of target species to support, it was dropped from the list after closer examination of the plant's complex and delicate ecological, social and economic context. While national commercial demand for !nara seed oil was recognized, the lack of harvester organization, the remoteness of the Kuiseb from other MCA---N opportunities, and the small and potentially declining INP resource base meant investment in !nara commercialization would entail unacceptable costs with limited benefits (MCA).

While the current scale and conditions of !nara harvesting, processing, and scale are not suited to the aims of MCA---N program, this does not mean that !nara lacks commercial viability or that barriers to heightened !nara market value are insurmountable. With external support and internal commitment, a carefully tailored intervention to facilitate improved market efficiency and competitiveness could leverage significant economic benefit for all involved in !nara commercialization.

Role of !Nara in Topnaar Livelihoods

The harvesting of !nara melons has historically played an integral role as a primary source of income and food security in many rural Topnaar livelihoods. The plant holds cultural value for Topnaars, as it symbolically distinguishes them from their greater Nama ethnic origins (Henschel et al, 2004). Currently, harvesters process the seeds from !nara melons for sale to a small---scale manufacturer, Desert Hills, as well as primary consumers in a small borough of Walvis Bay township called Narraville. Although more secondary demand for !nara seeds does exist in Southern Africa, it remains a currently negligible market for processors due to its volatile character and identified low ceiling for potential consumers (Stefanie Heummer pers. comm.). !Nara is harvested seasonally (November through May) both for commercial sale and subsistence use (book). Poorer Topnaars, who lack sufficient numbers of livestock or income streams to purchase food from Walvis Bay, are particularly dependent on the !nara as an emergency food source (Werner 2003). In addition, !nara roots are occasionally harvested for local use as a traditional medicine (Gillian Maggs---Kölling pers. comm.)

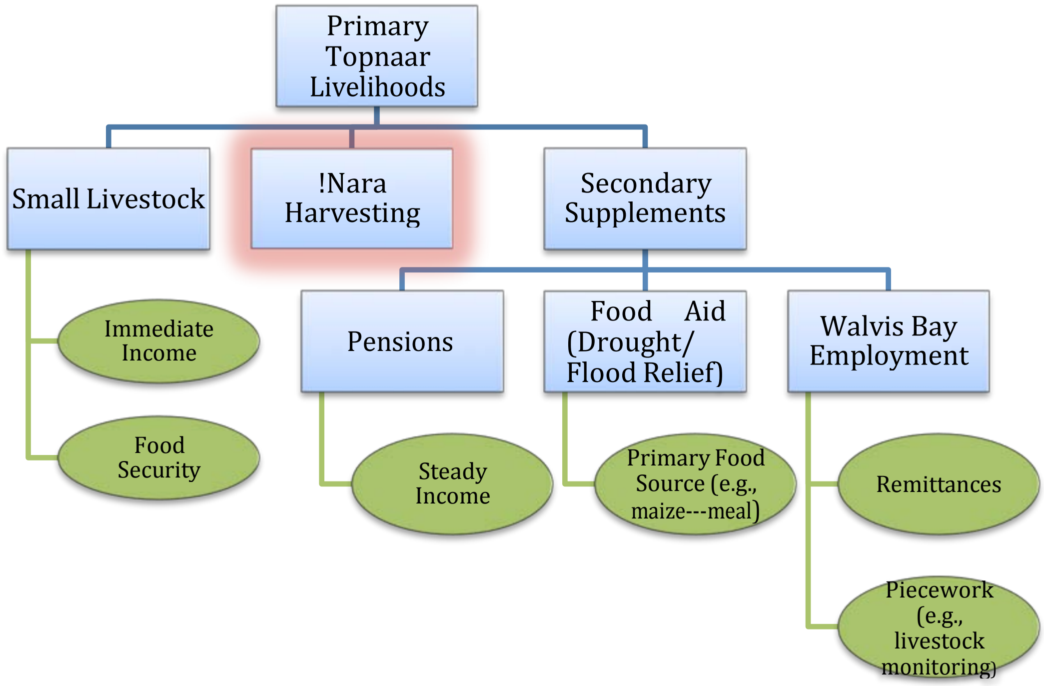


Figure 1: Diversification of Topnaar Livelihood Strategies

While !nara harvest and sale is a prevalent livelihood strategy among rural Topnaars, economic survival necessitates a broader diversification of activities and income sources. Small livestock herding is the most prominent agricultural activity, followed by small---scale gardening (Werner 2003). As shown in the diagram above, farming small livestock and !nara harvesting act as the primary rural Topnaar livelihood strategies. The scarce availability of other natural resources in the region, the multidimensional subsistence uses of the plant (e.g., foods, donkey fodder, and fluid), and the plant's value as a redeemable resource make !nara a primary livelihood strategy. In fact, those who harvest !nara own seven livestock on average, which represents a high quantity and statistical indicator of wealth relative to the Topnaar community (Legal Assistance Centre 2013). Pensions provide rural Topnaar households with the most reliable source of income, while foodstuffs also ration Topnaars key provisions for food and other variable purchases (e.g., transportation, cell phones, clothing). Community members also receive drought relief (i.e., three 12.5 kg bags of maize---meal, three bottles of cooking oil, and some fish per household) three times a year and flood relief (i.e., maize---meal, fish, beans, oil, and sugar) every two months (Legal Assistance Centre 2013). However, these forms of relief are only available for families owning homesteads and only if they are present during the drop---offs. Moreover, unemployed rural Topnaars rely heavily on remittances and piecework from associated urban workers in Walvis Bay (Legal Assistance Centre 2013). For one, rural community members often monitor livestock for urban Topnaars, who often use their salaries to increase livestock herds. Thus, rural Topnaar rely on a relatively balanced portfolio of livelihood strategies for economic survival, as the seasonal nature and intensive labordemands of !nara harvesting (among other variables) cannot singlehandedly provide for the year (Henschel et al, 2004).

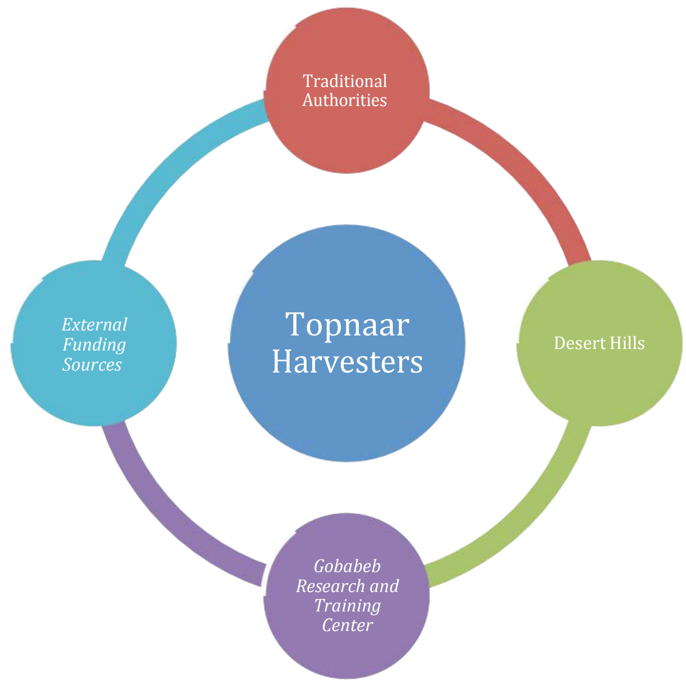


Figure 2: !Nara value chain actors (Porential service providers italicized)

Current Infrastructure/Context

In order to contextualize the !nara harvesting process, several relevant dimensions of local context and infrastructure must be considered.

For one, population statistics prove useful in identifying the Topnaar harvesting community. Although estimates vary due to fluctuating urban/rural migration, an estimated 350---380 people reside permanently in the Kuiseb Valley (Legal Assistance Centre 2013). In a study done in 2013 by the Legal Assistance Centre of Namibia, only 8 out of 174 surveyed Topnaars do not participate in !nara harvesting (Legal Assistance Centre 2013). However, harvesters have expressed increasing pressure from 'outside' harvesters from urban areas, who damage !nara plants through unsustainable harvesting practices.

Moreover, educational capacity in the community remains extremely low, as school---related costs often hinder parents from investing in their children's academic futures. However, as of January 2013, the national government instituted the constitutional right to free education in state pre---primary and primary schools, which has ostensibly outlawed direct school fees (Legal Assistance Centre 2013). Transportation and hostel costs, however, remain barriers to household investment in education. Nonetheless, our interviews with the Topnaar and associated literature indicate that the community recognizes the vital importance of education to poverty reduction (Hermann Areseb, pers. comm; Werner 2003). This institutional weakness, found throughout Namibia, acts as the prominent hurdle in diversifying Topnaar livelihood strategies, forcing community members to depend on !nara harvesting as a central income stream.

Rural Topnaar communities often struggle to access reliable transportation to and from coastal urban centers, though food provisions, banks, and post offices are all unavailable outside of coastal Walvis Bay (Werner 2003). Similarly, none of the settlements had access to electricity or landline telephones, forcing them to rely on the small population of car---owners or unpredictable car access provided by the Traditional Authorities for transport to Walvis Bay (H. Areseb, pers. comm.). This infrastructural gap represents a significant barrier to Topnaar harvesters, who receive a higher price per kilogram for their seeds if they deliver them directly to Walvis Bay.

Methodology

Our primary aim is to develop a basic understanding of the current market system of !nara harvest, processing and sale in Namibia. To achieve this goal, we employed a *value chain* framework, which allowed us to map the positions and relationships of the various players in the market system, as well as flows of income, information, and external inputs (Campbell). Our value chain research also exposed us to problematic players or relationships within the value chain where communication or organizational breakdowns result in inefficiencies and value loss. We also aimed to develop a basic understanding of the history of the !nara market system and how changes in power dynamics, social values and market opportunities have affected the market structure and !nara's value to various stakeholder groups.

Our information was obtained primarily through semi---structured interviews with stakeholders at various levels along the value chain (Hellin & Meijer 2006). Topnaar community members active in !nara harvesting for subsistence, supplementary income or professional opportunities were identified and interviewed, representing the primary producers of the value chain (H. Areseb, S. Swartbooi et al., pers. comm.). Desert Hills owner Stefanie Huemmer provided extensive information on her role as a small---scale processor, distributor and marketer of !nara products. Stefanie also described the dynamics of current and past value chain structures and linkages as well as offering insight on !nara distribution, marketing, and end market dynamics. Chief Kooitjie of the Topnaar Traditional Authority was interviewed regarding the political and cultural context of Topnaar !nara harvesting and the relevance of the Topnaar political environment to the dynamics of the !nara value chain. Julian Fennessey of the Natural Resources Institute, University of Greenwich (UK) provided insight into the broader context of INP commercialization in Namibia, !nara's broad market context and potential market value, and potential NGO/government support for !nara value addition. Dr. Gillian Maggs---Kölling described the role of Gobabeb Desert Research & Training Centre in evaluating !nara sustainable harvesting, Topnaar/!nara cultural value, and harvester organizational structures.

Our evaluation of the existing !nara value chain allowed us to identify potential intervention leverage points through which market efficiency and competitiveness could be improved (Campbell). We were also able to identify limiting factors to !nara's commercial value and development potential for the Topnaar. While our understanding of the market system is far from comprehensive, we utilized our limited knowledge to develop potential value---addition opportunities and generate a phased implementation plan for these proposed changes. We found the major weaknesses of the current !nara value chain to be the lack of communication and trust between primary producers (Topnaar harvesters) and primary processors (Desert Hills), resulting in a low quality raw material and a low price per kg. Poor organization of harvesters and declining interest in !nara harvesting among the Topnaar also pose major challenges.

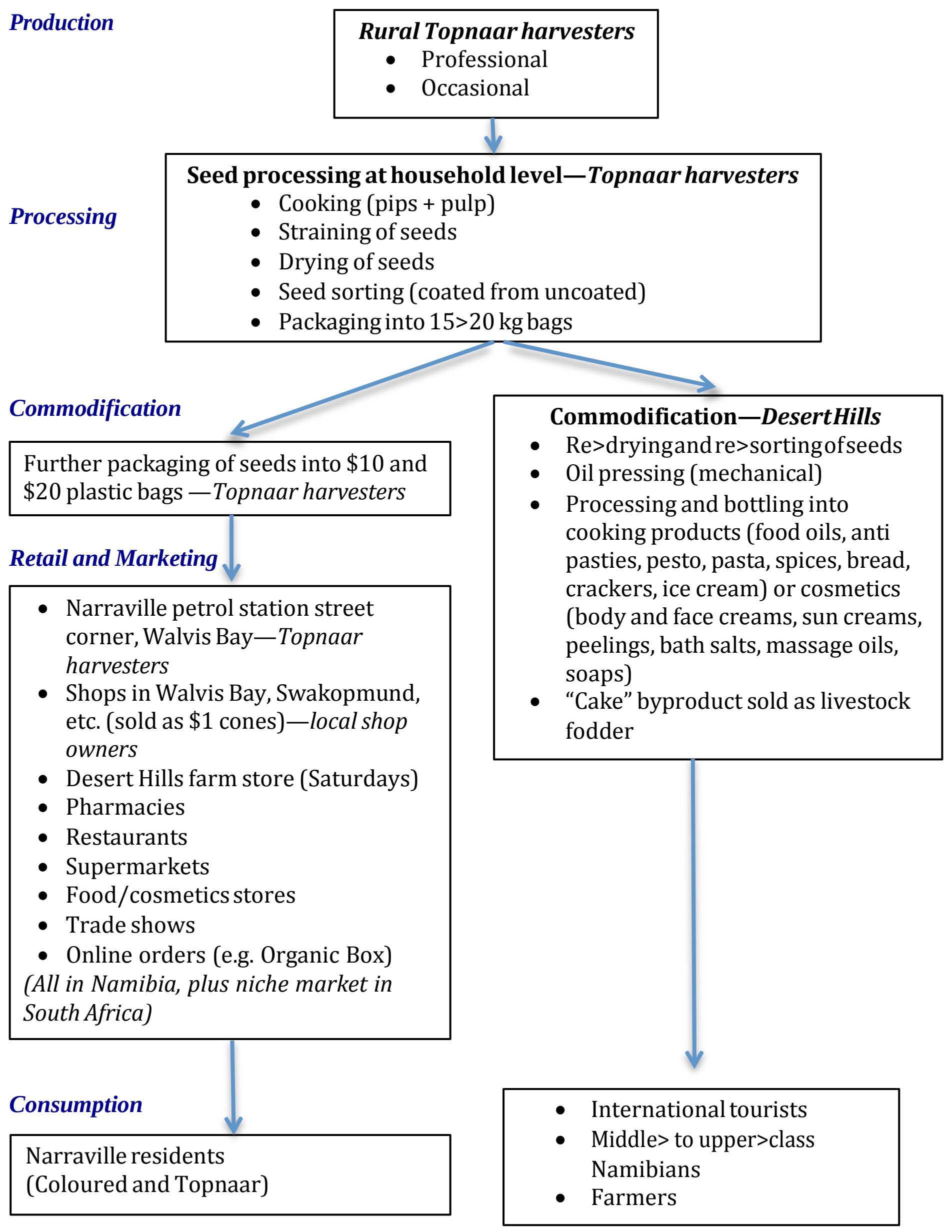
We have generated a multi---stage value chain enhancement plan in order to address these proposed barriers to !nara commercial viability. We have identified steps towards improved harvester organization, quality control, and communication along the value chain. With technical and financial support from external players and potential reforms to the political environment, the horizontal linkages between primary producers and vertical linkages to processors and distributors can be improved, resulting in greater efficiency, competitiveness, and economic benefit for all stakeholders.

Value Chain Approach to Market Mapping

A commercial product's *value chain* encompasses the full range of activities and services required to bring the product from conception to sale (Campbell). Value chains contain multiple levels through which the product must pass to reach its final consumers; the structure and linkages of a value chain's multiple levels and players are often complex and strongly tied to local political, economic and social conditions (Hellin & Meijer 2006). The strength and efficiency of a value chain's structure and relationships determine the overall market system's competitiveness and viability; a functional and efficient value chain is likely to provide benefits to all actors within the chain, from input suppliers to end market buyers (Campbell).

Value chain development interventions aim to facilitate improved products and processes where potential for upgrading exists; improved quality, quantity and efficiency at one point in the chain creates economic opportunities for all involved. Interventions target leverage points that significantly limit the competitiveness of the entire system and hinder progress towards development objectives—economic growth, poverty reduction, and sustainable resource management (Campbell). Value chain analysis is vital to identifying and quantifying constraints and priority reform areas within the market system to facilitate the development of a competitive strategy (Campbell). By examining the existing patterns of !nara harvest, processing and sale and identifying points of dissatisfaction, conflict, and inefficiency within the value chain, we hope to identify feasible steps towards increasing the overall viability of !nara products on the commercial markets. This offers a more feasible alternative to reforming the entire market system or attempting to pursue totally foreign income---generating opportunities. Since !nara harvest is historically central to Topnaar culture and small---scale commercial sale has been in practice for over a century, why not enhance the profitability of an existing market system and skill set? While the scale of the !nara market is not sufficient to meet the needs of the entire rural Topnaar community, any enhanced income or livelihood diversity opportunity is of significance in such a vulnerable and underemployed community.

!Nara Current Value Chain



In the **primary production** phase of the value chain, individual Topnaar harvesters collect !nara melons within national protected areas in Dorob National Park and Namib Naukluft Park, along the Khuiseb River. !Nara harvesting is a time---intensive, laborious process, requiring an average of three hours to gather one kg of seeds (Henschel et al., 2004). Harvesters often spend four months between November and April living at harvesting sites in the desert, gathering !nara for up to 11 hours a day. During the harvesting process:

- Wooden or iron rods are used to pick the fruit off of the thorny plant.
- Harvesters travel to and between hummocks by donkey cart or on foot.
- Collected !nara melons are covered with sand and plastic to ripen for three days.

Currently, ten to fifteen Topnaars harvest for commercial purposes (Sebedeas Swartbooi, pers. comm.); however, as many as 40 people may show up at the buying point with seeds to sell to Desert Hills. The production phase in its current form is purely individualistic. Harvesters collect their own fruit and sell only the products of their own labor. This practice, along with the lack of communal ownership of hummocks/plants, has led to a "free---for---all" situation in which !nara harvesting is an individual pursuit rather than a collaborative effort. This has hindered any self---organization within the harvesting community. Meanwhile, without any regulations governing resource use, or any organized bodies to enforce such rules, non---Topnaar outsiders are also reported to harvest !nara. Unsustainable and illegal !nara harvesting by non---Topnaar groups may be responsible for the alleged decline in the resource base; however, Topnaar feel they lack to political support and enforcement capacity to exclude unauthorized outsiders. Finally, Topnaar harvesters are primarily older community members and younger generations show little interest in carrying on the longstanding cultural tradition of !nara harvesting; should generational dynamics result in a refusal to participate in !nara harvesting, the ensuing decline in raw material availability could threaten the viability of the entire !nara market system (Henschel et al, 2004)

The **processing** of !nara fruit into seeds occurs at the household level during the harvesting season. These tasks are most commonly performed by male Topnaar, though this has not historically been the case. The melons are sliced open and their contents (seeds and pulp) poured into a drum/pot. The drum is placed over a fire and the seeds and pulp are cooked and stirred for 2---3 hours. The seeds are then strained through a tin sieve and spread out to dry on a plastic netting. After drying, uncoated seeds are separated from seeds coated with pulp. The two types of seeds are packaged separately into 15---20 kg cotton chicken bags (H. Areseb, pers. comm.).

The *vertical linkage* between household---level processing and commodification presents considerable opportunity for reducing value loss due to communication and coordination breakdowns. Previously, an external (non---Topnaar) middleman, Clive, bought seeds directly from harvesters and then sold them at a higher price to Desert Hills, providing a central seed collection point and a thorough quality check. Harvesters rallied together to oust the middleman from the system in 2012. Nominally, they felt cheated by the lower prices he paid them, but at a deeper level, his outsider status may have created a cultural conflict, and as a result, he was deemed unfit to act as their middleman (H. Areseb, pers. comm.). Since then, there has been no formal middleman in the value chain.

Instead, Desert Hills communicates with Chief Kooitjie and his assistants, and not directly with the harvesters. This situation is less than ideal because 1) Desert Hills pays the same price to harvesters for poorer quality seeds which must then be re---sorted, and 2) harvesters do not feel well---represented by the Chief in his contract negotiations with Desert Hills. Additionally, buying events are rather chaotic without a middleman, as many individual harvesters convene at a buying point and compete with one another to get their seeds sold, and Desert Hills executives must pay cash to each supplier, resulting in significant financial and safety risks for Desert

Hills and the Topnaar. Some Topnaar harvesters do not get their seeds sold because of oversupply (Desert Hills takes only 3,000 kg/year). Furthermore, transportation to the buying point is erratic and largely out of the control of harvesters, who rely on transportation provided by the Chief, costly taxi services, or neighbors' vehicles.

Following household---level processing, **commodification** of !nara seeds follows one of two distinct market pathways. Individual Topnaar harvesters may bring 'coated' seeds to the petrol station in **Narraville**, Walvis Bay, where they are sold for direct consumption in $10 or $20 plastic bags approximately one to two kg in size (H. Areseb, pers. comm.). Alternatively, harvesters deliver seeds to **buying points** in Walvis Bay for sale to Desert Hills at a price of $22/kg. At Desert Hills, seeds are further dried and sorted to ensure that only high quality, uncoated seeds are processed to maximize quality of end products. Seeds are then fed into an electric mechanical seed presser and oil produced.

Other ingredients are mixed with the oil, and the product is bottled for sale as a food product (oils, anti pasties, pesto, pasta, spices, bread, crackers, ice cream) or cosmetic (body face creams, sun creams, peelings, bath salts, massage oils, soaps, etc.). The "cake" residue of the oil pressing is sold as livestock fodder for $2.50/kg.

The **Desert Hills commodification process** is a crucial component of the value chain because !nara oil on its own attracts limited market demand. There are many well---established substitute goods, namely olive oil, so diversification of !nara oil products is essential for the viability of the business. In fact, low market demand for seed oil precludes Desert Hills from using all seeds provided by harvesters, explaining the annual quota of 3,000 kg of seeds. However, this quota remains flexible to account for variable circumstances such as diminished seed availability during drought years.

At the **Narraville marketing stage**, Topnaar venders sell their $10 and $20 seed bags at a street corner next to the petrol station. Usually two to three harvesters sell at a time, though the selling process is not formally organized. Seeds may also be distributed to small---scale shops in Walvis Bay and Swakopmund and sold there as $1 cones. Along the Desert Hills pathway, !nara seed oil products are sold at the Desert Hills store every Saturday. Products are also distributed through a marketing agent and sold at Namibian (and some Cape Town) pharmacies, restaurants, supermarkets, trade shows and online bulk orders.

The **end consumers** of Narraville !nara seeds are local residents, mostly coloured and Topnaar people. Regular purchase of seeds is often restricted to those with some cultural or historical tie to the Topnaar people (H. Areseb, pers. comm.). Cones of seeds are also purchased in shops by locals or tourists; little is known of the size and potential of this end market, though it has historically offered low returns to harvesters due to bulk buying and non---standardized seed prices. End consumers of Desert Hills products are mostly international tourists, middle--- to upper---class Namibians and a niche market of South Africans, as well as local farmers who purchase the goat fodder.

Business Model for Enhanced Efficiency and Value of !Nara Commercial Market

Here we present a multi---phase business model for the !nara trade. The aim of the model is to provide a framework for increasing harvesting efficiency, quality, and the market price of raw !nara seeds. These goals can be achieved through development of harvester organizational and management capacity, as outlined in the steps that follow.

Phase 1 (Year One): Formation of Topnaar Harvesters Association

- Democratically elected association members manage natural resources and provide monitoring, training, and oversight of contracts and agreements with Desert Hills. Association empowers Topnaar harvesters to collaborate and press for higher income. Elected members represent broader community of harvesters and understand challenges of this livelihood strategy. This devolution of responsibilities provide harvesters with more unified solidarity, as historical representation by 'outsider' middlemen such as Clive implied a lack of personal empathy and understanding of harvester hardships (S. Swartbooi, pers. comm.). Association functions similarly to Production and Processing Organization (PPO) described in business plan for *Commiphora* trade in Okondjombo Conservancy and Community Forest (Box 1). Facilitating organization (e.g. Gobabeb, DRFN) assists in association formation.
    - Due to organization constraints, it may be desirable for Gobabeb Research & Training Centre to defer facilitation responsibilities to parent organization Desert Research Foundation of Namibia (DRFN). Gobabeb's complex relationship with the Topnaar community and scientific research agenda may limit its effectiveness as a development facilitator; however, hosting and research support services to DRFN development work would be valuable.
- Topnaar !nara economy becomes formalized through registration of harvesters, after a period of training in sustainable harvesting techniques from committee. Registered harvesters issued an identification card and number, as is done with *Commiphora* harvesting in Okondjombo (Box 1). Community monitors employed to protect !nara resources from harvesting by "outsiders," and to monitor harvesting techniques. Currently, Topnaar express reservation in confronting foreign harvesters, due to outsider tendency to travel in larger packs than the more isolated, individualistic Topnaars (S. Swartbooi, pers. comm.) Thus, the deployment of community monitors and a more cohesive association could ameliorate these fears of potential hostility and allow Topnaars to assert more territorial authority over their !nara resources.

- Association members approach chief to request direct communication with Desert Hills in buying point logistics and contract agreements. Currently, both harvesters and Desert Hills identify a communication breakdown resulting from working through the traditional authorities. In order to ameliorate this situation, harvesters lobby the Chief for funding from Community Trust to initiate formalized functions of Harvesters Association. The Community Trust represents a fund managed by the Chief, consisting primarily of assets from the Topnaar concessions in both the Dorob and Namib---Naukluft National Parks (Chief Kooitjie, pers. comm.) While donations from the trust would prove useful to the nascent association, the acceptance of such funds could undermine the anticipated independence of the harvesters from the traditional authorities. Such grants need to come without strings attached from the traditional authorities, due to the current inefficiency extended by the Chief's office and resulting frustration from both the harvesters and Desert Hills.
- Thus, a potentially more self---sustaining avenue could become external donor grants. External donors (e.g. Environmental Investment Fund, Namibian GEF Small Grant Fund) provide initial funds and support for establishment of association and training of monitors before higher income from Desert Hills allows Association to be financially self---sufficient. See Appendix 1 for potential funding pathways.

Phase 2 (Years Two---Three): Introduction of Quality Control System

- One to three buying point managers provide quality control of seeds before sale/delivery to Desert Hills buying point. The buying point managers thoroughly check and weigh seeds, as done with *Commiphora* in Okondjombo (Box 1). Improved seed quality will for Desert Hills to increase price per kg paid to harvesters (currently $22/kg) (S. Heummer, pers. comm.). A portion of increased income is fed back into Harvesters Association and used to pay buying point managers, monitors, and cover costs of equipment (drums, scales, knives, etc.), transportation, and operational management. Harvesters paid from !nara Revolving Fund upon delivery of raw material to buying point (Box 1).
- Depending upon the institutional capacity and financial state of the association, association managers could pursue creation of village collection centers. As evidenced by the success of such locations in Cameroonian apiculture, collection centers allow buying point managers to more efficiently concentrate harvester output for transport to Desert Hills (Box 2). Such an organized space would also increase the feasibility of more immediate, direct payments to harvesters, which would better correlate with the historic community---identified benefits of !nara harvesting as a proximate source of disposable income.

- Auditing of quantity harvested and sales revenue to ensure transparency. This step involves a greater emphasis on product traceability among harvesters, as demonstrated by sustainable apiculture initiatives in Cameroon (Box 2). This introduced system of accountability engenders a more suitable environment for fluid quality assurance and management, as managers can monitor and evaluate individual harvesters for seed value. Historically, !nara harvesting has promoted harvester commitment to high seed quality due to personal association with end consumption within the community (S. Swartbooi, pers. comm.)
- Chief/Traditional Authorities removed from supply chain. The buying point managers become equivalent to 'middlemen', avoiding previous cultural conflict with non---Topnaar middleman and maximizing benefits for the people. Association provides technical assistance and training to buying point manager.

Phase 3 (Years Four---Five): Value Addition and Partial Control of Manufacturing Process

- Acquisition of a mechanical seed presser for !nara oil production using external donor assistance and Association funds. Training of association members to operate and maintain machine. Donor and Association funds also used for repairs and maintenance.
- Self---pressed !nara oil to Desert Hills for further processing, commodification, marketing, and sale (contingent on Desert Hills production levels).
- Continuance of quality control system before seeds are pressed into oil. Continued technical assistance from facilitating organization and experienced Association members.
- Payment from Desert Hills to Association on per liter of seed oil basis. Income goes to Revolving !Nara Fund, and is then used to pay harvesters along with buying point managers, monitors, and seed press operators.

Phase 4 (Years 5---onwards): Ownership of Entire Value Chain

- Association develops capacity to manufacture !nara seed oil products on its own. Markets and sells products in local shops (Walvis Bay, Swakopmund, etc.)
- Significant barriers include lack of technical expertise, lack of access to markets, and high start---up costs.

Box 1. *Commiphora wildii* and *Commiphora tenuipetiolata* in Okondjombo Conservancy and Community Forest. The successful utilization and commercialization of other INPs in Namibia can serve as examples of effective management strategies that could be adopted in the !nara business. In Okondjombo, *Commiphora* plants bear a resemblance to !nara in that they are harvested by local communities for essential oil production used in the cosmetics industry. According to the August 2013 draft Business Plan for this INP, a Producer and Processor Organization (PPO), comprised of 70 registered and trained harvesters, ensures that only community members carry out the harvesting of raw plant material (gum or resin). Upon registration, harvesters are issued a card and number for identification. Within the PPO, a management committee consists of nine democratically elected members. This committee is responsible for negotiating contractual agreements with downstream actors in the value chain; appointing and paying buying point managers; and monitoring buying points. The buying point managers play an important role in the value chain: weighing and recording of harvested material; checking that material meets quality standards; and paying individual harvesters upon delivery of material to the buying point. For every N$75/kg that the buying point manager receives from the Opuwo Processing Facility (OPF), N$50 goes to the Revolving Plant Fund (used to pay harvesters), N$5 to cover management committee expenses, and N$20 for equipment such as drums, bags, scales, and transport. Thus, individual harvesters benefit from immediate compensation for their work, and the management committee is financed by receipt of a portion of the income from raw material sale.

Aspects of this business model could be adapted and applied to the !nara enterprise. The establishment of an organized group of registered harvesters, like a PPO, would promote collaboration between individuals, empower them with leverage in contractual agreements, and curb harvesting by outsiders. The introduction of a buying point manager would help improve the quality of seeds sold to Desert Hills, thereby empowering harvesters to demand a higher, yet fair, price per kg. Finally, the divvying up of income received from Desert Hills would not only provide the individual benefits of immediate compensation, but would help finance the Association so that it could continue to manage the system, cover equipment and infrastructural costs, and even make capital investments to increase harvesting efficiency in the future. This would allow harvesters more time to pursue other, equally important, income-generating activities to support themselves.

Box 2. Forest---based apiculture in Cameroon. The revitalization of the apiculture sector in Cameroon largely derives from an analytical value chain approach employed to better leverage the position of impoverished beekeepers. Although honey represents a much more internationally desired commodity, several tenets of sustainable apiculture in Cameroon can be appropriated in making recommendations for the !Nara future. An interdisciplinary group called Guiding Hope acted as a facilitator for self---organizing beekeepers in the Djerem region. After identifying the unreliability of buyers in the value chain (e.g., price fluctuation every 2 weeks during harvest season), Guiding Hope intervened as a more stable buying---partner for the mobilized beekeepers, offering a higher---than---market price to the producers. Further, to establish a more accountable system of product traceability, the group introduced a system of registration, including beekeepers signing formal contracts. To better integrate the beekeepers into the chain, Guiding Hope also provided trainings for over 1,200 practitioners and developed village storage centers to ensure a very high level of quality control. The quality---control trainings allow for the storage centers to be managed by local beekeepers, elected by local beekeeping organizations. Guiding Hope's entrance into the commercial chain has empowered Cameroonian beekeepers to develop a highly quality---controlled and organized environment suitable for international trade standards and enter the global market.

Indeed, the success of such a value chain intervention can be exported to the current case of !Nara. For one, the devolution of quality---control to the producer level proved integral in both unifying beekeepers in the area and enabling them to access global demand for an array of hive products (i.e., diversifying beyond honey). The development of such community---run collection centers and quality---control management parallels that of Phase 2 of the future !Nara business model. This formalization of the harvesting process could yield a more influential role for the Topnaar harvesters, as increased accountability and product traceability allows for collection center managers to deliver a higher---valued product to the market. Additionally, the participatory action research (PAR) approach assumed in this case study addresses the historical mistrust developed by Topnaar in relation to intruding researchers. PAR deviates from the traditionally 'extractive' model of research in that it prioritizes locally identified objectives and subsequently experiments with research results directly within the community. If long---term research is undertaken, such an approach would prove effective in addressing Topnaar reservations in both interacting and partnering with external actors.

Micro---Opportunities for Value---Addition

The above business plan emphasizes strengthened horizontal linkages within the Topnaar harvester community coupled with strengthened vertical linkages between harvesters and Desert Hills in order to maximize quality and economic value of raw material to be processed into value---added food and cosmetic products. However, through development of alternative !nara products, the !nara market system may offer even greater economic opportunity to its stakeholders. For one, the sustainable use of !nara roots for medicinal purposes is practiced on a local scale and may have potential viability on the alternative medicine market. Currently, harvesters found removing !nara roots in high volumes for non---household purposes are subject to community reprimands (H. Araseb pers. comm.). Nonetheless, future studies investigating both the ecological impact of root---harvesting and the market system of the roots are essential prerequisites for pursuing !nara root commercialization activities.

The selling of Topnaar craftworks made from !nara materials may also have potential as a profitable micro---enterprise if properly implemented. Currently, the quality of handicrafts is too low for commercial standards (Legal Assistances Centre 2013; S. Heummer pers. comm.). However, Desert Hills executives expressed a sincere willingness to work with the Topnaar women's association on community projects, such as a soap---pressing venture or attractive hand---sewn packaging for !nara seeds. These products could be brought to markets through Desert Hills marketing pathways or be bought as souvenirs by visitors to Gobabeb or the soon to be constructed lodge. As demonstrated in the Cameroon case study, local experimentation in producing honey---based products (e.g., honey soaps) became a compulsory endeavor of community members over the long---term (Ingram and Njikeu 2011). The willingness of Desert Hills to both facilitate and endorse such entrepreneurial endeavors necessitates more research in this area. It seems that communication failures, largely due to unresponsiveness by traditional authorities, has undermined such opportunities thus far.

Discussion, Suggestions for Future Research, and Conclusion

The value chain and suggested business plan presented in this paper highlight the central actors and interactions of the !nara production system. By identifying market inefficiencies, breakdowns in communication and potential value addition opportunities along the chain, this tool may motivate stakeholders within the value chain or external actors to address these barriers to productivity, effecting significant improvements in the market's output for all stakeholders, including the vulnerable and income---insecure rural Topnaar communities for whom !nara holds particular cultural value.

Here it must be stated, however, that some aspects of the business model are more feasible and deserving of more immediate attention than others. Specifically, Phases 1 and 2 could realistically be implemented with the support of external donors and NGOs (e.g. Gobabeb or DRFN), whereas Phases 3 and 4 are less likely to occur anytime in the near future. It should also be noted that these last two phases are strongly contingent on the success of Phases 1 and 2, and even then are not guaranteed to provide long---term economic benefit to the Topnaar. This is because there are certain features of the value chain in its current form that make good economic sense and align with sound theory. According to the Law of Comparative Advantage, production sectors specialize in goods and services that they can produce most competitively. This is what currently happens: Topnaar people harvest !nara plants (as they have done for centuries), and Desert Hills specializes in commodity production and retail (areas in which the company's owners have expertise). This type of specialization should be maintained, at least in the short---

term. The purpose of Phases 1 and 2, then, is not to create a complete system overhaul, but to enhance the specialization of the system (e.g. by eliminating the need for Desert Hills to re---sort raw material) so as to make it run more efficiently and cohesively. Effective social organization amongst Topnaar and potentially with Gobabeb actors could also facilitate other productive cooperative ventures and trust between all players.

Successful implementation of the business model requires a more complete and accurate understanding of the complex interaction of Topnaar/!nara social, ecological, political, and economic system dynamics. Several key knowledge gaps exist, necessitating further research in advance or in tandem with initial implementation steps.

Areas in need of further investigation include:

- **Long---term sustainability of the !nara resource base**: with scientific support from Gobabeb and/or Dartmouth students, reliable measurements of !nara resources can provide the basis for the development of harvest quotas ensuring future health of the resource and ecosystem. Investigation of the destructiveness of various root and melon harvesting techniques could also inform harvesting extend and practices.
- **Potential harvest technological improvements**: should efficiency of !nara harvest be enhanced beyond levels possible using traditional technologies and techniques, harvesters may be able to pursue additional income---generating opportunities or may be more likely to continue harvesting !nara due to improved working conditions and hourly compensation. Cultural affiliations with traditional technologies may create barriers; further research is needed to determine the economic and social viability of technological development.
- **Generational dynamics of !nara harvesting:** how inclined are Topnaar youth to remain in the rural Kuiseb and continue the practice of !nara harvest? A decline in harvest labor availability would affect the material cost of raw seeds and potentially threaten the viability of the entire !nara market system.
- **Capacity for market expansion, further value addition, and Topnaar interest in entrepreneurial activity:** should initial harvester organization activities prove successful, further research must be conducted to assess the viability of pursuing further opportunities for value addition within the Topnaar communities. This will require continued analysis of !nara market dynamics, Topnaar social structures and ecological conditions.

An enhanced understanding of local conditions, potential pathways for further value addition, and the broader context of pro---active INP commercialization activities in southern Africa would allow for facilitators and stakeholders to identify and circumvent barriers that might otherwise prevent the realization of business model objectives. Additionally, familiarity with successful INP project structure and best practices could provide valuable insight and tools for !nara development activities (COMMIPHORA, APIARY). Any alterations or new developments must take place within the specific context of the complex socio---ecological system as it exists today. It is true that these informed interventions by themselves would not lift the rural Topnaar community out of poverty. However, if done committedly in a bottom---up approach, they would provide real tangible economic benefits and stimulate investment of time, money, and energy in additional, possibly even more productive, livelihood strategies.

Phase 1 Budget	
Potential Expenses	**Approximate Cost (US$)**
Outside Facilitation (e.g., Gobabeb hiring)[a]	$0---$50,000
Harvester Association Resources (e.g., phones and office supplies)	$500
Total	~$50,500

[a]Optional, contingent upon level of harvester self---organization and cohesion. Facilitator skill level and time commitment also spans from unpaid volunteer interacting with Topnaar highly irregularly to full---time qualified development expert taking a leadership role in community organization, political lobbying and economic analysis. We envision a part---time intern hosted at Gobabeb Research & Training Centre as a feasible and effective facilitation agent option.

Phase 2 Budget	
Potential Expenses	**Approximate Cost (US$)**
Buying Point Manager[s] (i.e., salaries)	$5,000
Harvester Support Tools (e.g., scales, burlap bags, calculators)	$2,000
Transportation (e.g., car, fuel, repairs)	Variable
Harvester Association Resources (phones and office supplies)	$500
Collection Center Infrastructure[b]	$10,000
Total	~$17,500 + Variable Costs

[b]Depending upon level of capacity of harvesters association.

Phase 3 Budget	
Potential Expenses	**Approximate Cost (US$)**
Seed Pressing Machinery	$7,500
Machinery Maintenance (i.e., repairs, replacement parts, filters)	$1,000
Oil Packaging	$500
Buying Point Manager[s] (i.e., salaries)	$5,000
Harvester Support Tools (e.g., scales, burlap bags, calculators)	$2,000
Transportation (e.g., car, fuel, repairs)	Variable
Harvester Association Resources (phones and office supplies)	$500
Total	~$16,500 + Variable Costs

Phase 4 Budget	
Potential Expenses	**Approximate Cost (US$)**
High---Quality Seed Press	$10,000
Machinery Maintenance (i.e., steel replacement part plus repairs)	$3,000
Production Facility	$10,000
Facility Upkeep	Variable
Electricity (i.e., generator)	Variable
Water Supply	Variable
Buying Point Manager[s] (i.e., salaries)	$10,000
Harvester Support Tools (e.g., scales, burlap bags, calculators)	$2,000
Transportation (e.g., car, fuel, repairs)	Variable
Harvester Association Resources (phones and office supplies)	$500
Total	~$35,500 + Variable Costs

Bibliography:

Campbell, R. Key Elements of the Value Chain Approach: Briefing Paper. Accelerated Microenterprise Advancement Project.

Hellen, J & Meijer, M. Guidelines for Value Chain Analysis. FAO.org (2006)

Henschel, Jon, R. Dausab, P. Moser, and J. Pallett (Eds) (2004). !Nara: Fruit for development of the !Khuiseb Topnaar. Namibia Scientific Society. Windhoek, Namibia.

Draft INP Business Plan for Okondjombo Conservancy and Community Forest (2013)

Ingram, V. and J. Njikeu (2011). Sweet, Sticky, and Sustainable Social Business. *Ecology and Society*, 16:1, 37.

Legal Assistance Centre (2013). Indigenous Peoples and Climate Change in Southern Africa: Report on Case Studies of Namibia's Topnaar and Hai||. Windhoek: Legal Assistance Centre, 1---120.

Werner W. (2003). Livelihoods among the Topnaar of the Lower Kuiseb. Windhoek: Desert Research Foundation of Namibia (ELAK. E. L.ATE Programme).

Appendix 1: **Potential Pathways for Development Funding**

Environmental Investment Fund Namibia (EIF)

- Up to US$35---50,000 in grant---funding capacity
- Eligible activities for Green Soft Loans include community---based natural resources and adaptation projects, as well as value addition
- Typically requires 3---4 months after proposal for disbursement of funding
- Links:
  - http://www.eifnamibia.com/index.php/downloads/documents/application---forms
  - http://www.eifnamibia.com/images/EIF_Green_Loan_Application_Guide.pdf

Nedbank Namibia GoGreen Fund

- Smaller capacity (disburses N$50,000 in environmental grants annually)
- Supports sustainable management of Namibian indigenous plants
- Requires detailed---breakdown of proposed budget, as well as organizations constitution and lead person's CV
- Links:
  - http://www.nedbank.com.na/hdetail.aspx?itemguid=833f4cd9---323f---497d---ad1f---9f641b9dfd73

The GEF Small Grants Programme (UNDP)

- Up to US$50,000 in grant---funding capacity (paid in three sequential installments)
- Sustainable development initiative focused on projects that conserve natural resources while enhancing livelihoods
- Links:
  - https://sgp.undp.org/index.php?option=com_content&view=article&id=274&Itemid=209#.Uny2ycjD96Y
  - https://sgp.undp.org/index.php?option=com_content&view=article&id=94&Itemid=160#.Uny3K8jD96Y.

Future Donor Possibilities (in the long---term): Indigenous Plant Task Team (IPTT) and the Ministry of Trade and Industry (MTI)

Appendix 2: Potential Leverage Points for Intervention in !Nara Value Chain

Value Chain Weaknesses	**Strategy**
Inadequate resource base	Cultivation, reduced predation, sustainable harvesting practice, excluding outsiders
Harvesting inefficiency	Cultivation, improved technology, harvester organization, transportation
Poor quality seed output	Improved technology, enforced standards
Ineffective linkage between primary producers and processors	Improved transportation Improved quality standards Improved quantity and price communication
Unnecessary intermediary players in value chain	Eliminate unnecessary intermediate players who take additional cut of seed profits
Limited market audience for !nara product	Seek out raw seed opportunities for consumers in Narraville, Windhoek, Swakopmund, Ovamboland Sell other !nara products: roots, crafts, chocolate, porridge
Topnaar exclusion from value addition processes	Topnaar involvement in oil pressing, cosmetics, packaging
Disorganized marketing practices and inconsistent commodity price	Reduced corruption among harvesters and political leadership Setting price to prevent underselling Improved transportation and storage

Appendix 3**: !Nara Value Chain Components**

Value Chain Stage	Actors	Activities	Tools	End Product	Notes
Primary Production Melon Harvest	Topnaar harvesters, potentially non-Topnaar illegal harve ters	Travel to fields, take melons, bury under sand to speed ripening	Wooden /iron rod, donkey cart, drums	Ripe/unripe !nara melon	Harvest labor strongly seasonal, harvest practices of outsiders often destructive to !nara
Primary Processing Seed extraction	Topnaar harvesters, potentially non-Topnaar illegal harvesters	Cut melons, scoop out flesh, boil pulp, strain seeds, lay in sun on net, pick through for bad seeds, seal in bags	Knife, whisk, firewood, pot, strainer, net, bags	Seeds (coated or uncoated) Pulp !nara shells	Seed quality affecting by quality of cooking, storage, and sorting by harvester. Pulp and shells valuable as livestock feed
Commodification, marketing and sale Narraville	Topnaar harvesters Shop owners	Travel to Walvis Bay, sell seeds to individuals in smaller quantities at higher price/kg or in bulk to shop owners at lower price/kg	Transportation, packaging	Packaged coated seeds for raw consumption	Desperation and embarrassment on the part of harvesters often resulting in underpayment for bulk seed sales to shop owners; this may reduce the overall market value of Narraville seeds

Transfer to Secondary Processing Desert Hills market	Topnaar harvesters Middle man/TA Desert Hills executives	Topnaar harvester travel to Wavlis Bay or arrange DH pickup for uncoated, sorted, bulk !nara seeds	Transport-ation, communi-cation capacity	Raw material transfer for further Processing /value addition, fixed value for !nara seeds	Desert Hills charges an additional fee of $2/kg for direct seed pickup due to logistical challenges and currently pays in cash to each harvester. DH executives would be willing to raise their price in return for more organized material transfer and improved quality. TA middleman is currently unreliable as a communication/ transportation linkage
!Nara Oil Processing Desert Hills	Desert Hills executives and employ-yees	Re-resort and dry seeds, feed through oil press to create !nara oil	Oil press, replacem-ent parts, electricity storage	Oil Seed cake	Oil pressing technology designed by Desert Hills executives and requires costly maintenance and upkeep. Press is currently operating at capacity to process 3000 kg seeds/year.
Food Product Processing Desert Hills	Desert Hills Executives an and Employ-ees	Utilize oil in salad dressings, flavored oils, pestos Package and distribute to Windhoek/ Swakopmund markets: groceries, shops and restaurants	!nara oil, food additives, packaging materials, transport-ation	Food products	Raw oil market highly volatile and unprofitable; addition is essential to commercial viability. Oil has few distinguishing features besides rarity and cultural value.

Cosmetics Processing Desert Hills	Desert Hills executives and employ-ees	Utilize oil in cosmetic creams, soaps, scrubs. Package and distribute to Windhoek/ Swakopmund markets	!nara oil, cosmetic s additives, packaging materials, transport-ation	Cosmetics products	Cosmetics market is more stable. !Nara oil is one of many components in cosmetics; additives are costly and difficult to obtain.
Marketing Desert Hills	Desert Hills executives and agent	Promote !nara products through weekend farm bistros, trade shows, and inclusion in various Namibian markets	Transport -ation, communic-ation, market evaluation, food/event, preparation	Marketing materials enhancing perceived value of all Desert Hills !nara products	Desert Hills has no formal market understanding but has adapted to changing conditions as it has grown. Agent is valuable for extending reach of products beyond the farm store and personal connections, but takes a significant cut of profits.

Making Sense of !Nara

A Proposal for a Long-Term Monitoring Study

November 15, 2013

Prepared By:

Aislinn I. McLaughlin
Andrew I. Milligan
M. Hemayat R. Chowdhury
Joseph T. Bonnell-Hall
Matthew B. Stanton
Samantha C. Dowdell
Tsomo Cuomaoji

DARTMOUTH

Introduction

The !nara (*Acanthosicyos horridus*) is a leafless, spiny, melon-bearing bush found only in the Namib Desert. It is a keystone species of great ecological, economic and cultural importance, and its value hinges on its continued existence, health, and productivity. The !nara is of fundamental cultural value to the Topnaar people, who have harvested the plant's melons for thousands of years (Klopatek and Stock 1994). Today, the Topnaar continue to consume !nara because it has high nutritional value and is one of very few local food sources. Additionally, the !nara bears some economic value, but the income that results from the sale of seeds is minimal, driving the Topnaar to seek commercial development of the !nara plant (DRFN and TCF, 2004). The Topnaar community, in collaboration with the Desert Research Foundation of Namibia (DRFN), has identified sustainable use and management as a goal, prompted by the fact that human-induced environmental and ecological change has had detrimental effects on !nara populations (Henschel *et al.,* 2004). A good management strategy is of vital importance to the continuing existence and productivity of the !nara plant.

Long-term monitoring

The overall purpose of long-term monitoring is to establish baseline data on ecosystem status and population trends; programs measure base indicators of resources at specific sites, as well as indicators that are correlated with critical ecosystem processes or properties. It is important to incorporate indicators and spatial variability into monitoring efforts because data collected must be interpreted in the context of complex ecosystems dynamics (Haystad and Herrick, 2003). Once collected, this information can be used to determine natural rates of change, subsequently distinguishing natural changes from externally-induced change, such as anthropogenically-induced biomass loss (Magurran *et al.,* 2010). The broader goal of identifying ecosystem changes through long-term monitoring is to inform decision-makers and guide management strategies. If ecosystems are continually assessed and thresholds of potential concern are correctly identified, permanent regime shifts may be avoided through management action (Haystad and Herrick, 2003).

Critics of long-term data collection claim that it is an inefficient and ineffective method of informing conservation scientists and natural resource managers; however, they fail to distinguish between "surveillance" monitoring and targeted monitoring approaches (Nichols and Williams, 2006). "Surveillance" monitoring is simply long-term data collection without a set of hypotheses or incorporation of models of system response to management practices. This form of data collection results in a multi-step approach to conservation: first, declines in population are detected through monitoring. Only once this decline is detected can management begin to conduct studies to identify causes of population decline, the results of which will influence active conservation. "Surveillance" monitoring adds subjectivity and a severe time lag between reaching a threshold and implementing management practices in response. Additionally, this approach does not discriminate between competing hypotheses of system response to management practices, nor does it directly identify causes or remedies for population decline (Nichols and Williams, 2006). In contrast, targeted approaches to monitoring directly assist conservation practices by testing hypotheses of system response to management practices. Targeted monitoring produces estimates of current system statuses as well as comparisons of model-based predictions against observed system dynamics (Nichols and Williams, 2006). This approach in the context of conservation emphasizes comprehensive knowledge of system dynamics, which allows for more immediate implementation of management practices in response to reaching a threshold of population decline. Targeted monitoring also improves the biological understanding of the environment on which management strategies and decisions can be based.

Long-term monitoring of the !nara plant

In order to evaluate !nara population health and productivity, it is necessary to assess current ecosystem status and to identify factors affecting !nara, especially threats to productivity. While there is existing literature on the !nara plant, most data is severely outdated and is not used collaboratively (Henschel *et al.,* 2004). Our goal was to establish a comprehensive long-term ecological monitoring program and create a single database for !nara ecological data. In our research, we sought to identify and collect data on variables that were indicators and/or determinants of !nara plant health and productivity. The variables we identified and chose to measure are: herbivory (includes spine length and 5-spine period), hummock size, biomass percentage, and total fruit count. Other variables of note, which were outside the scope of our study, are: groundwater availability, pollination, and large-scale population structure.

Herbivory presents an immediate threat to !nara fruit production. !Nara crickets and blister beetles consume the soft tips and flowers, while domesticated donkeys browse on the plants and fruits (Henschel *et al.*, 2004). Donkeys do not function as dispersal agents or pollinators, so the damage inflicted is not balanced by contributions to !nara productivity; in fact, plants that are not browsed by donkeys produce five to ten times more fruit than those that are browsed (Henschel *et al.,* 2004).

Thorns are an effective defense against herbivores (Milewski, Young, and Madden, 1991), and various plants have been shown to adapt to variations in herbivory rates by adjusting their thorn production (Agrawal, 1999; Karban and Meyes, 1989; Milewski, Young, and Madden, 1991; Young and Okello, 1998; Young, Stanton, and Christian, 2003). Specifically, *Acacia drepanolobium* has been shown to produce shorter spines in the absences of herbivory, and longer spines in its presence (Young and Okello, 1998; Young, Stanton, and Christian, 2003). *Acacia seyal* also produces longer spines on branches subject to giraffe browsing than on those out of reach of giraffe; moreover, on the browsed branches, *Acacia seyal* also produces *denser* spines (Milewski, Young, and Madden, 1991). Extrapolating from these points, we can use spine length and spine density as proxies for herbivory measurements.

Hummock size may serve as a proxy for hummock, and therefore plant age. The hummock grows in conjunction with the development of the !nara plant and root system. Data on hummock size may indicate the incidence and frequency of inundation and characterize the interaction between sand and wind on the hummock.

Live biomass measurements are important in determining fruit densities, and therefore the productivity of female plants. Comparisons of live and dead biomass percentages over time can help determine and predict trends in plant health. These biomass measurements will also serve to determine baseline rates of change in !nara populations in order to assess biomass loss in the future.

Total fruit count serves as a direct measurement of !nara productivity. It may also serve to estimate seeds available for dispersal; however, it is important to note that seed counts between fruits may be too variable to approximate availability for dispersal by total fruit count alone. It may be important to incorporate other factors, such as fruit size, in this estimation.

Fruit production and biomass serve as convenient proxies for the resilience and health of the !nara metapopulation. If there are high fruit yields, then there is high seed production, which should increase recruitment. If there is copious biomass in the population, then individual plants are prospering. Biomass and fruit count indicate not only current health, but also probable future trends. Moreover, they indicate the present and predicted value of the resource base.

!Nara depend on a perennial supply of groundwater less than fifty meters deep in order to sustain their high transpiration rate and to counteract their inefficient use of water, making them vulnerable to factors reducing the water table (Henschel *et al.,* 2004). Higher abundances of !nara and larger plants are found in areas with shallow water tables, such as riverbeds. The Kuiseb Delta is home to the highest densities of !nara plants, although the number of !nara began to decline following the construction of a flood wall barrier on the Kuiseb River in 1961 and an increase in groundwater extraction (Masaaki ITO, 2005).

Data on population structure, such as sex ratio, age structure, and mortality rate, might serve as indicators of overall health and productivity of !nara as a species. Because !nara is dioecious, it relies on interaction between male and female plants to produce fruit; age structure and mortality rate across the species as a whole could serve as warning flags before an imminent population fluctuation, which would heavily impact the ecology and economics of the region. In conjunction with biomass measurements, over time this information could also be used to substantiate or refute the claim that the number of !nara plants is declining.

Although we didn't consistently collect data at every plant on variables affecting pollination, the number of flowers on male !nara plants serves as a measure of pollen availability. Most pollination is achieved by only two bee species: *Amegilla velutina* and *Anthrophora auone* (Henschel *et al.,* 2004), leaving !nara vulnerable to shifts in pollinator populations.

We used a surveillance monitoring approach for data collection, due to our own limited knowledge of the ecosystem and the !nara plant; however, we recommend that Gobabeb work with the Topnaar to form a management strategy based on current and future data. We hope that long term monitoring of !nara plants will help identify trends in fruit productivity, biomass, etc. in order to inform decision-making. Additionally, we have included a detailed protocol of our monitoring procedure (Appendix I) so that researchers can use our data and our methodology to both answer set hypotheses and construct models of system response in order to more appropriately integrate findings into conservation and management strategies.

Methodology

The following methodology was used for collecting data on 16 distinct !nara hummocks during the period of 4th through 9th November 2013. The research was conducted in collaboration with the Gobabeb Training and Research Centre in !Nara Valley, located in the Kuiseb Delta in Namib-Naukluft National Park on Namibia's western coast (See Fig. 1).

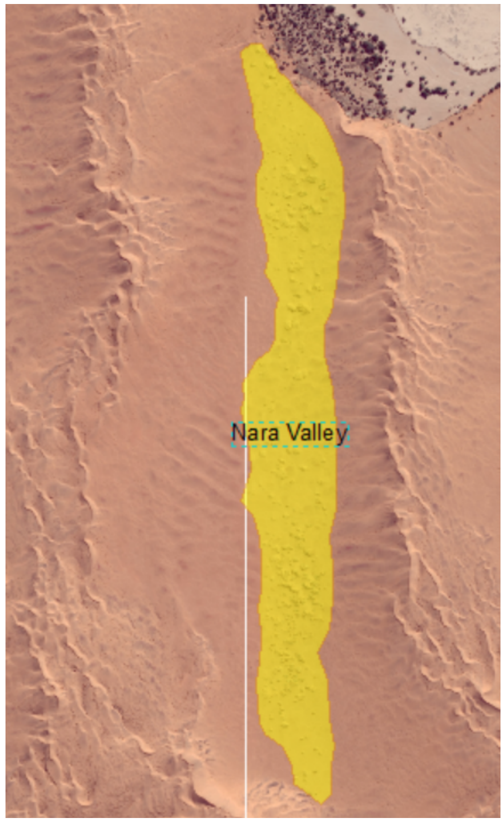


Figure 1: *Map of !Nara Valley*

Hummock selection and identification

!Nara hummocks were arbitrarily selected in !Nara Valley. Sex of the hummock was determined by assessing flower morphology and/or presence of fruit. GPS coordinates were taken from the center of each hummock and tied to a plant identification number (example: ENV001 = Ecology Nara Valley, Plant #1). Exceptionally large and irregularly shaped hummocks (see Fig. 2) were assessed as 2-3 (depending on size) individual hummocks.

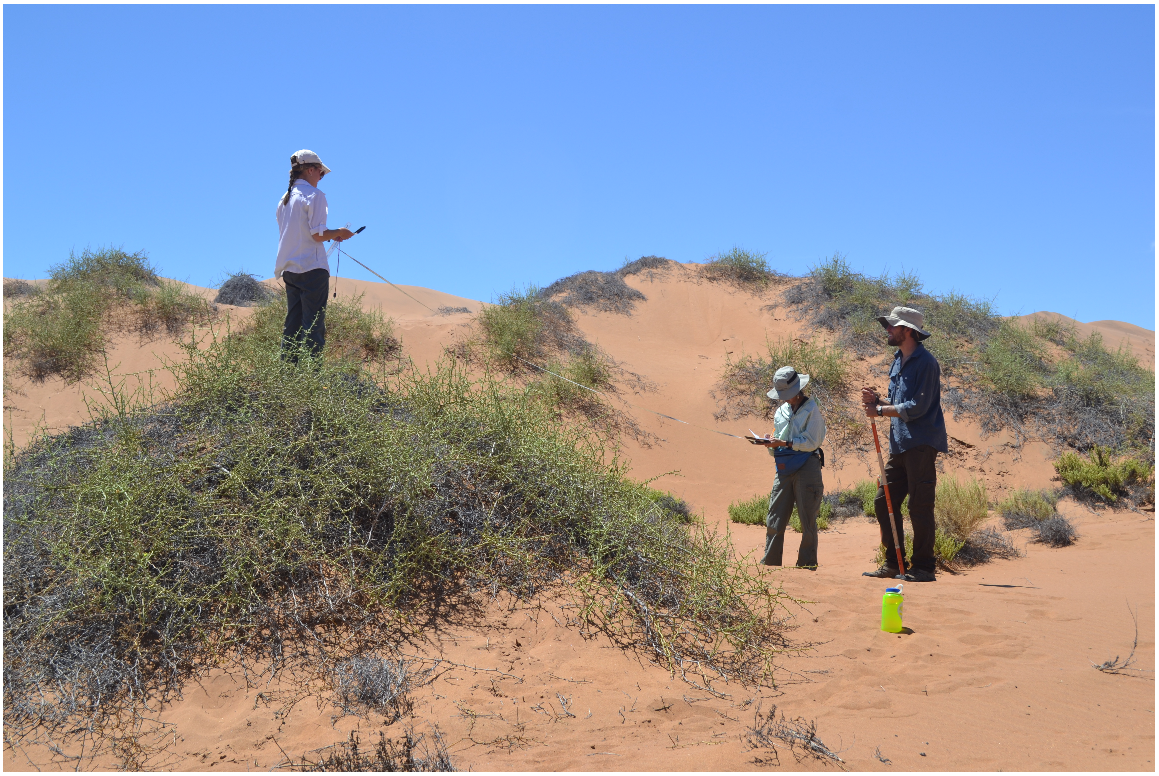


Figure 2: *Large and irregularly shaped hummock*

"Wagon Wheel Transect" Methodology

Eight transect lines were measured at 45 degree intervals from the center of each hummock to its base using a compass reading. Readings began at due magnetic North and proceeded clockwise around the hummock, ultimately representing 360 degrees of the hummock (see Fig. 3). The total length of each transect line was measured in meters from the base of the hummock up to its center. The following data were collected along each transect line, beginning from the base of the hummock and working up towards the center, as described below.

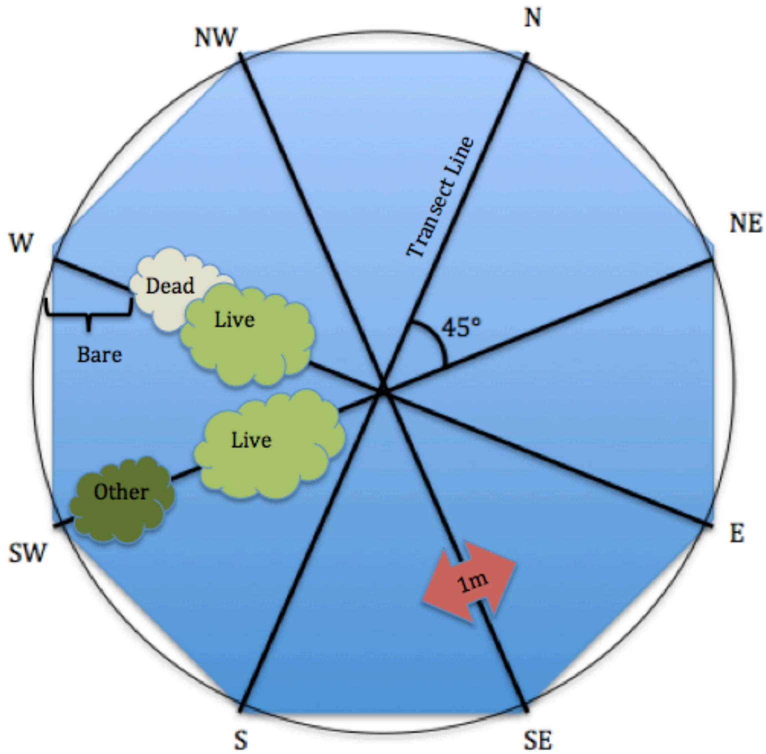


Figure 3: *Bird's eye view of transects on a hummock*

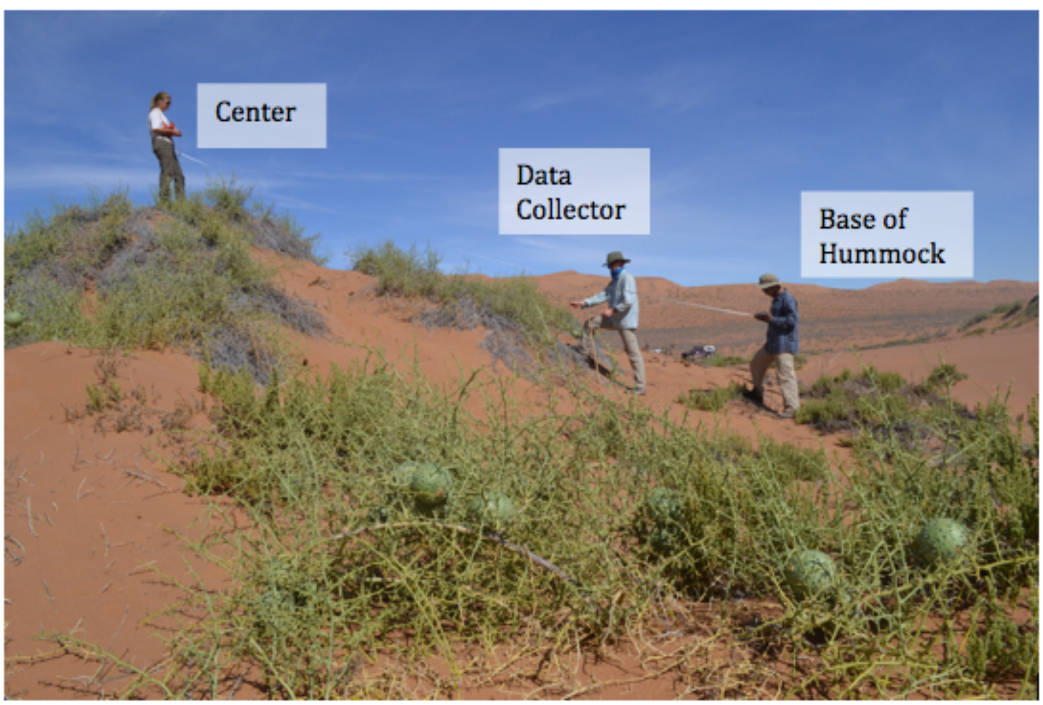


Figure 4: *Data collection jobs*

Biomass cover estimation

Sections on the transect line were classified as one of the four following cover classes: *living !nara, dead !nara, other shrub,* and *bare soil.* The extent of each cover class was noted by measuring the distance interval the class occupied on the transect line. For example, a transect line of 10 meters may have bare soil from 0 to 2 meters, dead !nara from 2 to 4.5 meters, living !nara from 4.5 to 7 meters, bare soil from 7 to 8 meters, other shrub from 8 to 8.5 meters and living !nara from 8.5 to 10 meters. When a living !nara interval was recorded, the height of the living !nara patch was also measured using a meter stick (see Fig. 5).

Figure 5: *Measuring height of biomass along transect*

To compute biomass, we calculated the surface area of the hummock by summing the surface areas of the eight triangular faces outlined by the transect lines. We then estimated the percentage of the hummock that was covered by live biomass by summing the total lengths of all eight transect lines, summing the total lengths of all live patches intercepted by a transect line, and dividing the former by the latter. We estimated total surface area of the live plants by multiplying total surface area of the hummock by the percentage of surface area covered with live biomass. Finally, we multiplied that surface area by the average height of all of the live sections on the hummock to get the volume of live plant mass on the hummock. Biomass (B) is given by the equation:

$$B = h\left(\frac{\sum_{i=1}^{8} L_i}{\sum_{i=1}^{8} T_i}\right)(S)$$

where h is the average height of live plants on the hummock, L_i and T_i are the distance of live plants intercepted by transect i and the total length of transect i respectively, and S is the surface area of the entire hummock.

!Nara spine measurements and herbivory recordings

Spine length and five-spine period measurements were taken for every living !nara patch interval on the transect line. The measurements were conducted on spines from the first living stem that touched the transect tape from the base toward the center. Five-spine period was measured starting from 10 centimeters below the apical meristem and proceeding down the stem. Five-spine period was defined as the length of the stem interval that contained five spines (see Fig. 6). Each of the five spines in the five-spine period was measured from its base to its tip. The presence or absence of herbivory was recorded by assessing the same stem (see Fig. 7).

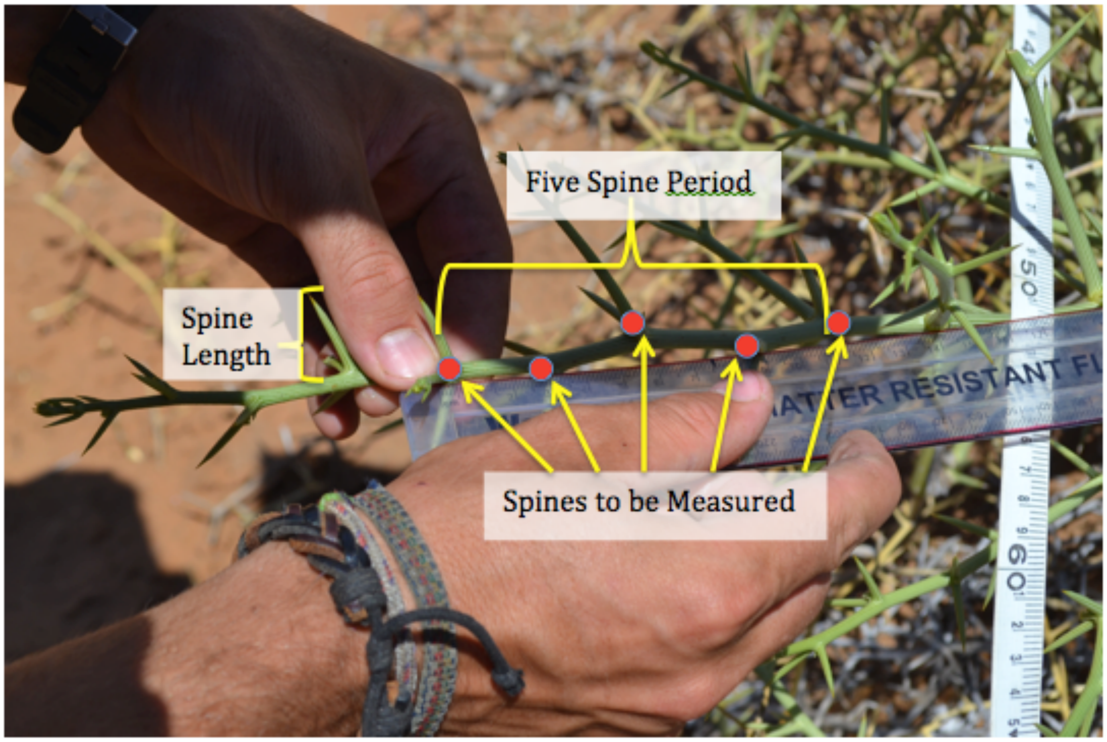


Figure 6: *Spine measurements*

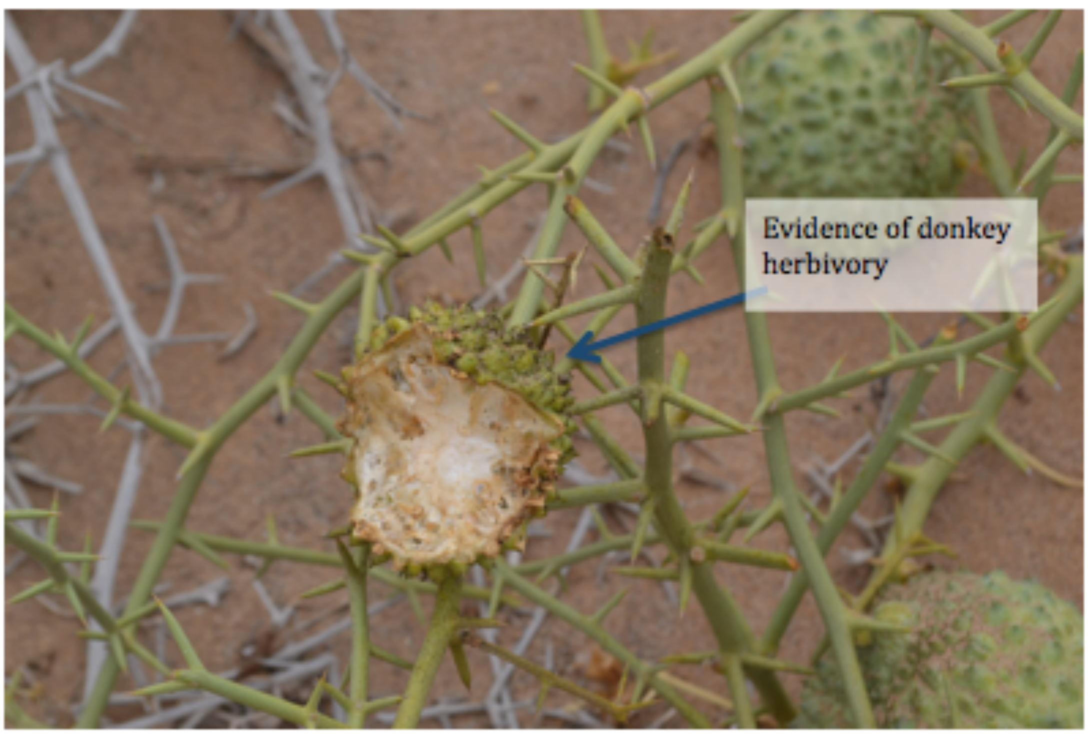


Figure 7: *Herbivory on a fruit*

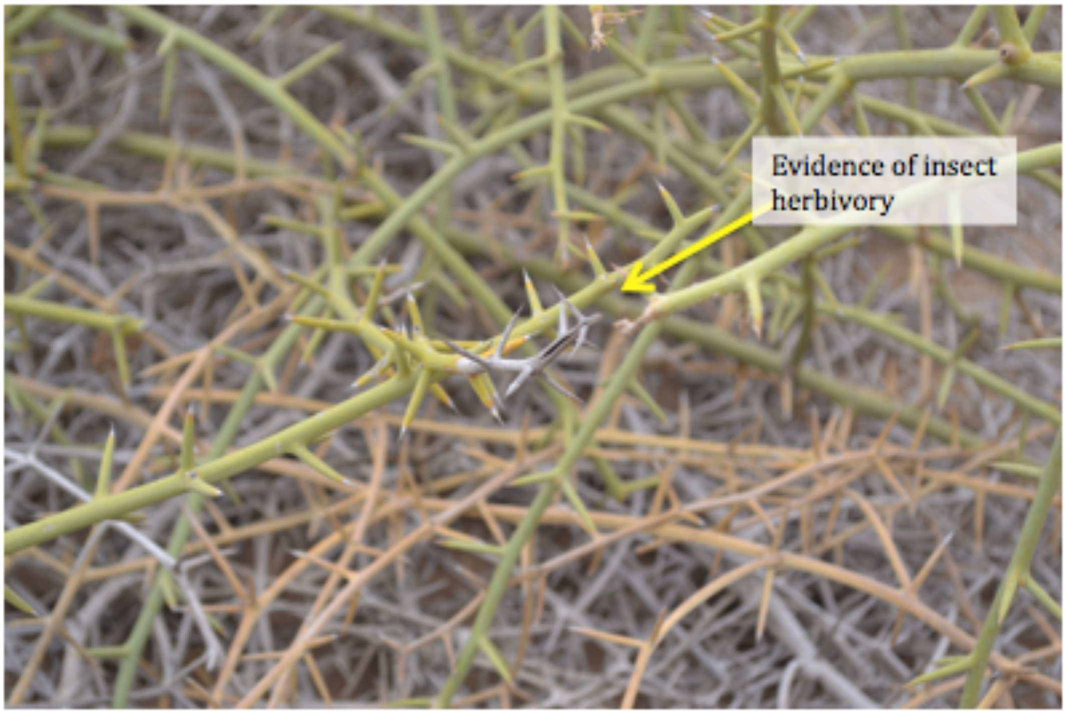


Figure 8: *Insect herbivory*

Fruit and flower measurements

On female hummocks, the circumference and location of each fruit within 0.5m on either side of the transect line were recorded. Circumference was measured by wrapping a string around the widest part of the fruit and measuring the length of string used (See fig.). A maximum of four fruits, chosen arbitrarily, were measured per living !nara patch. Additionally, the total number of fruits on the hummock was recorded. On male hummocks, the total number of open flowers within 0.5m of either side of each transect line was recorded.

Figure 9: *Fruit measurements*

Discussion of Methodology

Although the methodology in this study appeared controlled and precise, improvements could be made to enhance the accuracy of the techniques employed. In this study, hummocks were arbitrarily chosen, which was sufficient for the purpose of this paper: to develop a methodology for long-term monitoring of !nara hummocks. In order to select a more representative sample of the population, a map of all hummocks should be used to randomize selection of hummocks. Depending on the goals of future long-term monitoring, stratified random sampling may be more appropriate (e.g. to select equal numbers of male and female hummocks, to select equal numbers of large and small hummocks, etc.). Fruit circumference measurements could be done more accurately and conveniently using calipers. Herbivory was assessed using the first stem of a living !nara patch that touched the transect tape. However, if herbivory typically reduces the length of stems, this technique would underestimate the extent of herbivory on !nara because the tallest stems are often the first ones to touch the transect tape.

Data and Results

Biomass and Fruit Count

We analyzed total fruit count as a function of biomass, as calculated with the Wagon Wheel / Surface Area method. Our fruit counts displayed a Poisson distribution, so we fit the data with a generalized linear model. We only included data collected from female plants, as males do not bear fruit, and 2 female plants were disregarded because we did not have individual fruit counts for them. As a result of this analysis, we found that the total number of fruits borne by a female plant is strongly and significantly correlated with biomass—the greater the live biomass on a given hummock, the more fruits it will have (p < 2e-16; Fig. 10). Additionally, we found a similar correlation between hummock volume and live biomass (p = 6.88e-5; Fig. 11).

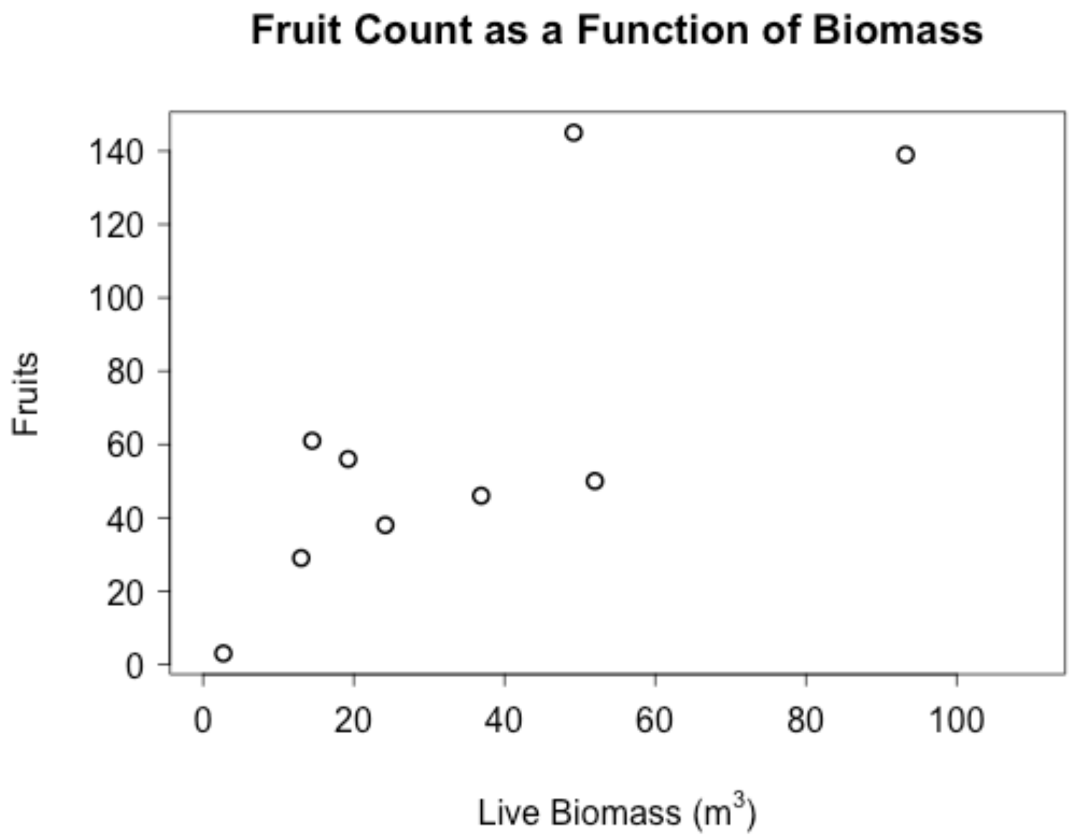


Figure 10: *The total number of fruits per hummock is plotted as a function of live biomass (in m^3). There is a positive correlation between biomass and fruit count, which suggests that fruit density is relatively constant throughout plant sizes. Larger female plants tend to have more fruits.*

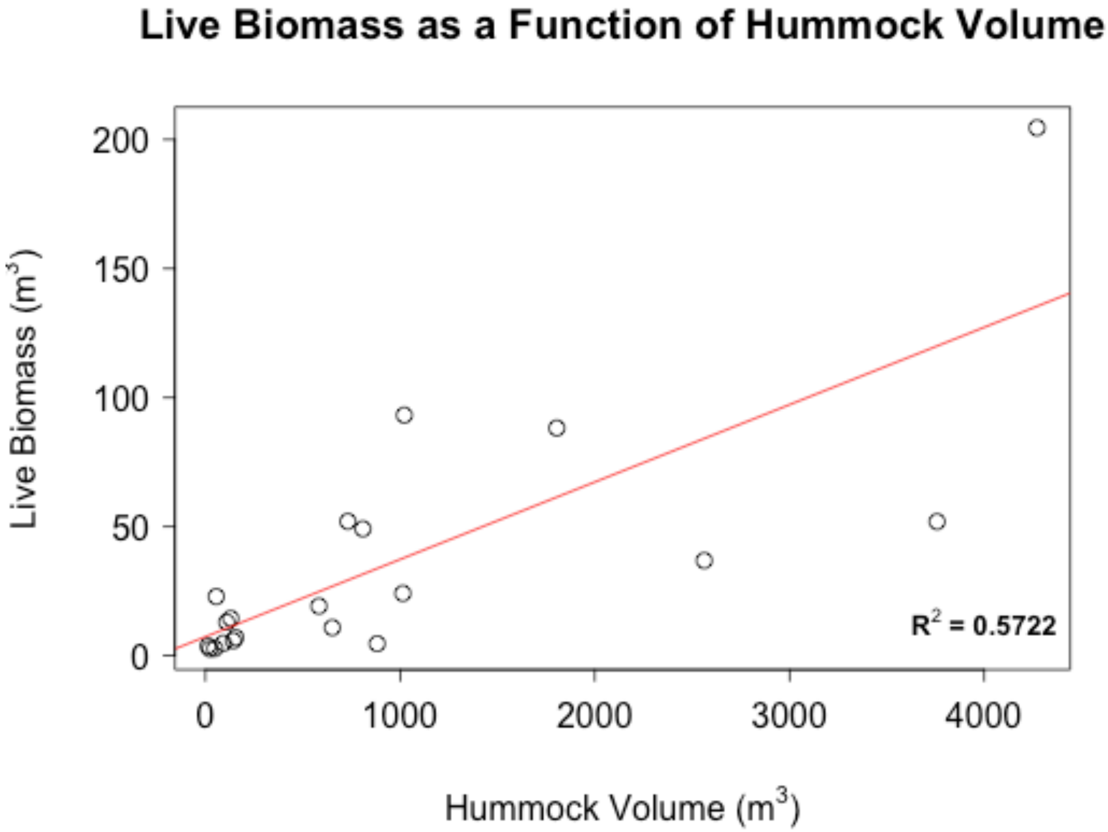


Figure 11: *Live biomass (in m³) is plotted as a function of hummock volume (in m³). The line of best fit (red, $R^2 = 0.5722$) demonstrates the positive correlation between hummock volume and biomass (p = 6.879e-5).*

Further, we found a correlation between sex and live biomass. Just as larger hummocks tend to have more live biomass on them, female !nara plants tend to have more live, above-ground biomass than males ($t = 2.2724$, $df = 11.81$, $p = 0.04258$; Fig. 12). Figure 12 compares the distributions of biomass for female plants and male plants. The female plants in our sample had an average of 54.34 m^3 of live biomass, while the males had an average of only 12.78 m^3. The largest amount of live biomass on a male plant in our sample was only 52.08 m^3, and even that is less than the average biomass on females.

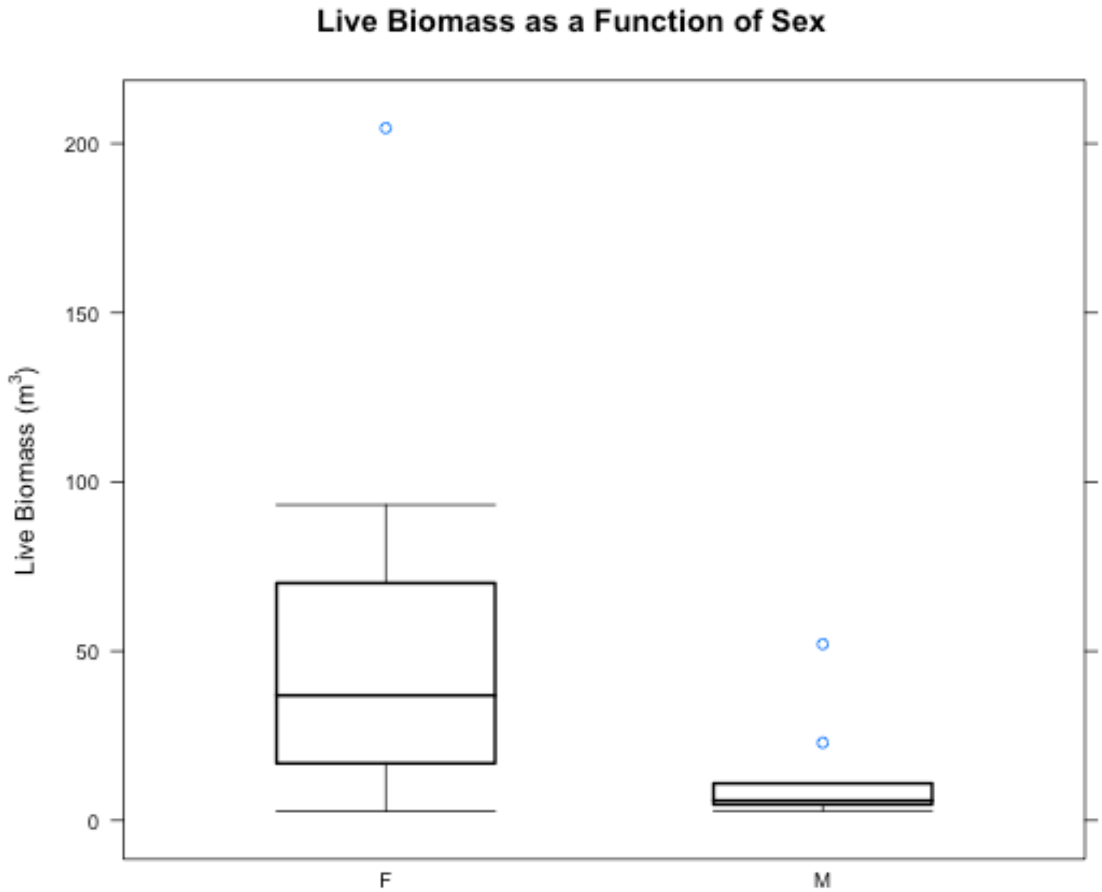


__Figure 12:__ On the left is the distribution of live biomass in female !nara plants; on the right is the analogous distribution in male !nara plants. The mean amount of biomass for females is 54.34 m^3, and the mean for males is 12.78 m^3. The difference between these distributions is statistically significant (p = 0.04258).

Finally, we found a correlation between sex and hummock volume. According to our baseline data, the hummocks on which male plants are found are significantly smaller than those on which females are found (t = 2.5132, df = 11.305, p= 0.02831). According to our calculations, the mean hummock volume for females in our study was 1462.52 m^3 while the mean calculated hummock volume for male plants was only 308.51 m^3.

Herbivory

The data we collected on herbivory were insufficient for us to conduct a worthwhile analysis on herbivory rates directly. However, extrapolation from the case of the genus *Acacia* to use spine length and density is supported by our data. There is a statistically significant, positive correlation between spine period (length of stem section containing five spine groups) and spine length (*p* = 0.01209; Fig. 13). Thus, we expect spine length to vary with spine period. While direct measurement of utilization rates will be improved upon in future stages of our long-term monitoring project, we can use our available data to make some speculations about herbivory.

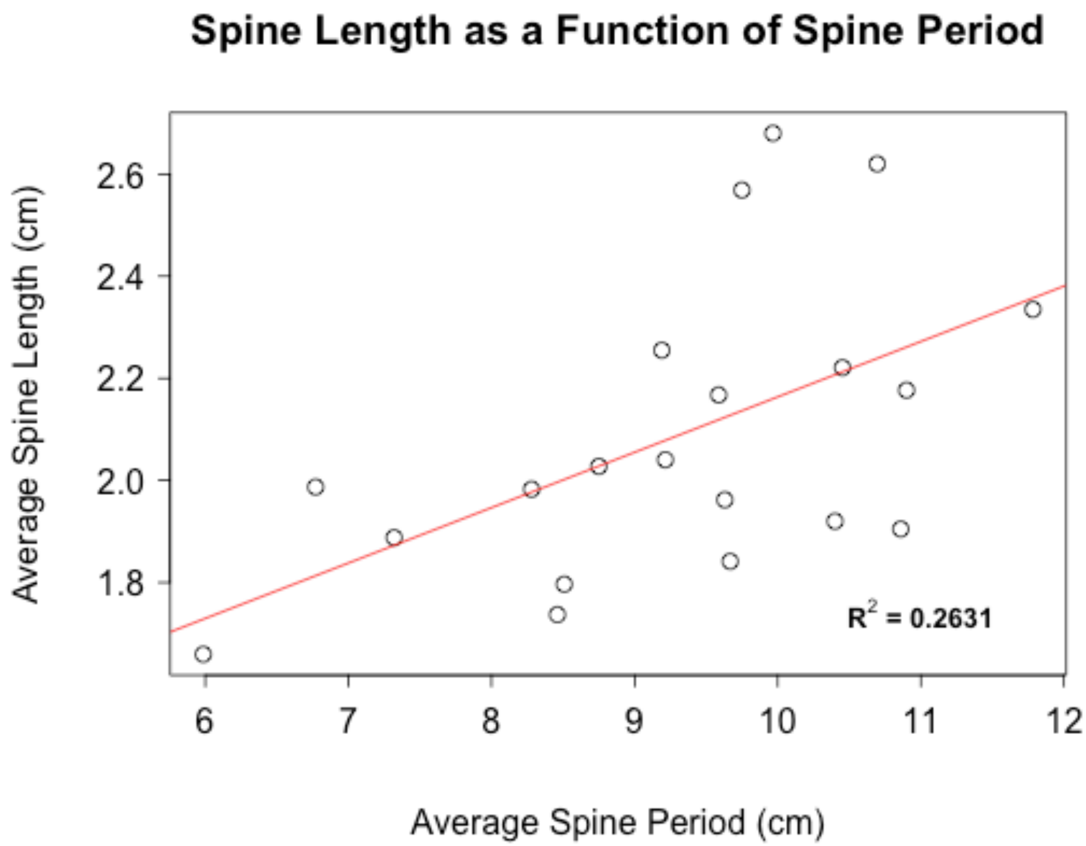


Figure 13: *Spine length is plotted as a function of spine period, and a line of best fit (red) is shown (R^2 = 0.2631). There is a significant, positive correlation between spine length and spine period (p = 0.01209). Both variables are referred to as "averages" because many measurements of spine length and spine period on a given hummock were averaged to produce one average spine length and one average spine period for the whole hummock.*

Additionally, we found that male !nara plants have a significantly greater spine period than female plants (*t* = -2.8246, *df* = 17.829, *p* = 0.0113; Fig. 14); in other words, spines are more dense on female plants than on male plants. While browsing a !nara plant, herbivores preferentially feed on new growth, flowers, and fruits; both male and female plants have new growth and flowers, but as only female !nara plants bear fruit, we expect female !nara plants to suffer more herbivory than male !nara plants (Henschel *et al.,* 2004). This further substantiates the use of a combination of spine length and density as a proxy for herbivory.

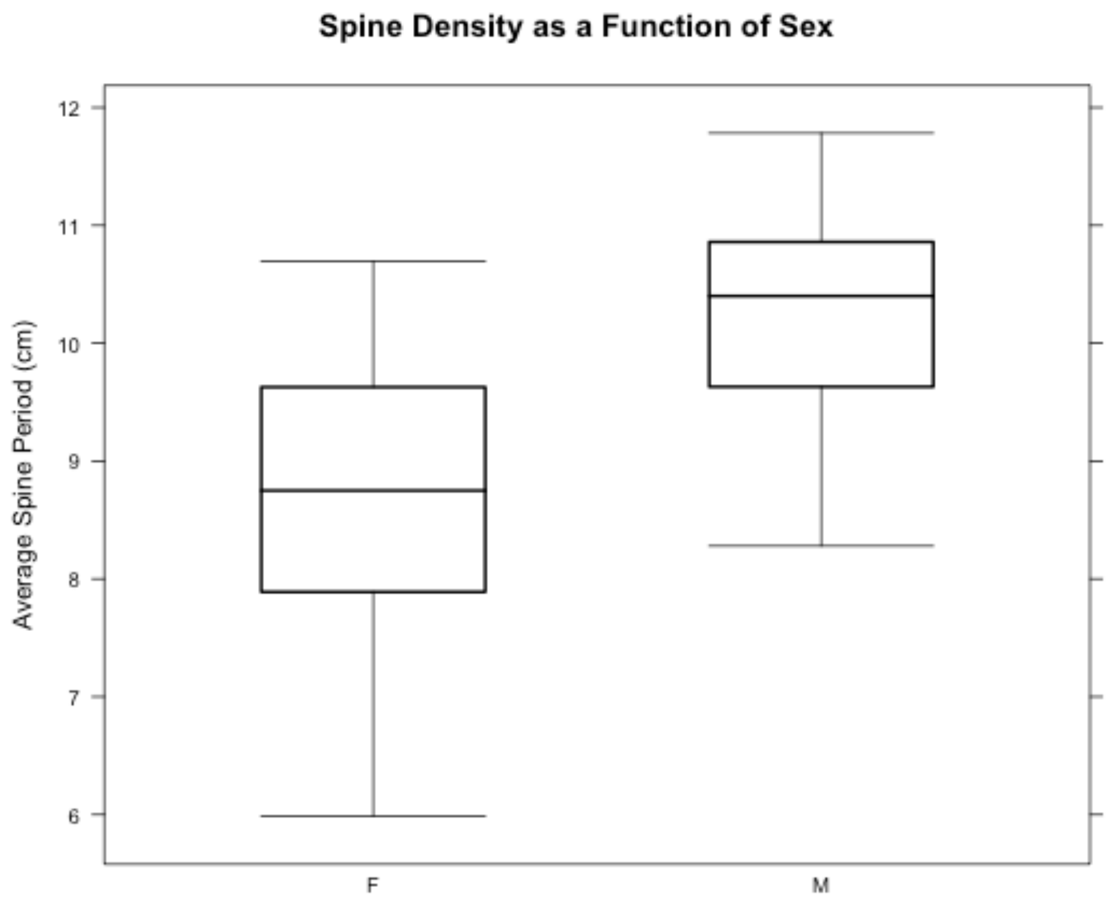


Figure 14: *This is a box and whiskers plot displaying the difference in the spine period distributions between the two sexes. The mean spine period for females is 8.610043 cm, and the mean for males is 10.162434 cm. The difference between these two distributions is statistically significant (p = 0.0113).*

IV. Discussion and Recommendations

Outside of the narrow spheres of academia, ecological data are only relevant and valuable if they are applied to the development of management strategies. Our data on the ecology of !nara must be couched in the broader context of targeted monitoring for the purposes of management and conservation. As we began this study with no explicit hypotheses, the data we collected amount to little more than aimless surveillance monitoring if they are not built upon and utilized by resource managers.

Interpretation of Results

Biomass and Fruits

Because fruits are positively correlated with biomass (Fig. 10), and because biomass is positively correlated with hummock volume (Fig. 11), a survey of a !nara patch for total biomass or even hummock volume could provide a useful indication of relatively how many fruits would be available in a given patch. This survey technique relies on the assumption that !nara population structure is roughly constant with respect to sex in different patches. Because our data suggest a correlation between sex and hummock volume (with female plants inhabiting larger hummocks), a survey of hummock volumes in an area could provide an indication of population structure with respect to sex as well; however, these findings need to be corroborated with larger sample sizes.

If a large-scale spatial survey method could be reliably employed to map out fruit availability, then it could be used to map out points of particular interest for the conservation and management of !nara as a resource. Additionally, knowledge of the spatial distribution of !nara productivity would be pivotal in targeting our monitoring project, making its findings relevant to all interested parties.

Herbivory

The most notable realization from the collection of herbivory data during our study was that it is necessary to develop a better method for collecting direct herbivory data; however, our data on spine length and density have some potential to be used as a proxy for herbivory rates. As there is a compelling argument for the existence of a positive correlation between spine length—and even spine density—and herbivory in species of *Acacia*, we have made the assumption that a similar trend is evident in !nara (Milewski, Young, and Madden, 1991; Young and Okello, 1998; Young, Stanton, and Christian, 2003). From this assumption, we can reason inductively to identify potentially corroborating evidence. Collecting data to definitively support or refute such a correlation in !nara was out of the scope of this study, though these data should be collected in the future.

Because spine length and spine period are correlated in our sample, and because spine period is shorter for females than for males, the assumed link between spine density and herbivory may indicate that females suffer from more herbivory than males, presumably because they have fruits. As herbivores who feed on !nara selectively browse on flowers, new tips, and fruits, and because both males and females have flowers and new tips, this conclusion suggests that at least some herbivores preferentially feed on fruits more so than flowers or new tips. This would cause them to choose a female with fruits over a male with only flowers and new tips. A higher rate of herbivory on females than on males could also be a result of the fact that females have more new tips, more flowers, or simply more biomass in general. This should be examined in more detail in the future.

In general, information about herbivory is vital to the development of conservation strategies and management plans for the !nara, because herbivory has a large impact on the !nara population (Henschel *et al.,* 2004). Some types of herbivory can destroy !nara plants, while others make seed dispersal possible. Knowing exactly how different types of herbivory affect the plants, and what factors impact herbivory is therefore necessary in order to manage the resource effectively and successfully.

Conclusions and Recommendations

We believe our data would be most effective if incorporated into a targeted monitoring approach to assess changes in !nara health and productivity and to identify causes of population decline and to determine the appropriate management response.

Management

It is important that Gobabeb share our data with the Topnaar so that they can identify thresholds of potential concern in the system, detect when they are reached, and respond accordingly. This response may involve a series of different approaches, informed by our long-term monitoring study, which will help discern the most effective management practices. Modifications of Topnaar management of the !nara plant might include implementing a quota system, evaluation of harvesting methods, and exclusion of donkeys from !nara fields.

Future Research

Our findings suggest that certain variables should be prioritized over others in the long-term monitoring study. Biomass and hummock volume are both positively correlated with fruit production, and serve as indicators of !nara vitality. Measurements of spine length should be continued as spine length is a known indicator of herbivory in other species (Young and Okello, 1998; Young *et al.*, 2003). Our analysis suggested that measuring fruit circumference is not useful within the scope of our study; however such measurements might be more useful in the context of seed dispersal or recruitment studies.

In order for our dataset to be valuable, it is vital for data collection to continue in the form of a long-term monitoring study of the !nara plant. In our pilot study, we identified some key variables and developed measurement methodologies. We established the foundation for a long-term monitoring project on the !nara that can be modified in order to adapt to newfound trends in ecosystem dynamics. Spatial variability is necessary in long-term monitoring to determine an accurate understanding of the !nara metapopulation. The sample size should be extended to include other study sites in Namib-Naukluft National Park: i.e. the Kuiseb Delta and Sandwich Harbour.

We recommend additional studies about the ecology of the !nara plant that have potential to enhance long-term monitoring protocol and to improve !nara management practices. A pollinator observation study would entail observing plants during the female flowering season and recording the number of flowers observed for a certain length of time. A list of pollinators that visit the flowers during that time period should be kept and the pollinators should be collected for identification purposes. Another study might involve looking at jackal populations and the way in which they affect seed dispersal. One interesting factor affecting jackal populations could be human populations because the local Topnaar view jackals as a threat to their livestock (Henschel *et al.,* 2004). Another potential study could be to superimpose the long-term ecological monitoring data with a groundwater availability map in an effort to update existing population-groundwater relationship mapping (Müller 2000). Additionally, we recommend future researchers monitor the relationship between human populations, groundwater availability, and !nara. Topnaar groundwater extraction and dam construction may have serious impacts on !nara recruitment and survival (Shilomboleni, 1998). A final study may also assess whether long-term monitoring of hummocks negatively affects their health. We noticed the act of walking on !nara hummocks while conducting research displaced significant volumes of sand, which may cause detrimental erosion.

Seeing the Big Picture

!Nara has been an integral component of Topnaar life for thousands of years. Today, the Topnaar harvest !nara melons as a food product for subsistence use as well as a valuable food oil and cosmetic product for commercial use. Paradoxically, very little is known about the major factors that currently influence the extent to which !nara grow, bear fruit, establish and survive in certain areas of the Kuiseb Delta.

In order to improve !nara management, we propose a long-term monitoring project be instituted by Gobabeb and Dartmouth. The monitoring project will fill gaps in knowledge about !nara's ecology not for the purpose of learning more, but primarily so the knowledge can be specifically applied to optimizing management strategies. Placing the long-term monitoring project in the context of optimizing !nara management strategies is the most important component of our proposal because if the monitoring is not focused on a particular goal, the data collection will be useless, 'blue sky' research.

V. References

Agrawal, A. A. (1999). Induced responses to herbivory in wild radish: effects on several herbivores and plant fitness. *Ecology, 80*, 1713-1723.

Havstad, K. and Herrick, J. (2003). Long-term ecological monitoring. *Arid Land Research and Management, 17,* 389-400.

Karban, R. and Meyers, J. H. (1989). Induced Responses to Plant Herbivory. *Annual Review of Ecology and Systematics, 20,* 331-348.

Klopatek and Stockt (1994). Partitioning of nutrients in *Acanthosicyos horridus*, a keystone endemic species in the Namib Desert. *Journal of Arid Environments*, 233-240.

Magurran, A., Baillie, S., Buckland, S., Dick, J., Elston, D., Scott, E., Smith, R., Somerfield, P., Watt, A. (2010). Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. *Trends in Ecology and Evolution, 25,* 574-582.

McDonald-Madden, E., Baxter, P., Fuller, R., Martin, T., Game, E., Montambault, J., Possingham, P. (2010). Monitoring does not always count. *Trends in Ecology and Evolution, 25*. 547-550.

Milewski, A.V., Young, T.P., Madden, D. (1991). Thorns as induced defenses: experimental evidence. *Oecologia, 86,* 70-75.

Milligan, A. (2013) Thompson hummock integration: an improved method for calculating hummock volume of *Acanthosicyos horridus.* Environmental Studies Africa Foreign Study Program, Culminating Experience, Dartmouth College, Hanover, NH, 5.

Müller, M. (2000). Ausbreitungsökologie der !nara-mellone (Acanthosicyos horrida, Cucurbitaceae). Diplom Thesis, Zoology III, Julius-Maximilian-University, Würzburg, Germany, 135.

Nichols, J. and Williams, B. (2006). Monitoring for conservation. *Trends in Ecology and Evolution, 21,* 668-673.

Shilomboleni, A. (1998). The !Nara and the factors that lead to its decline in *productivity*. Report on the NARA project, Gobabeb Training and Research Center, Ref.No. 15427.

Vaughan, H., Brydges, T., Fenech, A., Lumb, A. (2001). Monitoring long-term *ecological* changes through the ecological monitoring assessment network:

science-based and policy relevant. *Environmental Monitoring and Assessment, 67,* 3-28.

Young, T.P., Okello, B.D. (1998). Relaxation of an induced defense after exclusion of *herbivores*: spines on *Acacia drepanolobium*. *Oecologia, 115,* 508-513.

Young, T.P., Stanton, M.L., Christian, C.E. (2003). Effects of natural and simulated *herbivory* on spine lengths of *Acacia drepanolobium* in Kenya. *Oikos, 101,* 171-179.

Appendix I: *Protocol*

The following section details the long-term monitoring methodology described in the methods section above. This section is provided so that the procedure can be replicated by future researchers as closely as possible.

Hummock selection and identification

!Nara are leafless desert plants. They consist of multiple green spiny stems. These stems form dense patches of !nara. Over time, as the plant grows, sand and debris collect around these patches to form sandy mounds known as hummocks. Patches of both living and dead !nara stems are visible on the hummock. The green patches and raised nature of hummocks make them visible on satellite images (ie Google Earth) (GIS Team). Such images can be used to number each hummock on a map of an area where !nara grow. Using a random number generator in conjunction with the map, hummocks can be randomly selected for sampling.

Hummocks typically form around a single plant. Because !nara are dioecious (individual plants are either male or female), individual hummocks can usually be sexed as male or female. Sex is determined as follows:
Female: fruits may be present, flowers are present only between September and April, peaking October-November, a small bulb may be located below the flower bud.

Male: no fruits are ever present, flowers may be present at any time of year (Henschel and Moser, 2004).

GPS (Garmin): measure. walk up to the center of the !nara hummock and mark the waypoint on GPS. Record the waypoint in the dataset, alongside the plant identification number.

Assign plant identification number based on sample number and geographical area
If the distance from the base of the hummock to the center exceeds 50m in length, if the hummock has two or more distinct peaks, or if the shape is oblong; the hummock should be assessed as two or more individual hummocks. These sub-hummocks should have their own centers and their borders should touch but not overlap.

Wagon Wheel Methodology

The center of the hummock will also serve as the center of the wagon wheel. Transect line lengths should be measured from the center to the defined border of the hummock (i.e. where the slope of the hummock meets flat soil). Using a compass, determine magnetic north. This will be the direction of the first transect line. From this center, eight transect lines will be measured to the outer edge of the hummock, moving in a clockwise fashion. Each transect line will be 45 degrees apart, thus representing all 360 degrees around the hummock. The eight transects will therefore form the spokes of the wagon wheel, while the perimeter will resemble the outer rim of the wheel.

The lengths of the transect lines will be used to calculate biomass cover. It is important to also measure the angle of declination of each transect line (the angle down from a level plane atop the hummock to the transect line). This will facilitate the use of the Thompson Hummock Integration method for calculating hummock volume, as proposed by Milligan (2013).

Biomass cover estimation

Sections on the transect line were classified as one of the four following cover classes: *living !nara, dead !nara, other shrub,* and *bare soil.* Living !nara was defined as green stems that may or may not be fruit and/or flower bearing. Dead !nara was defined as dry brittle stems that were brown, gray or black in coloration. Bare soil was defined as areas of exposed sand with no significant plant cover. Other shrub was defined as any other plant species (alive or dead) covering any area of the hummock. Measurements were recorded by viewing from directly above the transect tape to avoid parallex error.
The extent of each cover class was noted by measuring the distance interval the class occupied on the transect line. For example, a transect line of 10 meters may have bare soil from 0 to 2 meters, dead !nara from 2 to 4.5 meters, living !nara from 4.5 to 7 meters, bare soil from 7 to 8 meters, other shrub from 8 to 8.5 meters and living !nara from 8.5 to 10 meters. For living !nara patches, height of the patch was determined by estimating the median stem height (imagine compressing tallest stems with a pie tin and measuring the height from the ground to where the pie tin settles). Be careful not to break stems while using the meter stick to measure the height.

To compute biomass, we calculated the surface area of the hummock by summing the surface areas of the eight triangular faces outlined by the transect lines. We then estimated the percentage of the hummock that was covered by live biomass by summing the total lengths of all eight transect lines, summing the total lengths of all live patches intercepted by a transect line, and dividing the former by the latter. We estimated total surface area of the live plants by multiplying total surface area of the hummock by the percentage of surface area covered with live biomass. Finally, we multiplied that surface area by the average height of all of the live sections on the hummock to get the volume of live plant mass on the hummock. Biomass (B) is given by the equation:

$$B = h\left(\frac{\sum_{i=1}^{8} L_i}{\sum_{i=1}^{8} T_i}\right)(S)$$

where *h* is the average height of live plants on the hummock, L_i and T_i are the distance of live plants intercepted by transect *i* and the total length of transect *i* respectively, and *S* is the surface area of the entire hummock.

!Nara spine measurements and herbivory measurements

Spine length and five-spine period measurements were taken for every living !nara patch interval on the transect line. The measurements were conducted on spines from the first living stem that touched the transect tape from the base toward the center. Five-spine period was measured starting from 10 centimeters below the apical meristem (growing tip) and proceeding down the stem. Five-spine period was defined as the length of the stem interval that contained five spines (See fig.). Each of the five spines in the five-spine period was measured from its base to its tip.
The presence or absence of herbivory was recorded by assessing the same stem. A stem was assessed as subjected to herbivory if the tip appeared to be blunt and bitten off, or if the stem appeared to have holes/decay, suggesting insect herbivory.

Fruit and flower measurements

Fruit of !nara are easily recognized. They are spherical melons (usually 15-30cm in diameter) with rough green skin and small uniformly distributed spikes. On female hummocks, the circumference and location of each fruit within 0.5m on either side of the transect line were recorded. Circumference was measured by wrapping a string around the widest part of the fruit and measuring the length of string used. However, for improved accuracy and efficiency, calipers may be used to measure the width at the widest point (ie diameter) of each fruit and used to determine circumference. A maximum of three fruits, chosen arbitrarily, were measured per living !nara patch. Additionally, the total number of fruits on the hummock was recorded by walking around the hummock to survey it from all vantage points. On male hummocks, the total number of open flowers within 0.5m of either side of each transect line was recorded. Open flowers were defined as flowers that had clearly bloomed, often with yellow-orange petals.

Appendix II: *R Outputs*

Biomass and Fruit Count

Fruit count as a function of biomass

```
Call:
glm(formula = Total.fruits ~ Biomass.sa.method, family = "poisson",
    data = subset(edata, Sex == "F"))

Deviance Residuals:
   Min       1Q  Median       3Q      Max
-6.632  -1.725  -1.596   1.894   7.427
```

```
Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       3.421463   0.077901   43.92   <2e-16 ***
Biomass.sa.method 0.017647   0.001345   13.12   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 290.88  on 8  degrees of freedom
Residual deviance: 133.20  on 7  degrees of freedom
  (2 observations deleted due to missingness)
AIC: 187.72

Number of Fisher Scoring iterations: 5
```

Biomass as a function of hummock volume

```
Call:
lm(formula = Biomass.sa.method ~ volume, data = edata)

Residuals:
    Min      1Q  Median      3Q     Max 
-68.026  -7.881  -5.124  14.823  69.163 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 7.364522   8.950046   0.823    0.421    
volume      0.029978   0.005833   5.139 6.88e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 31.57 on 18 degrees of freedom
Multiple R-squared:  0.5947,  Adjusted R-squared:  0.5722 
F-statistic: 26.41 on 1 and 18 DF,  p-value: 6.879e-05
```

Two sample t-test comparing biomass and sex

```
      Welch Two Sample t-test

data:  Biomass.sa.method by Sex 
t = 2.2724, df = 11.81, p-value = 0.04258
alternative hypothesis: true difference in means is not equal to 0 
95 percent confidence interval:
  1.640505 81.471663 
sample estimates:
mean in group F mean in group M 
       54.34014        12.78406 
```

Two sample t-test comparing hummock volume and sex

```
      Welch Two Sample t-test
```

```
data:  volume by Sex
t = 2.5132, df = 11.305, p-value = 0.02831
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  146.6879 2161.3306
sample estimates:
mean in group F mean in group M
       1462.522         308.513
```

Herbivory

Average spine length as a function of average spine period (hummock)

```
Call:
lm(formula = Avg.spine.length.H ~ Avg.spine.period.H, data = edata)

Residuals:
     Min       1Q   Median       3Q      Max
-0.35201 -0.17232 -0.01121  0.07999  0.52008

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         1.07876    0.36612   2.946  0.00863 **
Avg.spine.period.H  0.10848    0.03888   2.790  0.01209 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2478 on 18 degrees of freedom
Multiple R-squared:  0.3019,  Adjusted R-squared:  0.2631
F-statistic: 7.785 on 1 and 18 DF,  p-value: 0.01209
```

Two sample t-test comparing spine periods of males and females

```
      Welch Two Sample t-test

data:  Avg.spine.period.H by Sex
t = -2.8246, df = 17.829, p-value = 0.0113
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.7078388 -0.3969424
sample estimates:
mean in group F mean in group M
       8.610043       10.162434
```

Sex and Size Mapping of !Nara plants in !Khuiseb Valley
Wommack, R.W., Parker, S.K., Daigler, M.P.[1]
ENVS 84: Culminating Project
Professor Doug Bolger

Abstract

!Nara is a keystone species within the !Khuiseb Valley and most important cultural and economic resource for the local Topnaar community (Henschel et al., 2004). Nevertheless, the distribution of !nara within the Khuiseb River Valley is not well known; only two studies have attempted to map the species (Ito, 2005; Muller; 2000). Developing a more complete resource base of !nara within the Khuiseb delta may be important for the management and conservation of the plant, especially given the anecdotal evidence of a widespread decline in !nara abundance (Ito, 2005). Thus this study started the process of creating a more thorough map of the resource base. The study identified twenty-two potential !nara sites around Gobabeb Research and Training Center (sites A-V), of which, thirteen were surveyed (A-C, E-K, M, N, V) and nine analyzed (C, E, F, H, I, J, K, N, and V). Individual !nara plants were marked using GPS devices and identified by sex and size (large, medium and small). Additionally, some non-!nara landscape features were marked at most sites surveyed. No statistical significance was found regarding the sex ratio of !nara within or across sites; however, the distribution of male and female plants in sites K and E may suggest that small-scale spatial segregation of the sexes exists. Statistical analysis also found a disproportionately high number of large plants, and disproportionately low number of medium plants across all sites, which corroborates the widespread idea that !nara plants are long-lived, but struggle with recruitment (Henschel et al., 2004). Future studies could use satellite imagery to make better predictions of !nara distribution or investigate trends in the historical size and distribution of !nara plants.

[1] Order of authors determined by a round-robin rock-paper-scissors tournament.

Background

The !Nara plays a preeminent role in the lives and culture of the !Khuiseb topnaar. It functions as a source of identity for the Topnaar who historically distinguished themselves from similar ethnic groups by the fact that they alone harvested !nara (Henschel, 2004). Nowadays it remains a primary staple food and significant income source for the Topnaar people, especially in rural areas. Topnaar harvest the melons in the summer, eat the fruits, and either eat the seeds or sell them to retailers in Walvis Bay or to Desert Hills, an upscale oil processing company. Harvesters earn at least $N20-$N22 per kg of seeds, and the total income from selling !nara accounts for 43% of the annual income of the !Khuiseb Topnaar (Ito, 2005).

The !nara also functions as a keystone species in the !khuiseb valley. It provides shelter for burrowing animals, stabilizes sand dunes, provides a direct food and water source for insects, reptiles, mammals, and birds, and provides an indirect food source for beetles when the plant collects windblown litter (Henschel, 2004).

Despite the cultural, ecological, and economic importance of !nara, there have been few spatial studies to map the plant's distribution. Marcus Müller (!Nara, 2000), provided the most comprehensive study by mapping all !nara plants in 6780 ha surrounding Gobabeb. He then compared that data with the availability of groundwater, and hypothesized a correlation between !nara size and groundwater depth. Ito (2005) completed a much coarser mapping of !nara distribution in the !Khuiseb delta that marked patch locations but not individual plants. His study noted a decline in !nara plants along the northern channel of the delta. Harvesters anecdotally suggest that this decline is more widespread, but, aside from limited evidence of historical production levels (Henschel et al., 2004), no scientific studies have evaluated this claim. The study described in this paper is the start of such an analysis, and it could form the basis for future resource assessments necessary for the long-term conservation and management of this ecologically and socioculturally important plant.

This study is also the first to investigate the spatial distribution of sex of !nara plants. Spatial segregation of the sexes is common, but not universal, among other dioecious plants. Because successful reproduction is often more costly for female plants, they tend to grow in less-stressful conditions: sites that are moister, less exposed, sunnier, less saline, lower in elevation, and higher in nutrient concentrations (Bierzychudek and Eckhart, 1998). If sexual segregation of the sexes exists within the !nara population, it would have significant implications for harvest management. Similarly, this paper's investigation of !nara size could have significant implications for long-term fruit production, harvesting management, and resource development.

Methods:

An analysis of potential !nara distribution in the !Khuiseb Valley surrounding Gobabeb Research and Training Center was conducted using GIS satellite imagery in Summer 2013 (Chipman, 2013). This analysis identified twenty-two potential !nara sites around Gobabeb, which we classified with letters A-U (Map 1). In addition, we identified a site V located outside of Gobabeb's concession.

Using GPS devices, !nara hummocks were marked in sites A-C, E-K, M, N, and V over a five day period. Sites D, L, O, T, R, S, and U were not surveyed due to time constraints. On days one and two, !nara plants were marked around the perimeter of site G and within site V, respectively. Labels given to each plant included the letter of the site and a number that corresponded with the order in which a particular plant had been marked. On days three through five, the GPS coordinates of !nara and non-!nara landscape features were documented in sites A-C, E, F, H-K, M, and N, recording the sex and general size (large, medium, small) of each !nara plant. Although the attempt was made to mark all !nara plants within these sites, some were overlooked. Varying numbers of non-!nara features that resembled !nara hummocks were selected and marked at most sites. !Nara sex was determined by flower structure and presence of melons, and size was estimated subjectively by comparing plants across sites. Other observations regarding plant health, abnormal hummock size, and sex distribution were noted. Non-!nara features were marked using GPS devices. !Nara plants that fell outside of site boundaries were also marked using GPS devices and labeled with the letter of the closest site.

Results:

The GPS location was documented for 512 !nara plants and 95 non-!nara landscape features across fifteen different sites (Map 2). All plants in sites with fewer than ten plants were ignored in subsequent analysis. Thus, only 9 of the 15 sites (C, E, F, H, I, J, K, N, and V) were analyzed. These sites contained a total of 439 plants.

Overall, the !nara sample contained 207 females and 232 males, which is well within the range to be expected if the sex ratio of the entire population is 50%-50% (the two-tailed binomial distribution p-value= .252), as can be seen in Figure 1.There were 128 small plants, 112 medium plants, and 199 large plants. This suggests that the size of plants is not randomly distributed between size classes (Chi-square= 29.3075 df=2, p=4.325 x 10^{-7}). Furthermore, binomial tests suggested that large plants comprise more than 1/3 of the population (p-value=2.089 x 10^{-7}), and medium plants comprise fewer than 1/3 of the population (p-value=.004634), as can be seen in Figure 2. There was no evidence of relationship between sex of plant and size of plant (Chi-square = 1.479, df=2, p-value=.4774).

The presence of sex and size differences between different sites was also analyzed. The resulting 3-way contingency table analysis found that there was significant variation in size and sex across sites (chi-square=127.1, df=42, p-value=1.7 x 10^{-10}). There was not a significant variation in sex distribution across sites (chi-square=9.7, df=8, p-value =.286), as seen in Figure 3. But there was significant variation in size distribution across sites (chi-square= 84.4, df=16, p-value=2.7 x 10^{-11}), as seen in Figure 4. A posthoc chi-square analysis revealed that sites V, N, K, and C had disproportionate distributions of sizes (Figure 5).

Discussion:

In general, Jonathan Chipman's prediction of !nara sites was accurate, since all predicted sites that were sampled contained !nara. With the exception of site B, Chipman's analysis proved conservative in that !nara extended well beyond the range of predicted sites. These sites were subsequently obvious to distinguish on satellite imagery, as seen in Map 3. This suggests that an updated GIS landscape classification program could easily locate !nara patches more successfully than Chipman's conservative initial assessment. This may have enormous potential for mapping !nara distribution within the !khuiseb, Angola and northern Namibia (Henschel et al., 2004; Gwash, pers. comm., 2013).

Statistical analysis demonstrated no significant variation in sex ratio within or between sites, which suggests that !nara does in fact follow a 50%-50% sex ratio (Figure 1). This 50-50 sex ratio was observed within individual sites as well as the total !nara population sampled (Figure 3). Additionally, the distribution of !nara in sites E and K suggests that intra-site sexual segregation of !nara may exist (Map 4), however, confirmation of this hypothesis requires spatial analysis beyond the scope of this paper. Such hypothesized segregation may correlate with differences in micro-scale environmental conditions as female plants tend to grow under less-stressful conditions than male plants (Bierzychudek & Eckhart, 1988).

Significant variations were demonstrated in the distribution of size classes within and between sites. Statistical analysis also found a disproportionately high number of large plants and a disproportionately low number of medium plants across all sites. If plant size is correlated with age, these findings support other scientists' descriptions of !nara having a low recruitment rate and high longevity (Henschel et al., 2004). Plant and hummock size may also correlate with ground water availability such that larger plants grow in areas with shallower groundwater (Muller, 2000). Thus, sites with few large plants may have relatively deep groundwater tables, and sites many large plants may have a shallow groundwater table. Additionally, the presence or absence of flooding events may affect !nara size distribution. Ito (2005) found that !nara hummocks located near or in riverbeds experience periodic flooding events that wash sand downstream, influencing hummock size and structure, which may be the reason Site V, the only site we surveyed in a riverbed, contained a disproportionately low number of large !nara plants (Figure 4).

Contrary to the findings of McLaughlin et al. (2013), no relationship was found between !nara sex and size. Admittedly, the size classification system used in this study was subjective and less thorough than McLaughlin et al's (2013) biomass size calculations. However, that paper's conclusions were based off of a sample-size of 20 plants at a single site, compared to our 439 samples across nine sites.

These results provide a good starting point to develop a resource assessment for the ultimate conservation and sustainable harvest of !nara. Going forward, more extensive mapping could monitor the size, age, and sexual distribution of !nara plants, which could help policy-makers and managers maintain a healthy !nara population for Topnaar harvest within the !Khuiseb region.

Ethics:

Our study was conducted with the purpose of adding to the scientific knowledge of !nara in the !Khuiseb valley. Because we were initially granted permission to survey !nara distribution by both Gobabeb and Topnaar Chief Kooitjie, we perceived a lack of ethical constraints concerning our methods. However, in light of Megrue et al.'s (2013) findings regarding tensions between Gobabeb, the Topnaar community, and Chief Kooitjie, we have come to acknowledge the ethical complications surrounding the distribution of our findings, which may alleviate or accentuate local power struggles over control of !nara resources.

In many other communities the advent of GIS mapping has had significant effects on indigenous power dynamics. For example, the use of GIS by Powderhorn Park neighborhood in Minneapolis, MN "fostered changes in the language and information used in neighborhood dialogue and some of the fundamental assumptions and priorities that guide the [neighborhood association's] decisions" that altered power relations within the neighborhood and between the neighborhood association and the state (Elwood, 2001).

In addition, alternative forms of mapping such as counter, community and sense of place mapping may be important to consider in addressing ethical concerns going forward. These alternatives were envisioned to counter dominant representations of property regimes and land use practices, self-define and represent place, acquire control over natural and other resources, and mobilize collective action by community members within a localized geographic scale as a form of resistance to historical marginalization (Mollett, 2013; Parker, 2006). These mapping techniques pursue goals of empowerment, transparency and inclusion that could be included in future !nara mapping studies to alleviate the ethical concerns discussed in our paper (Parker, 2006).

Future Work:

Our preliminary analysis had many significant findings, but we look forward to future studies to deepen our understanding of !nara plant size, sex, and general distribution. In general we see the need for three major projects (listed in descending order of importance):

1) !Nara identification and location prediction via satellite imagery.

This study identified 512 !nara plants and 95 non-!nara hummocks. A future study may run an image classification program within ArcMap to analyze the pixel characteristics on a satellite image of !nara plants and non-!nara features, and then extrapolate that information to search larger satellite images for !nara locations. This analysis could be done by a group of FSP students in collaboration with Chipman. This is potentially an incredibly easy, yet powerful method to map !nara distribution across the !khuiseb region, as well as find !nara in satellite images in northern Namibia and southern Angola. Such an analysis could form the basis for a resource inventory assessment necessary for the future conservation and management of !nara.

2) Historical analysis of !nara distribution

Another future GIS !nara study could compare historical satellite imagery with modern satellite imagery in order to analyze changes in !nara distribution, size, and prevalence over time. This study could also compare Markus Muller's !nara distribution data in 1998 to the data collected in this study. This type of temporal analysis could determine past changes in !nara size and prevalence and monitor future changes. Given that !nara size correlates with number of fruits (McLaughlin et al., 2013), monitoring !nara size via satellite imagery over time may be the best way to monitor !nara population health and fruit production for conservation and harvest management.

3) Further large scale sex and size studies of !nara distribution

There are a number of secondary ecological studies that could be completed. One idea is to complete a spatial statistics analysis of the data in this study to test whether there is small-scale sexual segregation of !nara plants, and if so, whether this segregation is correlated with differences in nutrients, elevation, or groundwater of micro-environments. Because results from this study contradict results from McLaughlin et al.'s study, a more rigorous analysis of correlation between !nara size and sex could be conducted by scaling up McLaughlin et al.'s biomass sampling method (2013).

References:

Bierzychudek, P. & Eckhart, V. (1988). Spatial segregation of the sexes of dioecious plants. *The American Naturalist*, 132, 34-43.

Chipman, J. (2013). Personal Communication. Dartmouth College.

Elwood, S. (2002). GIS use in community planning: a multidimensional analysis of empowerment. *Environment and Planning*, 34, 905-922.

Henschel, J., Dausab, R., Moser, P., & Pallett, J. (Eds). 2004. !Nara. fruit for development of the Khuiseb Topnaar. Namibia Scientific Society. Windhoek, Namibia.

Ito, M. (2005). Changes in the distribution of the !nara plant that affect the life of the Topnaar people in the lower Khuiseb River, Namib Desert. *African Study Monographs*, 30, 65-75.

McLaughlin, A. I., Milligan, A. I., Bonnell-Hall, J. T., Chowdhury, M. H. R., Stanton, M. B., Dowdell, S.C., Cuomaoji, T. (2013). Making Sense of !Nara: A proposal for a long-term monitoring study. Dartmouth College Environmental Studies African Foreign Study Program.

Megrue, C. G., Williamson, K.A., Oszkinis, K. A. (2013). Socio-political dynamics of Gobabeb-Topnaar Relations. Dartmouth College Environmental Studies African Foreign Study Program.

Mollett, S. (2013). Mapping deception: the politics of mapping Miskito and Garifuna space in Honduras. *Annals of the Association of American Geographers*, 103, 1227-1241.

Parker, B. (2006). Constructing Community Through Maps? Power and Praxis in Community Mapping. *The Professional Geographer*, 58, 470-484.

Appendix

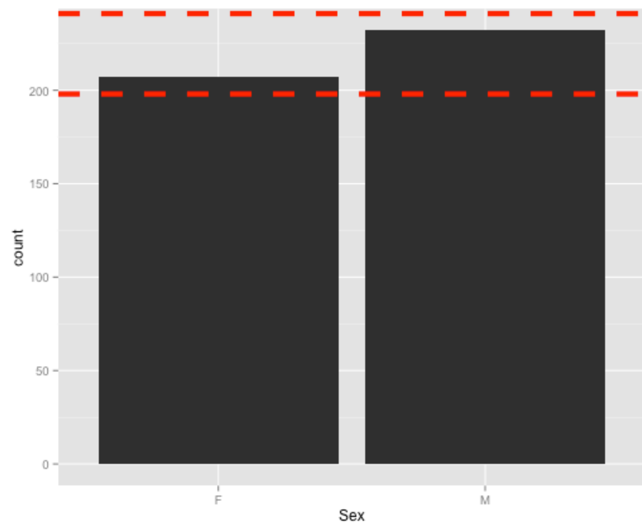


Figure 1: There were slightly more males than female plants in our sample, but the distribution was still well within the 95% confidence interval (Red dotted lines) of a 50-50% expected sex distribution.

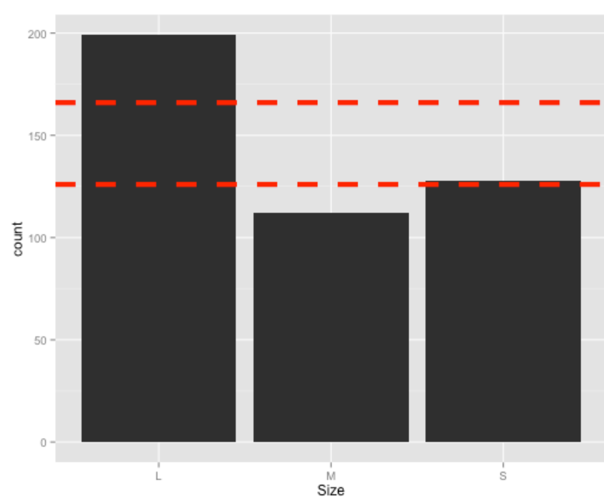


Figure 2: There were disproportionate The red lines represent the 95% confidence interval around the hypothesis that each size category has 1/3 of the total sample. Thus, it is obvious that large plants are disproportionately common, and medium plants are disproportionately uncommon. Small plants fall within the expected range.

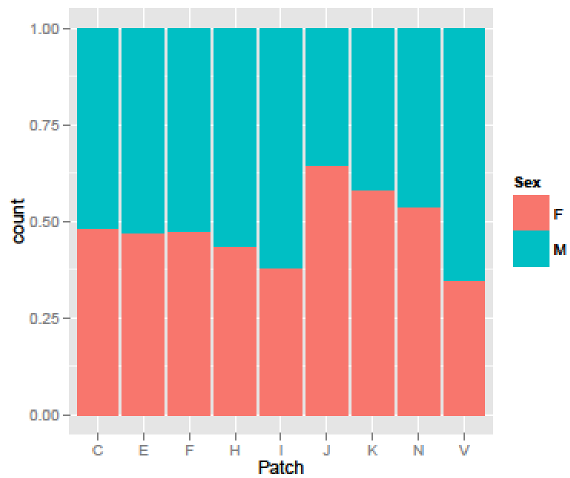


Figure 3: There were some differences in the sex ratios between sites, but they were not statistically significant. Sex ratio remains consistent within the sites.

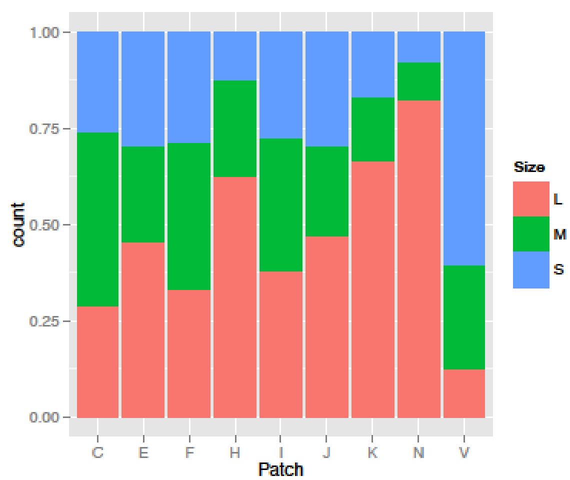
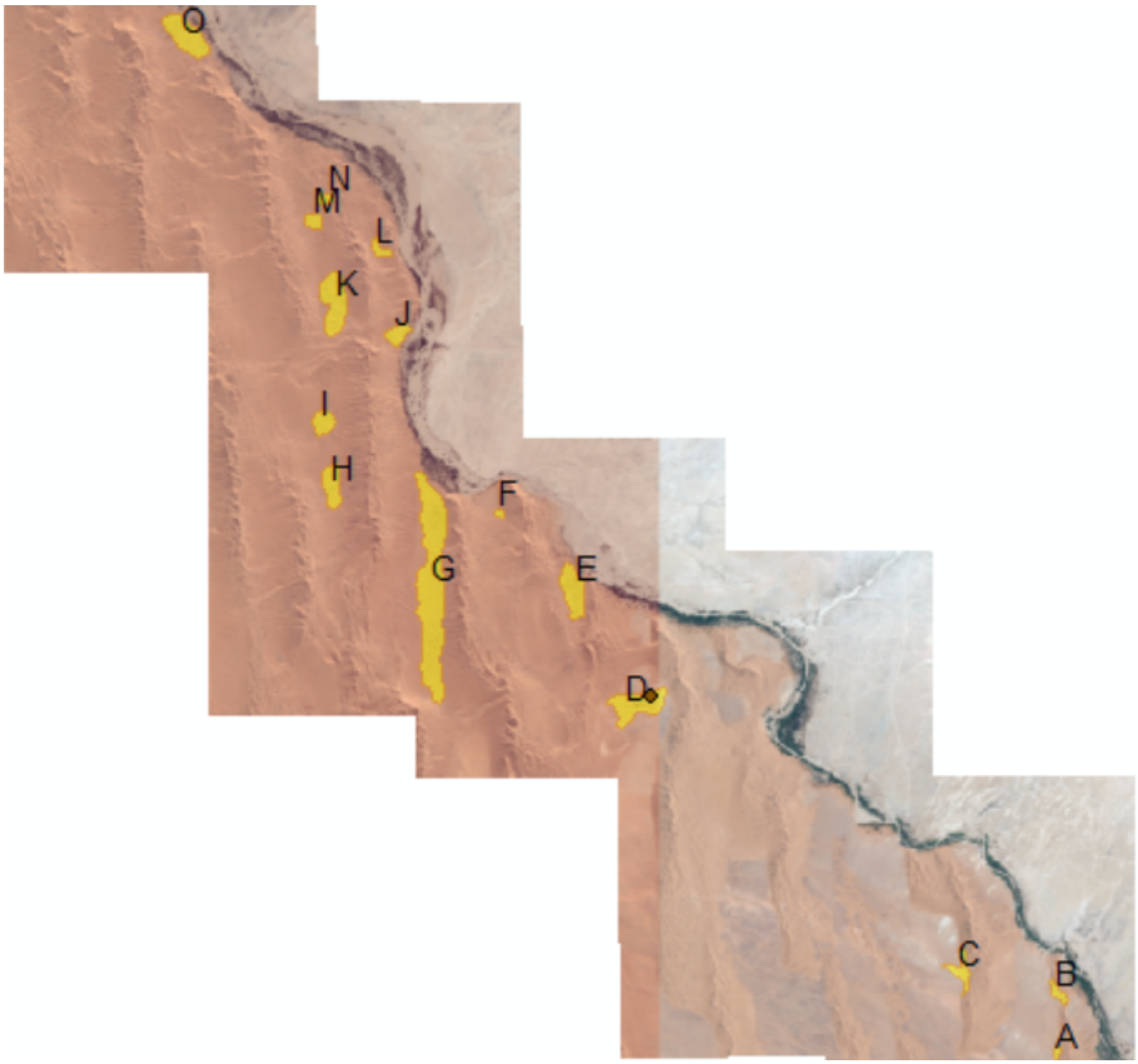


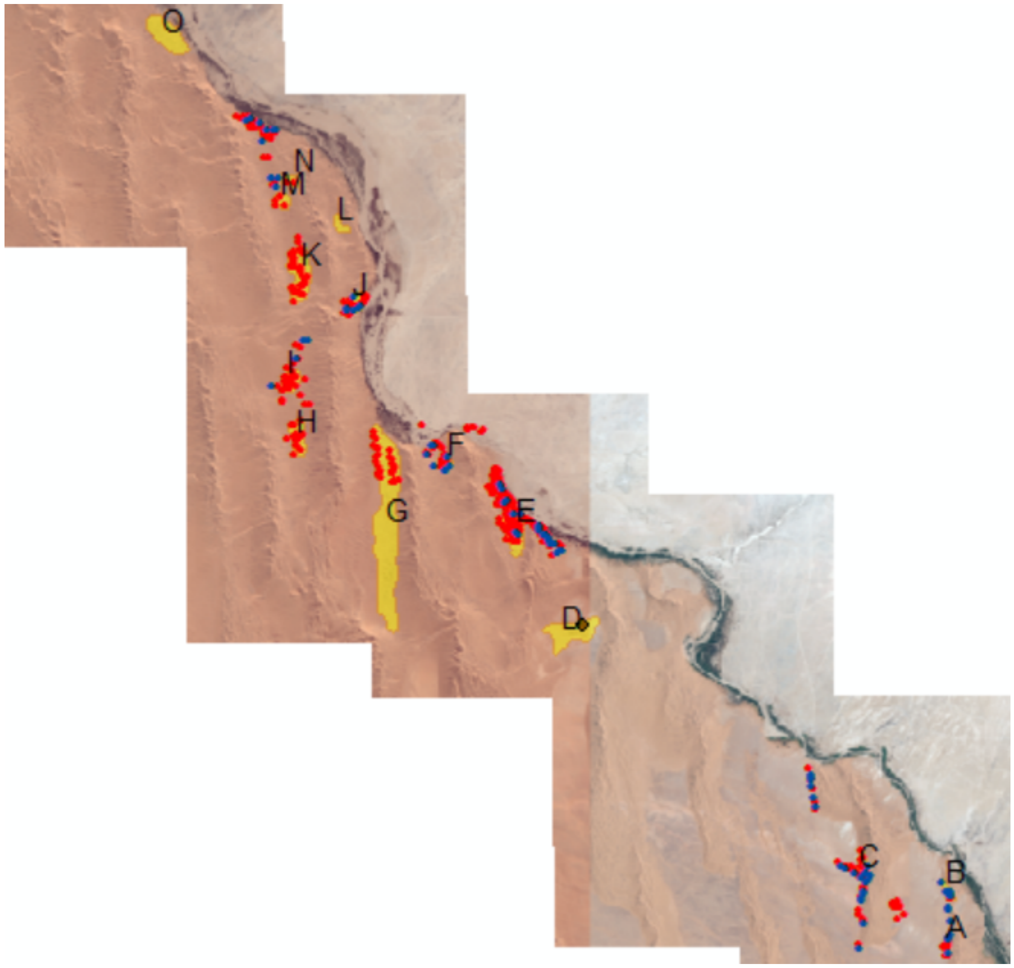
Figure 4: There were statistically significant variations in the size distribution between sites. A post-hoc chi-square test showed that four sites were generally responsible, as can be seen in Figure 5.

		Site			
		V	N	K	C
Size	Large	-	+	+	ø
	Medium	+	-	ø	ø
	Small	ø	-	ø	+

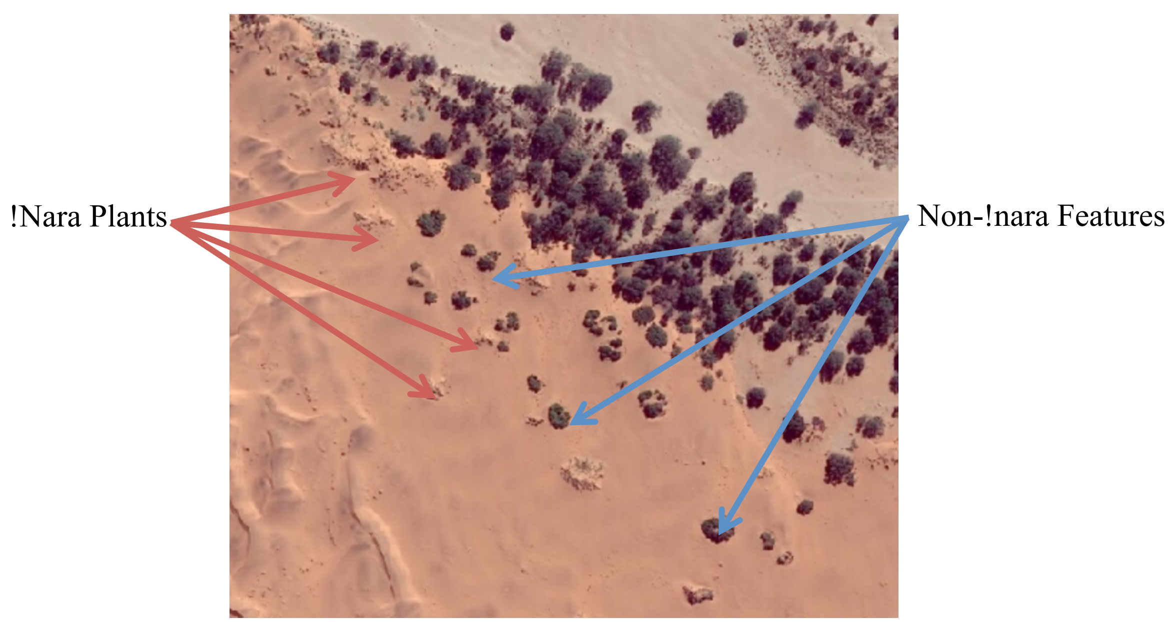
Figure 5: A posthoc chi-square analysis of all nine sites showed that sites V, N, K and C showed disproportionate distributions of size classes. For instance site V showed disproportionately few large !nara plants and disproportionately many medium !nara plants.



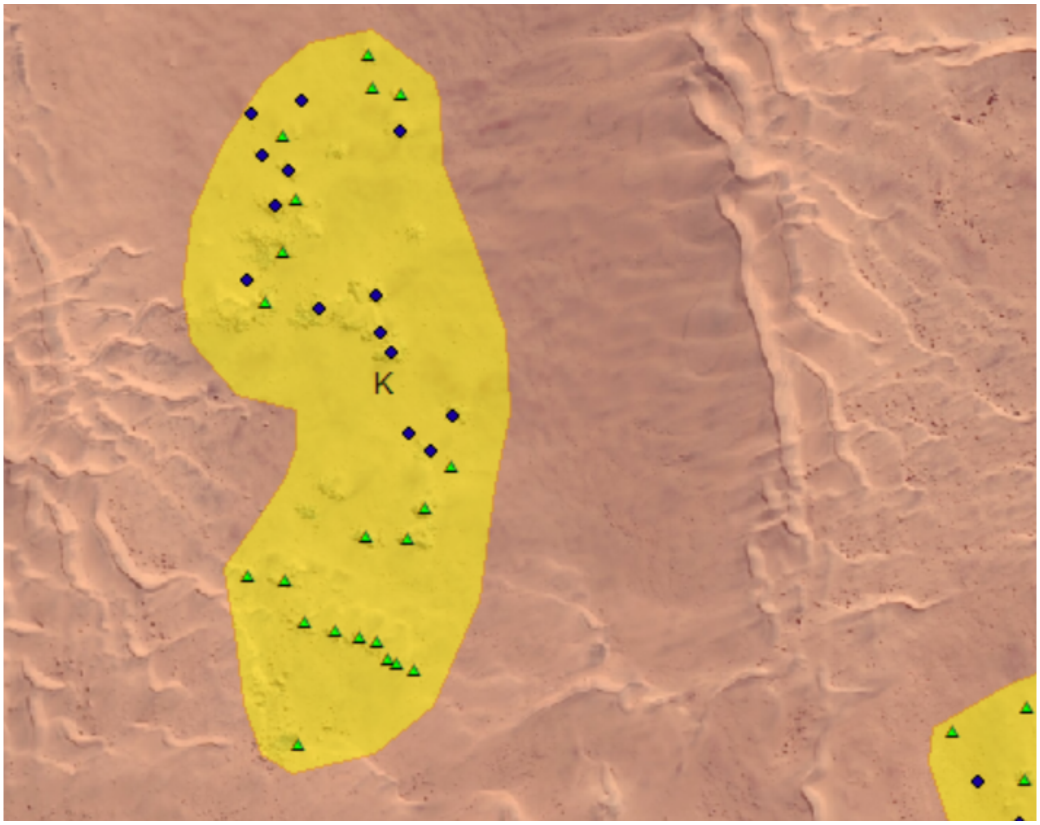
Map 1: Potential !nara sites initially dentified by Jonathan Chipman using a modern satellite image. Site V was located off this image to the northwest.



Map 2: GPS locations for 512 !nara plants (marked in red) and 95 non-!nara features (marked in blue)



Map 3: !Nara plants (in red) can easily be distinguished visually from non-!nara features (blue) on satellite imagery.



Map 4: Site K suggests that sexual segregation of !nara may exist within sites. Female plants (green triangles) dominate the southern portion of the site, whereas the sexes are mixed in the north. Further spatial analysis could test this hypothesis.

Trust, Respect, and Loyalty: The Socio-Political Dynamics of Gobabeb-Topnaar Relations

Chris Megrue, Krystyna Oszkinis, and Katie Williamson

November 2013

Dartmouth College Environmental Studies Foreign Study Program, Southern Africa

Table of Contents

I. Introduction ………………………………………………………… 3

II. Methods ………………………………………………………………. 3

III. Perceptions and Capacity …………………………………………… 4

Topnaar **………………………………………………………………. 4**

Gobabeb Desert Research Station **………………………………… 6**

Topnaar Traditional Authority **…………………………………….. 8**

IV. Results ……………………………………………………………… 10

V. Conclusion …………………………………………………………… 11

VI. Biases and Ethics …………………………………………………… 13

VII. Suggestions for Further Research ………………………………... 14

VIII. Acknowledgements…………………………………………………... 14

IX. References ………………………………………………………….. 15

I. Introduction

This paper examines the current socio-political environment in Topnaar communities in the Lower !Kuiseb Valley of the Namib Desert in coastal Namibia focusing on the relationship between the Topnaar and the Gobabeb Desert Research and Training Centre. The authors of this report were three students from Dartmouth College in a foreign study program exploring conservation and development in southern Africa. We spent one week at Gobabeb designing a research proposal and executing preliminary research in an area we thought both important and feasible in this short time. Our group's focus was to explore the relationship dynamics among Gobabeb, the Topnaar Traditional Authority (TTA), and the Topnaar Community. Our narrower focus was to understand and make recommendations to improve the Topnaar-Gobabeb relationship because we felt we had the most potential influence at this intersection. We observed early in our time at Gobabeb the tense relations between all of these actors and decided that a formal approach and report was the next step to consolidate the opinions of each group and legitimize past studies in the area.

After reviewing similar studies of indigenous communities in conservation areas, we found support for our reasoning that the social structure of communities is an integral part of any fieldwork and provides important context for gathering successful data. For example, Kepe and Williams (2008) conducted an ecological study of the wild buchu plant in Elandskloof, South Africa, which we discovered had a strong resemblance to the !nara plant of the Topnaar. They concluded that "more social studies are needed in order to fully appreciate what is needed to ensure sustainability of a high value natural resource in the midst of poverty" (58). Additionally, Kepe (2012) pointed to "local people's mistrust of the government and absence of political will" (406) as preventing the conversations necessary to build important relationships between communities and the local government. We agree that only through collaboration among all groups will conservation and development be viable, sustainable, and effective.

II. Methods

We conducted a study of the socio-political conditions surrounding the interactions of the key stakeholders in the Lower !Kuiseb Valley region from November 3rd to November 9th, 2013. Initial data collection included interviews with these key groups: the Topnaar people, Gobabeb staff, the Topnaar Chief as member of the Traditional Authority, and several peripheral actors. We conducted two rounds of informal interviews in Topnaar communities, with two households at Soutriviert and four at Armstraat, as well as one in Naraville with Topnaar Chief Kooitjie. The ages of the interviewees ranged from 19 to 60 years old. Sebedeus Swartbooi, the community liaison for Gobabeb and our translator, facilitated the interviews and advised us on local customs. Phone interviews were conducted with Desert Hills, the Legal Assistance Centre of Namibia, Uri Adventures, and the Namibian Association of Community Based Natural Resource Management Support Organizations. We contacted The Ministry of Environment and Tourism, but we were not able to get a response during the time of the study. We also had personal discussions and email exchanges with various Gobabeb researchers and employees, including the current director. We took notes during and after interviews and discussions, which were categorized by topic and then analyzed for qualitative statistics. We also performed a literature review of published articles and internal Gobabeb documents, which we synthesized for recurring themes. After collecting our data, three key stakeholders emerged — Gobabeb, the Topnaar, and the Traditional Authority — and the resulting socio-political dynamics that shape their interactions.

III. Perceptions and Capacity

This section serves to describe how we understood the three main actors' perspectives of their own and others' responsibilities and actions in the Topnaar community in order to show the different viewpoints that shape their relationships.

Topnaar

While we only spent a short time in the Topnaar community, we felt that we gained valuable perspectives from the community members who spoke with us. Topnaar community members expressed trust, respect, and loyalty as the core of their interactions and therefore the strength of their relationships also reflected these values (Community Interviews). However, the Topnaar expressed a general feeling of powerlessness to enact any change in their community because of their lack of access to natural resources, lack of employment and income, and the Traditional Authority's structure (Community Interviews; LAC, 2013).

The Topnaar community report being close-knit and treating one another like family. We learned that community members believed they had common visions and formed committees such as Topnaar Community Concerned Group that formed to address the neglect from the Traditional Authority and has led to a social rights investigation from the Ombudsman of Namibia (Namib Times, 17 Sept. 2013). Other smaller committees like the harvesters' committee and women's council also served important roles by creating Topnaar organization and communication among villages, although they were debated among community members as functioning effectively (Community Interviews). We found the committees to be a good example of what the Topnaar alluded to as lack of capacity. The Topnaar formed the committees with the intention to bring people together and solve a particular issue, yet they felt the funding and resources were not available to make any significant changes in their community.

The Topnaar relationship with Gobabeb is based on the Topnaar opinion that Gobabeb is an educational and employment resource that operates apart from the community (Community Interviews). There are workshops, environmental education programs twice a year at the local school and employment for ten Topnaar people that boost relations between the two groups (Community Interviews). Gobabeb seemed to embody an image of success, educational empowerment, and wealth driven by foreigners to the Topnaar. For instance, one Topnaar man asked if there was any chance his daughter would be able to work at Gobabeb one day, as that to him would guarantee her upward mobility in the future (Community interviews).

In contrast, the interviewed community members were frustrated by Gobabeb's lack of involvement in the villages and sharing research (See *Table 1*). Over half of them described an experience where they felt like research subjects instead of beneficiaries of the research study and did not receive any feedback about the information they provided (Community Interviews). One former Gobabeb staff member's reflections voiced her irritation about Gobabeb's focus on research and not community development (Boothway). She had urged Gobabeb to involve the communities in research projects and studies but received little support for her concerns. Furthermore, Sebedeus felt that Gobabeb had not listened to his recommendations on how to engage with the community. In fact, he told us he stopped giving Gobabeb the minutes of the guides' committee meetings because he felt that the staff must first review his past reports before receiving new ones (Community interviews). Overall, the Topnaar opinion of Gobabeb is very dependent on the tangible acts they see in their communities and the way they are treated.

The Topnaar relationship with the Topnaar Traditional Authority is a tense and contentious one. Five out of seven community members strongly expressed their distrust and anger regarding the chief and his perceived selfish attitudes towards their community (See *Table 1*). A parallel study conducted on Topnaar-government relations in 2009 found that most of the 22 Topnaar interviewed considered the TTA to be self-serving and not helpful to the wider community. They also admitted that they rarely knew what projects the TTA was actually pursuing, because they did not communicate with Chief often (Magnusdottir, 2013).

Outside of interviews, the current Ombudsman's investigation generated a list of complaints from over 60 community members on a number of issues including: lack of transparency on finances, not following customary law codes of reelection, accessibility, insensitive requests from the community elders, and support for community projects such as providing transport (Namib Times, 5 Nov. 2013). The Traditional Authorities Act mandates traditional leadership to be receptive to the community's needs as well as democratically elected; neither of which seems to be in effect according to seven out of eight community members (LAC, 2013). While the Topnaar seem to voice valid concerns, their lack of communication with the Chief might explain their frustration more than the Chief's actions. Regardless, the Topnaar strongly believed their leadership to be the driving force of improvements in their livelihoods, and without a change in leadership, they have little hope for future change in their communities.

Gobabeb Research and Training Centre

Gobabeb explains its main objective as pursuing a future of greater environmental sustainability and thus centers its activities on scientific research for issues ranging from local Namib Desert conservation to global climate change. The two main functional programs of Gobabeb are youth-focused trainings and providing the equipment, lab facilities, and technical assistance for high profile scientists that head research in over ten "science theme groups" (i.e. dune morphology, atmospheric sciences, etc.). These activities serve to fulfill its obligations as a joint venture organization between the Ministry of Environment and Tourism (MET) and the Desert Research Foundation of Namibia (Gobabeb Research and Training Centre, 2013, web).

Despite this current structure, the Topnaar perceptions of Gobabeb as a development agent do stem from some realities. While Gobabeb is still in the process of developing an official policy of its role as a neighbor to the marginalized Topnaar people, it has historically and is currently pursuing several avenues to work with the Topnaar community (Gobabeb interviews). The main Gobabeb promotional document describes how the institution has been evolving its goals to "contribute to poverty alleviation and to improving the livelihoods of the poor in the region" (Boothway, n.p.). Even since Gobabeb's founding, the Centre has performed poverty alleviation through occasional Topnaar student scholarships and educational support for employees' children beginning in 1990 (Nakanyala and Shifidi, 2009). According to an internal document of Gobabeb-funded and facilitated programs with the Topnaar, Gobabeb has increasingly interacted with Topnaar through education programs and more participatory research methods beginning in the late 1990s (Gobabeb Research and Training Centre, 2009). Gobabeb hosts community workshops in a variety of skillsets, including sustainable agriculture, water management, brick-laying, and solar heating, and invites community members to annual "Open Days." Gobabeb reports having increased Topnaar inclusion in research projects and gathering information on their livelihoods. They also make an effort to attract researchers to explore topics applicable to Topnaar needs. For example, 2009 was declared the "Year of the !Nara," and there has been international involvement to do interdisciplinary research surrounding this culturally and economically significant plant (Gobabeb Research and Training Centre, 2013, web).

Nonetheless, Gobabeb staff members perceive their relationship with the Topnaar people to be poor, and they struggle to determine their place on the spectrum between being an independent research station and a development agent in the community. Limited funds and institutional capacity are consistently named as the limiting factors for expanding their work and include the structural limitations and prescribed output obligations by outside authorities. First of all, most of the work done by the full-time interns is technical and relatively short-term; the employee base completes specific, prescribed assignments for which financial, technical and social capital are pre-allocated (Gobabeb Interviews). Therefore, proposed development projects likely cannot be funded without submitting a specific funding request. Compared to the structure of research, development work requires longer-term capacity building programs, with a focus on application rather than accumulation of knowledge. Devoting staff's time to development projects could directly conflict with Gobabeb's obligations to funders to complete its primary function of performing ecological studies.

Gobabeb recognizes its position as a valuable resource in an otherwise highly isolated region. It is poised as a catalyst for improvement in the region due to its experience as a professional organization with global connections, a consistent visitor base, an active working relationship with the government, scientific resources, and capacity for training. Gobabeb is therefore actively seeking to establish a mutually beneficial relationship with the Topnaar that fits within its mission as a research station.

Topnaar Traditional Authority

The Topnaar Traditional Authority (TTA) is a main actor in the complex web of socio-political relationships in the !Kuiseb Valley. The TTA's perceptions towards the Topnaar people, the Namibian Government, and themselves have been the basis for their actions and their construction of a long-term development strategy. The TTA's leader, Chief Kooitjie, holds an egalitarian view about how to use the Topnaar Community Foundation and Trust money and resources as well as resources from their ancestral land; he explained that all Topnaar, whether they live in the concession, Naraville, or Swakopmund, should all equally benefit from the TTA's limited amount of funds and resources they have.

However, Chief Kooitjie also said to us, "We are a weak, small and helpless people." The Namibian Constitution does not formally acknowledge indigenous communities' rights and land concessions are currently under debate (LAC, 2013). National park regulations limit socio-economic opportunities for the Topnaar by prohibiting bricks as housing materials and restricting hunting area boundaries (Magnusdottir, 2013). The Chief pointed out that the Topnaar depend on aid from the Government's Ministry of Environment and Tourism as well as grants and donations to the Foundation from outside funders. The TTA has reached the conclusion that tourism is crucial for long-term sustainable development. The land on which the Topnaar live is a valuable asset; the Chief stated that the Topnaar would be the richest people in the country if they were able to develop their ancestral land. Because they are the sole inhabitants in the park, the Topnaar have exclusive rights to acquire concessions in the park and explore the enormous potential for tourism since the park is one of the most visited attractions in the country (Magnusdottir, 2013). However, the fact that they are in a National Park complicates the power dynamics and their right to use the land since it technically belongs to the state (LAC Interview, 8 Nov. 2013). Under the current national legislation it is easy to get resource rights in a concession, but gaining the formal land use rights for developing business and income-generating opportunities in a concession is a difficult process because of conservation ethics (CBNRM Interview, 8 Nov. 2013).

Within the park, the TTA also perceives Gobabeb as a great asset that is underutilized through its ability to help educate the Topnaar and be a partner in development. According to the Chief, the Topnaar see themselves as the owners of Gobabeb since it is on an abandoned piece of their land and was negotiated with the previous TTA (Magnusdottir, 2013). Moreover, the Chief wished for Gobabeb to be more aware of its presence in the Topnaar community and the reciprocal relationship that should result between them. He also conveyed his concern that only short-term researchers visit the Topnaar community, and very few permanent staff have introduced themselves or talked with community members (Chief Kooitjie Interview).

During our interview with the Chief, we believe that he saw the Namibian Government as a "father" figure who was responsible for providing the Topnaar with resources and saw himself while the TTA was a "mother" figure who acted as an enabler and middleman of these resources. Chief Kooitjie said that since his people were uneducated, it was up to the TTA to provide any help it could to the community. While the TTA pays for community funerals, we felt that they still prioritize their limited power and influence towards higher levels of government and authority to lobby for legal rights and the increased power over their future development. We observed this rationale when the Chief described the TTA as the driving force behind the fundraising for the construction of the local school and clinic; however, he told us that without securing legal rights to land, the "keys" and power of locally spurred development projects become government owned and undermine the Topnaar vision for local development.

We believe that the TTA often sees itself as a middleman whose role is to communicate the needs and problems of the community to the relevant authority figures. For example, in the case of the Armstraat water crisis, the TTA shuttled the community's stress over high water prices to the relevant organizations at higher levels instead of taking direct action (Gaomas, 2006). From their view, the TTA sees local Topnaar communities as responsible for their own development. Chief Kooitjie explained that "efforts [to help pay the Armstraat water bill] should also come from the community and particularly the youth in it who should not just rely on the pensions of the elderly...they should help themselves by seeking a business response to raise the funds" (Gaomas, 2006, n.p.). The TTA believed that all Topnaar deserved benefits from the Community Foundation and Concession Trust, but their limited amount of money was spread thin; the TTA cannot afford to do more than help subsidize basic needs such as maize meal, communal funerals, and the limited amount of meat that they get from their right to hunt 55 animals in the park a year. Therefore we concluded that the TTA believed that its role was to acquire the best opportunities it could for the Topnaar people and then hand them down to the community.

The Chief and the TTA were frustrated both by their lack of power that was dictated by the Namibian Government and the Topnaar perception that the TTA neglects Topnaar concerns. The TTA knew its unpopular reputation within the community, but Chief Kooitjie believed his "hands were tied." The TTA's position prevents it from meeting many of the demands from the community for services such as cellular service, electricity, and more water infrastructure because the power lies with bigger players like the MET.

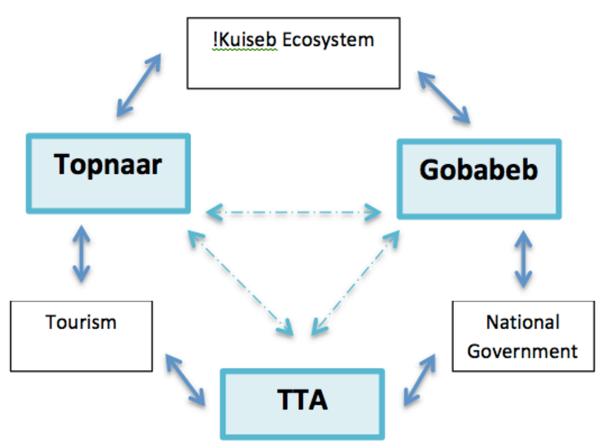
IV. Results

Table 1: Perceptions from Interviews on 11/5-11/8. Interviewees include: Topnaar Villagers (6), Uri Adventures (1), Chief (1), Desert Hills (1), Sebedeus (1)

	Interviewees who believed this statement	Total number of interviewees surveyed for this question
Distrust of TTA	6	9
Indifferent of TTA	3	9
Chief and TTA do not work for community	7	8
Community unity	6	8
Positive interactions with Gobabeb	7	7
Want to interact with Gobabeb management more	7	8
Negative interactions with foreign researchers	5	8
Communication is a problem in relationships	10	10

V. Conclusion

Our research produced a wide array of differing perceptions among all the stakeholders in the socio-political system of the Lower !Kuiseb Valley, which we feel prevent productive communication and cooperation. First, the Topnaar people saw Gobabeb as equally a resource for development and scientific research and therefore were frustrated by the inconsistency of their education and outreach efforts. Meanwhile, Gobabeb defined its personal mission as shifting towards development but acting primarily under a structure of scientific research. Second, we found that the Topnaar perceived the TTA to ignore all input and concerns by the Topnaar people, but the Topnaar interest in tangible, immediate, livelihood improvements conflicted with the TTA's envisioned role as enacting more long-term solutions. Similarly, we believe that the TTA viewed the Topnaar people as unmotivated to take action to improve their lives, while the Topnaar viewed the position of the Chief to be impeding their attempts to organize and make progress for development initiatives. With such differing viewpoints, we feel all three groups would benefit from understanding others' perceptions in relation to their own. A successful case study in the Solomon Islands showed that by bringing together different stakeholders around an issue such as water management, social learning can occur that builds trust and understanding for future decisions and collaborative problem solving (Hoverman et al. 2011).



This diagram illustrates our understanding of the Topnaar, TTA, and Gobabeb interactions as well as the other factors that indirectly affect the relationships. Our main conclusion is that each actor is connected to others through mutual interests, however their lack of communication among one another prevents the overall goal of sustainable development. After reviewing our findings, we decided on the following recommendations for Gobabeb because we felt this is the only actor in the system that we had any validity providing comments for. As foreign students, we can relate much more to Gobabeb's mission and purpose than trying to identify with the Topnaar community or Chief. We also have an influence over Gobabeb's decisions because of Dartmouth's strong relationship with Gobabeb. Our general thoughts for Gobabeb are to find ways of strengthening their relationships based on shared interests in order to create a better understanding among all groups. Interactions with the Topnaar community especially in any capacity-building outreach programs such as research participation or educational trainings will help to empower the Topnaar in their development goals.

1) *Creation of a Topnaar Outreach Committee*: This committee's role would be to consistently meet with members of the Topnaar community and ensure that the needs of both Gobabeb and the Topnaar are heard and considered. The membership would ideally be comprised of Gillian, Sebedeus, Chief Kooijtie, and at least three community leaders elected from different villages. It is vital that this committee have permanent staff from Gobabeb in order to observe changes over time as well as integrate sufficient community input. Ingram and Njikeu (2011) present a similar process, "participatory action research," which is a "continuous cycle of systematic planning, taking action, observing, evaluating, and reflecting as the basis for the next cycle of planning." Such an approach would help to create a system of communication that addresses the needs of everyone involved.

2) *Continuation of educational outreach, workshops, and trainings with evaluations to measure effectiveness*: The Topnaar who spoke to us about these events had positive experiences, and we encourage Gobabeb to maintain these programs as building blocks for the relationships between the two groups and empower the Topnaar to feel they can effect change to their livelihoods.

3) *Quarterly reporting of Gobabeb's work and projects to the community*: Sebedeus and other members of the Topnaar Outreach Committee would be ideal candidates to send out to the communities to foster a feeling of involvement among the Topnaar and Chief. We believe the community members may not all be interested in the reports, but they should have the choice to be informed.

4) *Outreach to community for !nara research participation*: Two of our community interviews revealed that the Topnaar would be willing to help out with ecological and economic research on the !nara plant but need formal instructions from Gobabeb. We therefore believe Gobabeb should take advantage of the Topnaar expertise and experience with the !nara plant. This could also provide beneficial employment, internship, or shadowing opportunities for the Topnaar.

5) *Joint tourism and marketing*: Gobabeb has a small tourism operation running at the center, and we believe the Topnaar could benefit from Gobabeb's assistance in setting up a system of partnering tourism ventures. This could take the form of accommodation at Gobabeb with Topnaar cultural tours, as one of the women in Soutriviert expressed she would be interested in making her home the Topnaar "cultural village" to promote tourism. Since the Topnaar perceive researchers also as tourists, Gobabeb could promote tourism among its researchers and visitors. We thought Gobabeb could offer local handicrafts and !nara products for sale to these incoming visitors where most of the proceeds go back to the community.

These recommendations attempt to improve the communication and collaboration between all three stakeholders by recognizing that each of their current perceptions and priorities are valid given their understandings, but therefore different as well. Our goal is to have Gobabeb, the Topnaar community, and the Traditional Authority better understand each other's perspectives in order to address everyone's needs and move forward in a way that fosters trust, respect, and loyalty.

VI. Biases and Ethics

We recognize our strong biases during the time of this study due to our time and resource constraints. First, our guide, Sebedeus, confirmed ahead of time which individuals we could speak with, so our Topnaar sample is very subjective. Some community members also have been directly involved with Gobabeb through employment or child support, so their responses may be influenced by this history. The Topnaar in our study were also only living in rural areas, so the whole urban Topnaar population was not represented. Second, we did not thoroughly survey for community members who sided with the chief and only have Chief Kooitjie's own thoughts for the TTA. Finally, our experience and time to collect data was only seven days without having extensive prior knowledge of the region or groups involved. We did our best to account for these biases and limitations in our results and recognize that many of our conclusions are based on assumptions and subjective perceptions.

Our group also acknowledges that our project brings up a number of ethical concerns. Power dynamics were a possible barrier as we were white, American students working through a prestigious research center and studying local people who are disadvantaged in many ways. We had to take note of culturally sensitive behaviors and questions especially knowing about the tense relations between each pair of actors in the system. We asked permission of all of the people we interviewed through Sebedeus' translation and were respectful when one community member did not want to speak with us. Our biggest ethical challenges remain as determining who would have access to the results, confidentiality of the interviewees, and how we can best share the information with the communities (Indigenous Peoples Specialty Group 2010).

VII. Suggestions for Future Research

- Assessing the viability of tourism expansion in Lower !Kuiseb River Valley and a potential joint venture tourism lodge between Gobabeb and the Topnaar
- Complete analysis of the various Topnaar committees' structure, function, and capacity
- Exploring social learning case studies and methods on how to incorporate past research into the Topnaar socio-political
- Expand this research into the broader Topnaar community including urban residents, TTA employees, youth, women, elders, etc.

VIII. Acknowledgements

We would like to thank Gillian Maggs-Kolling and the Gobabeb staff, Chief Kooitjie, Topnaar communities, Doug Bolger, Tom Kraft, and our guide, Sebedeus, for their time and thoughtful comments throughout our research and analysis. We also appreciate the time and support from Uri Adventures, the Legal Asssistance Centre, and the Namibian Association of CBNRM Supporting NGOs.

IX. References

Boothway, L. How my vision regarding engagement with the Topnaar Community fits within the wider framework of the Gobabeb Training and Research Centre's mandate, mission and vision. Personal Reflection.

CBNRM Interview. 8 Nov. 2013.

Chief Kooitjie Interview. 6 Nov. 2013.

Community Interviews. 3-11 November 2013. Armstraat and Soutriviert.

Coria, J. and E. Calfucura. (2012). Ecotourism and the development of indigenous communities: The good, the bad, and the ugly. *Ecological Economics 73*, 47-55.

Gaomas, S. (2006). Namibia: Community grapples with a huge bill. *New Era*. Web.

Gobabeb Interviews. 3-11 November 2013.

Gobabeb Research and Training Centre. (2009). Gobabeb-Funded or Facilitated Programmes concerning the Relationships between the Topnaar Community and Gobabeb (or DRFN at Gobabeb) after Independence.

Gobabeb Research and Training Centre. (2013). Research. Accessed from: www.gobabebtrc.org.

Hoverman, S., Ross, H., Chan, T., and B. Powell. (2011). Social learning through participatory integrated catchment risk management assessment in the Solomon Islands. *Ecology and Society*, 16: 2, 17.

Ingram, V., and J. Njikeu. (2011). Sweet, sticky, and sustainable social business. *Ecology and Society,* 16: 1, 37.

Indigenous Peoples Specialty Group. (2010). Indigenous people's specialty group's declaration of key questions about research ethics with indigenous communities. *Association of America Geographers*.

Kepe, T. (2012). Land and justice in South Africa: exploring the ambiguous case of the state in the local claims process. *African and Asian Studies 11*, 391-409.

Kepe, T. and S. Williams. (2008). Discordant Harvest: Debating the Harvesting and Commercialization of Wild Buchu in Elandskloof, South Africa. *Mountain Research and Development, 28: 1, 58-64.*

Legal Assistance Center. (2013). Indigenous Peoples and Climate Change in Africa: Report on Case Studies of Namibia's Topnaar and Haillom Communities.

Magnúsdóttir, K. (2013). Guests in their Homeland: The situation of the Topnaar community, the traditional but not legal residents in the Namib-Naukluft Park. Reykjavík, Iceland.

Nakanyala, J. and T. Shifidi. (2009). How do the Topnaars perceive the role of Gobabeb in their lives, and community at large? A Summary Of The Interview Of The Osswater Community. Internal Gobabeb Minutes.

Namib Times. (5 Nov. 2013). Ombudsman bid to find Topnaar solutions. Web. Accessed from: <http://www.namibtimes.net/forum/topics/ombudsman-bid-to-find-topnaar-solutions>.

Namib Times. (17 Sept. 2013). Captain Kooitjie under fire – Topnaar community concerned group calls for accountability. Web. Accessed from: <http://www.namibtimes.net/forum/topics/captain-kooitjie-under-fire-topnaar-community-concerned-croup-cal>.

Werner, W. (2003). Livelihoods among the Topnaar of the Lower Kuiseb. Environmental Learning and Action in the Kuiseb Programme. *Desert Research and Foundation of Namibia.*