



South American Camelids: their values and contributions to people

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Abstract

South American Camelids (SACs) make several material and non-material contributions to people and are a key component of the Andean biocultural heritage. From the perspective of the IPBES' Conceptual Framework, SACs constitute the “nature” component in the complex system of interactions between human societies and the Andean mountain environment. There are four SAC living species today, two of which are wild, or *Salqa*, in the indigenous cosmovision: guanaco (*Lama guanicoe*) and vicuña (*Vicugna vicugna*). Llama (*Lama glama*) and alpaca (*Vicugna pacos*) were domesticated 5000 years ago, and are therefore *Uywa*, in the indigenous cosmovision. Both wild and domestic camelids were, and in several cases still are, the most highly appreciated resource for Andean livelihoods. Historically, camelids and their contributions have been used by Andean people since the peopling of the Americas over 11,000 years ago. In this paper, we present three case studies (*chakus* for vicuña management, llama caravans, and llama nanobodies) to bring attention to the essential role of vicuñas and llamas for Andean communities today, their intercultural linkages with the Western world, and telecoupling interactions.

Keywords NCP · Nature contribution to people · *Vicugna vicugna* · *Lama glama* · Andean altiplano · Values

Introduction

The Intergovernmental Platform on Biodiversity and Ecosystem Services' (IPBES) conceptual framework (Díaz et al. 2015) is a model to analyze socioecological interrelationships. The multiple flows within components in this framework can reveal sustainable or negative trends for nature conservation. In the context of this framework, “nature” refers to the natural world, with an emphasis on biodiversity.

Within the context of Western science, it includes categories such as biodiversity, ecosystems, ecosystem functioning, evolution, the biosphere, humankind's shared evolutionary heritage, and biocultural diversity. Within the context of other knowledge systems, it includes categories such as Mother Earth and systems of life (IPBES 2019).

South American Camelids (SACs) are natural beings, members of the tribe Lamini of the Camelidae family. As the other Camelidae tribe, Camelini, including the large humped dromedary (*Camelus dromedarius*) and Bactrian camel (*Camelus bactrianus*), SACs are adapted to the extreme conditions of the dry, high-altitude Andean steppes, which has allowed people to settle and thrive in arid lands (Franklin 2011). The four extant SAC species have two very different origins: those that derive from nature without the participation of humans, evolved by natural selection in the wild, and another group that is a co-creation or co-product of nature and the people who inhabited the Andes 5000 years ago. The wild species, guanacos (*Lama guanicoe*) and vicuñas (*Vicugna vicugna*) are *Salqa* (‘natural’, ‘untamed’) in the indigenous and local knowledge (ILK) taxonomic system and they are protected by the *Malkus* or mountain deities. The domestic species llama (*Lama glama*) and alpaca (*Vicugna pacos*) are *Uywa*, or “the ones that

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Guanaco

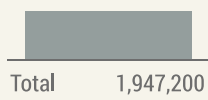
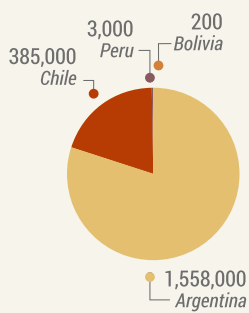
Wild-Salka



(*Lama guanicoe*)

Two subspecies:
Lama guanicoe cacsilensis (north)
Lama guanicoe guanicoe (south)

Weight 100-120 kgs.
 Height at the withers 120 cms.



Vicuña

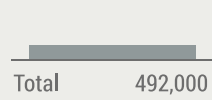
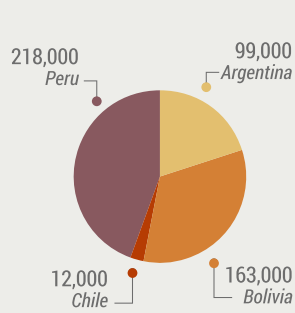
Wild- Salka



(*Vicugna vicugna*)

Two subspecies:
Vicugna vicugna mensalis (north)
Vicugna vicugna vicugna (south)

Weight 45 kgs.
 Height at the withers 90 cms.



Llama

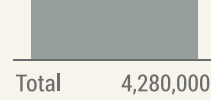
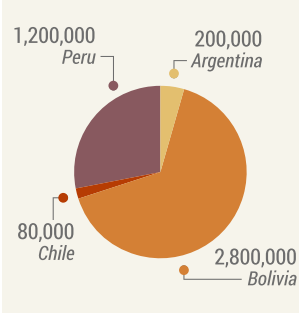
Domestic-Uywa



(*Lama glama*)

Two breeds:
Q'ara (tall and strong, short woolled)
Tampulli (hairly, long wooled)

Weight 130 kgs.
 Height at the withers 110 cms.



Alpaca

Domestic-Uywa



(*Vicugna pacos*)

Two breeds:
Suri (long straight fiber)
Huacaya (wavy fiber)

Weight 60 kgs.
 Height at the withers 90 cms.

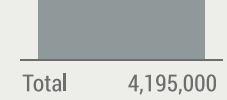
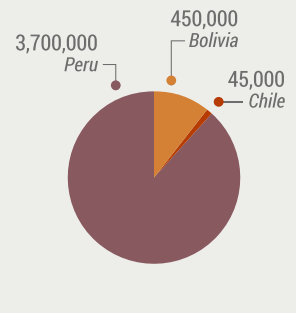


Fig. 1 Brief description of the 4 species of camelids. Vicuñas were introduced in Ecuador in 1989, 1993, and 1999 and actually, the population is approximately 7000 individuals. Ecuador also reintroduced alpacas (current population 6700) and llamas (current population 10,000). Chile and Ecuador, FAO 2005. Gonzalez & Acebes 2016. Acebes et al. 2018. Census of Agriculture, Perú (2012). Ministry of Production Bolivia (2005). National Agronomic Census Argentina (2008). Vilá 2012

belong to people” (Flores Ochoa 1977). The original distribution of the four species includes the Andean high-altitude grasslands, the Altiplano, and the Patagonian arid steppes (Fig. 1). Both wild and domestic camelids have been and, in several cases, still are, the most important resource for Andean indigenous and local communities (IPLCs).

Historically, wild camelids have been used by Andean human groups since the earliest peopling of the Americas, for over 11,000 years (Yacobaccio 2009). Archeological evidence shows that vicuñas and guanacos’ contributions to people were essential to the dispersal in the Andes of early American hunters, who benefited from their meat, skin, fur, and even their bones for making tools (Yacobaccio 2001). The exploitation of vicuñas has been regulated since the expansion of the Inca Empire, as a part of the Imperial economic governance system (Cieza de León 1553). Pre-Hispanic capture (*Chak’u*) of vicuñas involved a large group of people walking slowly and holding ropes with colored strings to drive thousands of vicuñas into large stone corrals for shearing their ultra-fine fiber and culling some individuals (Custred 1979). Since the Spanish conquest, the vicuña population has suffered dramatic losses due to indiscriminate hunting, dropping from 2 million specimens to under 10,000 in 1964 (Wheeler and Hoces 1997). The high price of vicuña fleece in the international market of luxury goods led to the killing and overexploitation of this species, which pushed vicuñas to the brink of extinction (Yacobaccio 2009). After 30 years of proactive, effective protection and management, vicuña populations have recovered sufficiently to make sustainable management projects viable (Lichtenstein and Vilá 2003) for the “benefit of the Andean people” (Convenio Internacional para la Conservación y Manejo de la Vicuña 1979). With a world population of approximately half a million vicuñas, management plans conceived within the paradigm of conservation through sustainable use have been developed in the last decade. Today, live shearing of vicuñas is the only legal way to harvest vicuña fleece, and it is widespread throughout the Andes, albeit with great variability in techniques and therefore, varying degrees of success in terms of sustainability goals (Acebes et al. 2018).

Like vicuñas in the north, the essential role of guanaco in prehistoric Patagonian life is clearly expressed in rock art and zooarchaeological assemblages. Guanacos were exploited intensively for meat, fat, blood, tendons, bones, and skins for clothing and to build shelters. They were the

main source of resources for the pre-Hispanic indigenous communities, and they also complemented the resource base of many other farming and pastoralist groups (Miotti 2012). The instrumental, intrinsic, and relational values of this species in the *Selk’nam* culture were expressed in their worldview in multiple ways, as well as by their language—mostly extinct today—that had more than eleven terms to describe guanaco diversity. The *Selk’nam* identified sacred areas in which hunting guanaco was taboo, to allow the species to breed freely, and they also maintained several religious and spiritual connections with the animals (Gusinde 1931). After the colonization of Patagonia by European sheep farmers at the end of the nineteenth century, both the indigenous groups and guanacos were killed to clear land for sheep pastures; by 1910 Patagonian rangelands supported about 12 million sheep (Aagesen 2000). These direct actions targeting guanacos due to their perceived role as competitors for sheep has resulted in a dramatic drop in the guanaco population, from over 10 million specimens to approximately 1.5 million in Patagonia, a trend that continues today (Franklin 2011). In the Valdes Peninsula, guanacos have concentrated in the few low stock or sheep-free areas, in a pattern that has been described as “choosing from what is left” (Antún and Baldi 2020). Successful capture and shearing projects have emerged as a conservation strategy through sustainable use of guanacos (Carmanchahi et al. 2015; Lichtenstein and Carmanchahi 2012). These projects have a high value for conservation and sustainable development goals, but supporters of guanaco killings have argued that they are expensive in terms of infrastructure and personnel requirements.

Vicuñas and guanacos were the ancestors of domestic camelids and, in some Andean settings, the wild ancestor and the domesticated form live in sympatry (Franklin 2011). More than 5000 years ago, northern guanacos (*Lama guanicoe cacsilensis*) were domesticated by indigenous communities, transforming them into llamas. This co-production changed life in the Andes, as it prompted the transition from hunting to herding and the emergence of village-like settlements (Yacobaccio and Vilá 2016). Llamas were an essential part of the biocultural heritage of the Inca culture (Flores Ochoa 1977; Grebe 1984; Vilá 2012, 2014) but the use of llamas as a resource also suffered a large impact after the Spanish conquest and the introduction of exotic cattle, such as sheep, goats, and cows. The social value of this species also changed during historical times, from a highly respected and valued resource in both material and symbolic terms during pre-Hispanic times to being contemptuously regarded as “animals from the Andean Indians” in the Colonial period and early Republican years. More recently, a shift in the cultural environment has led to a renewed appreciation of llamas, associated with the empowerment of indigenous and local knowledge, the recognition of indigenous rights to land, and the acknowledgement of the key ecological role

of SACs as low impact grazers in arid steppes by conservation ecologists. Thus, llamas have recovered in part, their traditional status as iconic animals of Andean biocultural landscapes.

In addition to llamas, another species was co-produced in the northern Andes: alpacas, whose domestication originated from wild vicuñas (Marin et al. 2017) including substantial hybridization with guanaco/llama (Kadwell et al. 2001). Alpacas were the most important animal for pre-Hispanic groups occupying high-altitude wetlands, providing high-quality fiber and meat (Murra 1965). In the indigenous *Quechua* language, *Allpaka* is related to *allpa*, which means “land”, and *kamay*, which means “to animate”. Thus, *allpa-kamasqa* can be loosely translated to “animals of the living land”. Alpacas are restricted to the Northern, more humid altiplano, typically the Peruvian high-altitude grasslands.

As was made clear by the Global Assessment of Biodiversity and Ecosystems Services by IPBES (2019), humans and biodiversity are intrinsically related, and the IPBES conceptual framework (IPBS CF) provides a mean to visualize the relationships and flows between natural and anthropic components (Christie et al. 2019). As nature components, camelids provide numerous nature contributions to people (NCP), which can be direct, such as their fiber, or indirect, in relation to their multiple adaptations that have earned them their classification as “low impact grazers” (Baied and Wheeler 1993). SACs have morphological (padded feet, mobile lips) and physiological adaptations, such as increased digestibility due to retention of particles in the pseudo-rumen that allows them to use forage low in protein and high in fiber, in addition to high efficiency in the metabolic use of water (compiled in Gimpel and Bonacic 2006). Thus, thanks to this herbivore-plant co-adaptation, the maintenance of grassland in which they feed can be counted among camelids’ NCPs, including water regulation, carbon sequestration, and biomass production (NCP categories 1, 4 and 12) (Díaz et al. 2018; Martin-Lopez et al. 2019).

From a biocultural perspective, SACs have different relational values and roles within diverse worldviews, including the scientific, indigenous, and local knowledge systems, and these roles and values have also undergone change over time. Camelid NCPs can be analyzed in the context of diverse values and perceptions -as resources or commodities, sacred beings, utilitarian, non-human companions, etc. These values and perceptions motivate the decisions made by different stakeholders and the type of interactions they have with these animals, from strict conservation strategies to poaching.

The intensity of a person’s valuation and emotional connection with nature is related to several factors including his/her sensitivity, and intellectual experiences (Ives et al. 2019).

Understanding the values and attitudes of indigenous people and local communities (IPLCs) towards wildlife use should be a research priority for in situ sustainability and conservation management (Arias Arevalo et al. 2017; Pratt et al. 2004). But in the globalized world, even camelids are altered by multiple human drivers, some of them involving long-distance interactions (telecouplings). While the concept of *buen vivir* (“good living”) has its origin in Andean IPLCs and is firmly rooted in the relationship between Andean people and SACs, today it is impossible to approach conservation from an isolated “natural” or “social” science perspective. Many institutions and international organizations have emphasized the need for an integrated approach that incorporates an intercultural human dimension into biodiversity- conservation policies and programs (Batisse 1986; CEESP 2003; IPBES 2019). As scientific conservation practitioners, in this paper, we seek to describe our experience working with wild vicuñas *chakus* and llama caravans, as case studies to illustrate the multiple contributions to people of a wild and a domestic camelids species. We emphasize the diverging significance and meaning of these species and their contributions to different stakeholders: IPLCs, the scientific community, local authorities, *llameros* (lama caravaneers), local schoolchildren, luxury fiber companies and high fashion brands, and molecular biology labs.

Materials and methods

We selected three case studies in which members of the VICAM team were professionally involved (the authors were main researchers in two of them) to illustrate human interactions with two species that are the most common camelids in the Altiplano, NW Argentina.

- 1) Vicuña management practices (*chakus*).
- 2) Llama caravans.
- 3) Llama nanobodies.

The first two are based in Santa Catalina, one of the densest endemic distribution areas of both camelids in the Altiplano of Jujuy Province, Argentina.

Santa Catalina is a small traditional town, located in the mountain range of Rinconada, in the fluvial valley of the Santa Catalina River, at 3800 m above sea level. It is the northernmost town in the country, bordering with the Plurinational State of Bolivia. Founded in the seventeenth century, the town consists mainly of adobe (dried mud) houses clustered around a historical heritage church. Santa Catalina concentrates the administrative, political, sanitary, commercial, religious, festive, and educational functions in the area, including an elementary and a high school.

The pre-Hispanic communities that lived in this area had strong interactions with camelids, as proven by the petroglyphs depicting these animals in the northern sector of the village. The current indigenous habitants are united in three communities called Aukarpina Champi, Athu Saphi and La Cruz. There is also a cooperative of livestock producers (COOPASAC), which bring together local landowners. The main economic activity in the area is breeding -sheep and llamas- to produce fiber, skins, and meat. Governmental aid programs also constitute a significant source of income for many households.

Field data

The ethnobiological data presented in this paper were obtained during a participatory process developed over the past decade, comprising communal meetings, workshops, fairs, and other events, in which the authors have generated intercultural dialogues and exchanged information. Data collection methods included:

1. Ad libitum surveys during the Annual Santa Catalina Fair (llama caravans) and vicuña *chakus*.
2. Participant observations.
3. Recorded dialogues between participants in these public events.
4. Specific questionnaires, especially regarding camelid valuation and use.
5. Unstructured interviews and open surveys.

Data on *chakus* were obtained from the vicuña management plan of Santa Catalina, a joint project between the VICAM research group (technical manager) and the COOPASAC (local manager) that began in 2011. The management plan involves diverse stakeholders, including representatives of IPLCs, the local school communities, interdisciplinary researchers and university students. To date, we have held over 20 meetings with local communities and COOPASAC, contributing to build capacities among locals (approximately 200 people) and training over 150 students. Together, we developed four *chaku* events between 2012 and 2018. The fluent dialogue between our different knowledge systems was key to conduct successful *chakus*.

Data on llama caravans were obtained annually from 2011 to 2019, at the 2 to 3-days-long fair that precedes the town's Patron Saint anniversary celebration (Saint Catherine of Alexandria, or *Santa Catalina*) on November 25th. Over the last seven years of research at the fair, 260 open interviews were recorded (37 per year, in average) covering a variety of topics related to llama caravans. The results presented here are based on the information collected in those interviews that specifically matches the elements of the IPBES CF.

All the survey was conducted under the code of ethics for research, research-action, and ethnoscience collaboration in Latin America (Version two) of SOLAE, the Latin-American Society of Ethnobiology.

Data on llama nanobodies was obtained by a non-systematic literature review and by a dialogue with an expert in molecular biology.

Data analysis

The data were analyzed using a deductive approach and classified into categories following the IPBES CF, as described in their seminal paper (Díaz et al. 2015). These categories were:

Anthropogenic assets

Built-up infrastructure, health facilities, knowledge (including ILK systems and technical/scientific knowledge, as well as formal and non-formal education), technology (both physical objects and procedures), and financial assets, among others.

Drivers: natural or anthropogenic (human-induced) factors that cause a change in nature, either directly or indirectly. *Direct drivers*, also called *pressures*, operate directly on nature, while *indirect drivers* operate by altering the level, direction or rate of change of one or more direct drivers. *Direct anthropogenic drivers* are the result of human decisions, namely, of institutions and governance systems and other *indirect anthropogenic drivers*, which concern the ways in which societies organize themselves. They are the underlying causes of environmental change that are external to the ecosystem in question, on which they operate through direct drivers. Finally, *direct natural drivers* are not the result of human activities and are beyond human control.

Nature: the natural world, with emphasis on the diversity of living organisms and the interactions among themselves and with their environment.

Nature's benefits to people: All the benefits (and occasionally losses or detriments) that humanity obtains from nature.

Along with these categories, the information was analyzed by considering the different values that stakeholders assign to these elements and relationships, as defined by Arias Arevalo and colleagues (2017): *instrumental value*, or usefulness as a means to an end; *intrinsic value*, or the value of nature, ecosystems, or life as ends in themselves, irrespective of their utility to humans, and *relational values*: the importance attributed to meaningful relations and responsibilities between humans and between humans and nature.

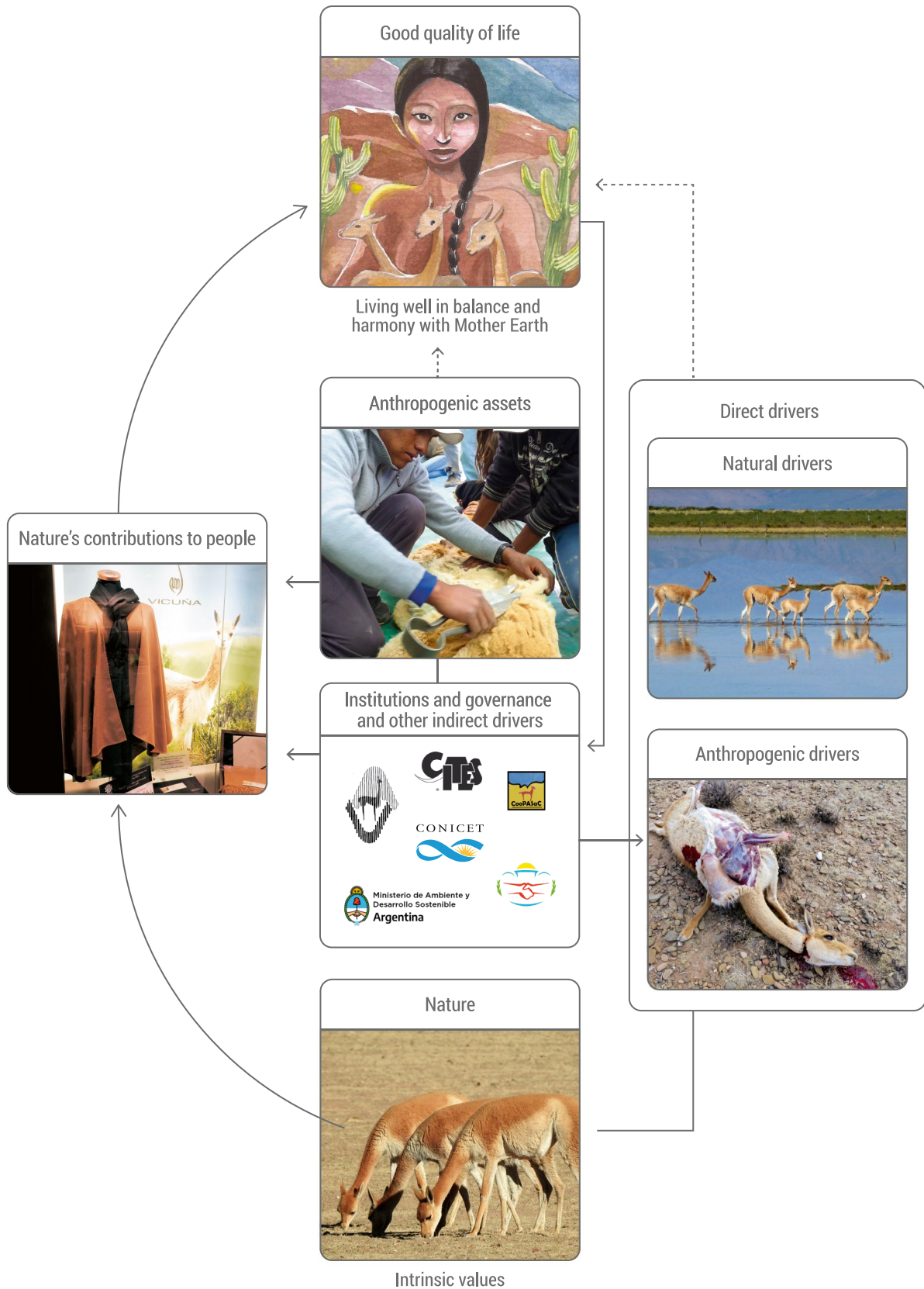


Fig. 2 Images from vicuñas case study (*chaku*) visualizing some real images of components. The quality of life is “Pachamama with vicuñas” an original drawing of Carlos Julio Lopez owned by VICAM. The photographs of vicuñas in “nature” is Yanina Arzamendia’s authorship. Bibiana Vilá is the author of the rest of the photographs

Results

Chakus: the case of vicuña management

The nature element analyzed in this case study is the southern vicuña (*Vicugna vicugna vicugna*). The local perception of this species includes an intrinsic valuation of vicuñas as animals owned by the Pachamama (Mother-Earth) deity, they are her property. “*But who do they (vicuñas) belong to? ... I say they belong to nature ... to La Pachamama, you cannot own the vicuña, ... it is not allowed*” (AG local community member, male). *Coquena* is the shepherd-deity that protects vicuñas, he/she (it has an ambiguous gender) appears permanently in oral narrations about the species in this area (Vilá 2014, 2015): “*My aunt’s nephew [...] said he once found a baby vicuña, he wanted to take her home, she was alone in the field ... Suddenly a Coquena appeared to him and said to him:—Leave that vicuña alone, it is mine, what’s wrong with you? Release her. And he released her and left, crying and scared. Coquena was like a little boy or a goblin, with a very big hat ... Coquena said: Leave it [the vicuña] because she is my property, she belongs to me. So, from that moment on, every time that my aunt found a little vicuña, she never raised it [in her arms] because she was afraid*” (GL local community member, female).

As presented in the introduction, vicuñas have one of the most valuable natural fibers in the world that, if it is well managed, can contribute greatly to the quality of life of Andean IPLCs. The high quality of vicuña fiber has been appreciated since pre-Hispanic times, and local people who had woven it before its exploitation was banned said that vicuña wool is “*very thin, soft, tiny, fluffy, is (...) How beautiful it is to spin ... soft, if it is done with a thread lathe ... the wool is soft*” (PM local community member, female).

In Fig. 2 we consider vicuñas and their values to people in the context of the IPBES CF. The nature element in question is the vicuña itself, a wild, low impact grazer with one of the finest fibers in the world, which is used as raw material for luxury garments (NCP). To obtain this fiber in a sustainable way it is necessary to employ a specific technique of capture, shearing, and release called *chaku* (anthropogenic asset). Several institutions and legal frameworks are involved in this process, and their policies shape the activity, including international agreements (CITES, Vicuñas convention), governmental agencies from the national (Ministry of Environment, the National Research Council), and provincial levels (Ministry of Environment of Jujuy), and local organizations

(COOPASAC). Direct natural drivers can include very strong storms that cause flooding. The anthropogenic driver that is the most serious threat to the conservation and long-term survival of the species is poaching. Quality of life involves, among other elements, the strong cultural link between vicuñas and the local belief in Pachamama as the mother of life and of vicuñas. These components and values are described in Table 1.

Stakeholders, operating through CF components and their flows, can either facilitate or hinder the sustainability of the system and thus enhance or compromise its ability to contribute to the wellbeing of local communities. Some of the main actors involved in the drivers described in the CF for the vicuña case study can be found in Table 2.

Llamas

Llamas are the result of a co-production between wild northern guanacos and human societies. They are domestic multi-purpose animals that provide fiber, meat, bones and dung, and they have a deep bond with Andean culture. The Central Andes is a complex mosaic of landscapes and humans, whose livelihoods require material ecosystem resources from different altitudes. In the past, this necessity was met by implementing a vertical complementarity strategy, using llama caravans for transport (Clarkson and Briones 2001; Nielsen 2002). Caravans arrive annually to Santa Catalina to participate in an event that can be traced back to the nineteenth century: the town’s patron saint’s anniversary celebration on November 25th, which was preceded by a fair. The fair is a traditional market where pastoralist products such as fiber, dried meat (*charqui* and *chalonga*), fat, and vegetables are sold and bartered for industrial food products (flour, sugar, pasta). The fair also includes used and new clothes and toys, traditional medicine, small appliances, furniture, and typical food and drink stalls. Llama caravans arrived from Bolivia (nor Lipez area) after a 6-day journey across the mountains, bringing llama fiber to exchange for industrial foods that come to the fair by truck from large cities in NW Argentina. People who lead and travel in the caravans (*llameros*) belong to indigenous communities and are bilingual Quechua-Spanish speakers. The main exchange is llama fiber for 50-kg sacks of flour; the exchange rate can vary considerably, from 44 kg of fiber to one sack of flour in 2013, to nine to one in 2018. Truckers claim that the rates are based on international commodity prices. For the *llameros*, the fair is their greatest opportunity to obtain a yearly supply of processed or industrial foods; since they do not use money, bartering is the only way to acquire them. Intra-ethnic exchanges usually involve smaller quantities and a greater diversity of products; the value of the barter is agreed between the two parties and it is not subject to the fixed prices of the external market. Caravans are currently

Table 1 Main Components and drivers of vicuña management (*chakus*). IPLC: Indigenous peoples and local communities

Components	Case study	Value	Description	Other
Nature	Vicuñas	Intrinsic relational	Wild populations	Living in the Andes before humans peopled the area
Nature contribution to people	Vicuñas fiber	Instrumental relational	One of the softest and finest animal fibers (12–14 µm in diameter) 300–500 U\$\$/ Kg 200 gr/ individual in <i>chakus</i> every three years	Highly valued by pre-Hispanic cultures (Inca and others)
Anthropogenic assets	Knowledge: Scientific research on population trends Capture and shearing procedures with animal welfare techniques Observations by indigenous and local communities Technology: built capture infrastructure and procedures Funding Formal and non-formal education and capacity building Trade and international market	Intrinsic relational	All the material and non-material components of the vicuña management plan and activities	This asset is intrinsically related to the next
Institutions, governance and other indirect anthropogenic drivers	Luxury fashion industries European designers International bodies: CITES Vicuñas Convention National Laws Regional authorities IPLC organizations Traders and export companies	Instrumental relational	All the material and non-material components of international trade Technology and financial assets in textile industries Price of vicuña fiber in the international market Authorization and control for legal marketing	Technology (both physical objects and procedures) and financial assets Vicuñas are <i>res nullius</i> with the guardianship of the provincial governments, who can delegate usufruct to local communities
Direct natural drivers	Climate Diseases Predators Livestock	Instrumental relational Relational Intrinsic instrumental Intrinsic Relational instrumental	Oligopsony. Inequalities in trade negotiations that abuse IPLCs Extreme daily and seasonal variations Parasitic diseases regulate vicuña populations Pumas and foxes Regulate vicuña populations Tolerance of local herders (or lack thereof) towards coexistence of vicuñas with livestock	Vicuñas are obligated drinkers and grazers Sarcoptic mange could affect vicuña populations Pumas can prey on adults and young, foxes only attack young Pastoral system is based in natural pastures. Vicuñas feed in llama and sheep grazing areas, there may be overlaps and competition
Direct anthropogenic driver	Poaching	Relational instrumental	Cross-border poaching is difficult to manage	Poaching led vicuñas to the risk of extinction

Table 1 (continued)

Components	Case study	Value	Description	Other
Good quality of life	Local indigenous community's wellbeing Pachamama well treated	Intrinsic relational	Communities receive income from the fiber of vicuñas Intangible links between the vicuñas and the IPLCs that contribute to cultural identity and integrity	<i>Buen vivir</i> . "Good living" as an Andean concept

scarce and are in danger of extinction if they have not gone extinct already (Vilá 2018). As noted by locals "... they [llameros] used to come in greater numbers ... they would cover all this mountain with llamas ... the wool is not worth much, because of this they do not come [...] There are no more llamas because people have already changed, vehicles arrive, when vehicles did not arrive before, now one can pay for a truck, it picks them up and they come." (LW, female). The reasons include the climate and socioeconomic drivers since improved economic conditions in Bolivia have enabled llama producers to engage motor vehicles for the journey. An ex *llamero* pointed out that "before there was no mobility [meaning 'motor vehicle'] and we all had to walk with llamas (...), once you have mobility, you cannot walk, it gets tiring after a while, that's the problem, people are weaker, now everyone has mobility thanks to Evo [Morales, the President of Bolivia]" (HU participant in the fair that came from Bolivia). Another factor that is bringing about the end of caravans is the little enthusiasm shown by young members of the local communities to continue with the activity (Vilá 2018). Some of the components and drivers of llama caravans described are presented in Fig. 3 and detailed in Table 3.

The stakeholders of llama caravans, operating by the components and flows, show the vulnerability of this livelihood (Table 4).

Llamas and their special antibodies

One of the most surprising NCPs from llamas -and all members of the Camelidae family- are their unique antibodies. Recombinant gene technology has made it possible to extract small antibody fragments called nanobodies (Nbs) or VHH (variable heavy homodimers) from camelid heavy chain antibodies. Camelid VHHs have exceptional physicochemical properties, including the possibility of humanization, which makes them uniquely well suited to deliver biologically-active compounds (Unciti-Broceta et al 2013). Llamas have become a significant animal in recent human immunology research because they have smaller and simpler nanobodies that fit into more recessed binding sites on the viral surface (Wesolowski et al 2009) and can be used for a variety of therapeutic applications. To cite just one example, VHHs are able to withstand extreme pH values and are therefore very effective to deliver immunotherapy for diarrhea caused by rotavirus (Maffey et al. 2016). These antibodies are used for experimental and therapeutic research in many laboratories which means that llamas are kept as lab animals in several research institutes around the world.

The quality of life component of the conceptual framework is represented as the potential cure of several diseases through vaccines and therapeutic techniques using llama nanobodies (Table 5).

Table 2 Main actors and the role of the anthropogenic drivers described in the CF for the vicuña case study

Component	Stakeholder	Role/description
Institutions and other indirect drivers of change	International CITES	To ensure that international trade in specimens of wild animals and plants does not threaten their survival. To establish specific trade conditions for different species. Authorizes export and import through a licensing system
	International vicuña convention	Article 1: The signatory governments agree that the conservation of vicuñas constitutes an alternative of economic production for the benefit of the Andean population and commit to its gradual use under strict governmental control, applying the techniques for the management of wild fauna determined by their competent official bodies
	National and regional environmental government	To set guidelines for sustainable management, law enforcement, and surveillance (inspections for the authorization of the legal sale of fiber; wildlife crimes) and to apprehend and prosecute poachers through security forces and the judicial system
	Associative local Andean boards (Communities and cooperatives)	To receive usufructuary rights for the capture, shear, and trade of vicuña fiber through public tenders, or direct sale. Some have the technical ability to weave handmade garments. They are IPLCs with very little income, most of them making just enough to cover their basic needs. They have inequity in negotiations with traders
	Traders and export companies	Financial capital for the purchase of fiber
	Extra-Andean (mostly in Italy, rest of Europe, Japan and USA) luxury fashion industries	To trade vicuña garments in the international market. Buyers belong to an affluent social class that is able to pay thousands of euros for a garment
	European designers	Telecoupling
	Weaving craftswomen	A market for typical handmade <i>ponchos</i> exists among the rural squirearchy
	Research, academic, technical institutions and Universities	To provide data for guidelines on the management of the species. Design of management plans and technology, intercultural dialogue with IPLCs
	Anthropogenic direct drivers	Poachers (can be members of communities from neighboring countries)
Trained researchers, technicians and local community members		Sustainable use: <i>Chakus</i> can be performed with techniques that allow zero animal mortality. It reinforces traditional resource use and community organization
Improvised and untrained people		Unsustainable use: The lack of proper capture techniques and procedures can put vicuña populations at risk
Conservationists		Actions to increase vicuñas populations
Local peasants (some)		Disturbance: due to perceived competition for pastures, vicuñas are chased away from llama and sheep grazing areas
Local peasants (some)		Tolerance: Vicuñas are valued in relation to deities, Coquena (their shepherd), and the Pachamama who protects them. Their presence is accepted based on possible or real use

Table 2 (continued)

Component	Stakeholder	Role/description
Anthropogenic assets	Local communities or cooperatives	IPLCs individuals trained and advised to carry out vicuña management. Drivers of wild vicuñas into a corral
	IPLCs builders	Local manufacturers of the capture funnel and corral
	IPLCs Shearers	Specialists in shearing with scissors
	Researchers	Research on vicuñas ecology, animal welfare, and management impact. Technical procedures and technology of capture and shearing. Research on biological and social conservation and use of vicuñas. Environmental education
	Local schools	Environmental education, from a mixture of traditional and Western hegemonic knowledge on the Andean environment
	Luxury garment businessmen, shopkeepers European designers and industries	They employ numerous people in industry and commerce

Discussion

The conceptual framework was applied to landscapes (mountains), natural resources (fisheries), and several ecosystems (Díaz et al. 2015; IPBES 2019; Martin-Lopez et al. 2019), including the socio-cultural valuation and knowledge of IPLCs (Christie et al. 2019). This is the first work to apply the framework to vicuñas and llamas, providing a useful tool to analyze interrelationships between natural aspects, local knowledge, institutional and socio-economic issues. One added value of this approach is the clarity with which the CF shows the problems in camelid management arising from the “wild vs. domestic essence” categorization of SACs. By applying the CF, the relationships that increase or hinder the sustainability of the system could be readily observed. Separated CF of llamas and vicuñas has allowed us to compare the situations of two related species in the same ecosystem, as well as the different challenges and research questions that need to be answered to devise appropriate solutions. For example, the main “natural driver” in the altiplano is the harsh climate, which is the same for both species. However, vicuñas are directly exposed to its effects, whereas people act as buffers between these natural drivers and llamas—e.g. the lightning strike killed the shepherd, not the llama—protecting the animals from natural agents when possible. Similarly, while anthropogenic drivers that affect vicuñas include poaching, that costs the animal its life, among llamas, this is not an issue. Instead, it is the use of vehicles to replace llama caravans to transport the fiber one of the main drivers of change among llamas and their interrelations with people and the habitat. Thus, this novel application of the CF to think about traditional environmental issues, such as the roles of camelids in the altiplano, has

helped to advance the understanding of the complexity involved in these roles and in the implied interactions with diverse stakeholders.

We also found this CF useful to organize and reflect upon the results of interdisciplinary research from a problem-oriented perspective (Kueffer et al 2012). By describing the systems, the role, disparate power and interests of stakeholders, their geographical location, the diverse institutions and processes, the fiber and the thousand dollars garment, the resulting CF is solidly based in reality, rather than in theoretical constructs or expectations. Among other benefits, this has helped us to demystify pernicious messages, such as the idea that “vicuña is the gold of the Andes” that could provide a quick and uncomplicated way to generate income for IPLCs.

This CF has also incorporated the voice of partners outside the academia. For example, llama caravans are undergoing a process of change, whose outcome will depend primarily on the attitudes of *llameros* and young members of the local communities. These attitudes are among the CF’s anthropogenic drivers and assets, both influenced by institutions that can be located very far away, such as the International Wool Textile Organization in Belgium, or very nearby, such as the local school. Our framework brought to light both the factors that can predict the extinction of llama caravans while simultaneously explaining the maintenance of llama fiber trade transported by vehicles.

In terms of opportunities to research camelid conservation problems cannot always be equated to their endangerment as a species; in some cases, it is quite the opposite, with specific conservation challenges arising from the species’ abundance. Abundant species attract far less attention from biodiversity conservation institutions, which hinders the maintenance of in situ research and sustainable

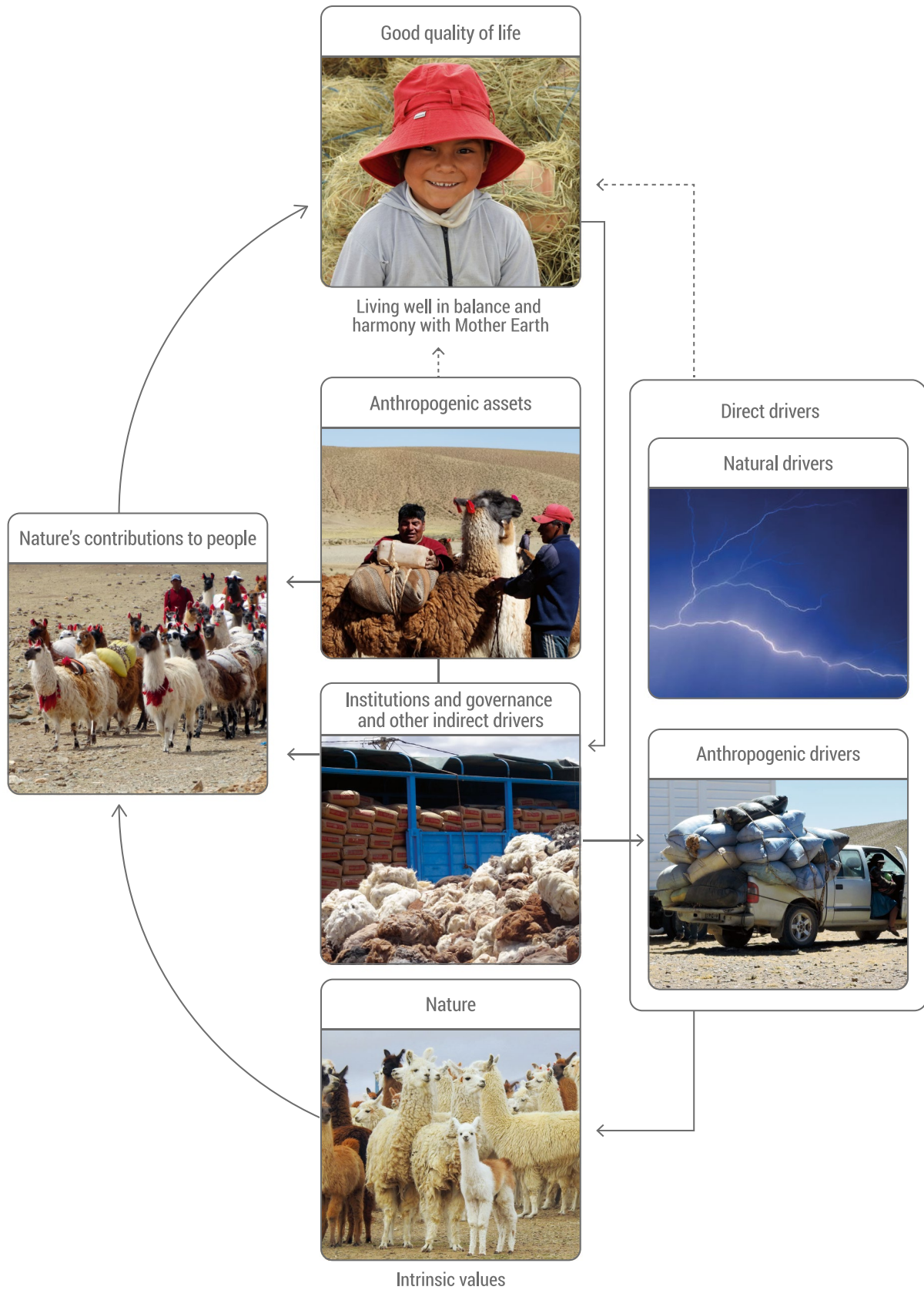


Fig. 3 Images from the llama's case study visualizing different images of the CF components. All the photographs were taken by Bibiana Vilá except the lighting (natural drivers) obtained from the internet. The imagen of Madeleine (Good quality of life) has the girl and her mother's permission

management projects. But abundance has enough merits to be considered as a significant phenomenon for conservation in itself. As has been eloquently expressed by Redford and colleagues (2013), “Wildlife in abundance, sometimes referred to as wildlife spectacles, helps inspire us and builds connections with the natural world... Abundance is a buffer from perturbation whereas rarity is perpetual vulnerability”. In other words, the abundance of a wild species has a relational value, and it can contribute to protecting other species. In this sense, protecting wildlife abundance can be considered to have an intrinsic value as part of a comprehensive strategy for sustainable use, particularly in species that are amenable to human management.

Vicuñas *chaku*

Vicuñas have intrinsic value due to their particular adaptations as low impact grazers in harsh, desert environments; they also have instrumental value as fiber producers, and several materials and relational values due to their close relationship with Andean cultures. For distant western stakeholders of international textile industries, vicuñas are a way to achieve huge profit margins. The role of local Latin American environmental authorities is crucial to bridge the extremely wide cultural gap between producers and buyers (Lichtenstein 2010). Textile companies usually lobby local environmental authorities in Latin America. Unfortunately, this results in a biased mediation which is almost always in favor of the greatest economic power. Vicuñas management under strict animal welfare protocols has shown biological sustainability in Argentina (Arzamendia and Vilá 2012; Arzamendia et al. 2010, 2014; Vilá et al. 2010) but anthropogenic drivers (direct and indirect) interact in such a way that the long-awaited sustainable development goals are yet to be achieved.

Vicuña management via *chaku*-like practices has the potential to significantly increase the income of Andean communities (Lichtenstein and Vilá 2003), but a detailed market analysis (Kasterine and Lichtenstein 2018) has revealed that only 2–6% percent of the garment retail price actually reaches Altiplano communities. Due to cultural—and even language—barriers, IPLCs are poorly suited to stand their ground against international textile companies, who have more resources and lobby capacity to tilt the scales in their favor when negotiating trade conditions. In this sense, national institutions and governance systems—the indirect anthropogenic drivers as per the IPBES

Conceptual framework—have a critical role to play to reduce asymmetries and guarantee fair trade. The situation is not new; Sahley and colleagues (2004) pointed out that, because vicuñas can be live-shorn by indigenous communities, it is the “ultimate” eco-friendly, wild animal product for the high-end fashion industry, which opens up a precious marketing opportunity. But they also noted that peruvian bureaucracy and legislation create serious difficulties for peasant communities to participate in the chain of production and commercialize their fiber. Lichtenstein (2010) also described complex relationships between local communities and the global market and underscored the importance of government policy in helping communities overcome these inequalities.

In Argentina, IPLCs cooperatives and communities have received technical and material governmental assistance for the *chaku* activities, either from provincial governments or the national science agency (National Research Council, CONICET) and academic and technical organizations, in the form of free professional technical support for environmental assessments and drafting of vicuña management plans, supplies (e.g. nets on loan) and staff, such as volunteer university students and security forces, to assist in vicuña captures. This support has allowed IPLCs to afford production costs in a monopsony situation, where a single buyer controls the market of vicuña fiber. However, prices have decreased to less than 400 dollars per kilogram (Kasterine and Lichtenstein 2018) and external support for the sale of the fiber is considerably less developed, which involves cumbersome procedures for IPLCs. Of the 18 NCP reporting categories (Díaz et al. 2018), the price of vicuña fiber only reflects category 13, its instrumental value, which is fixed by international markets. As can be appreciated in this work, vicuñas also account for other NCP categories, such as learning and inspiration (category 15), physical and psychological experiences (16), maintenance of options (18) and especially category 17, or “supporting identities”, since the *chaku* is both a technique and a ceremonial event, deeply rooted in Andean cosmovision and tradition.

Llamas

The two llama case studies were selected to illustrate the wide spectrum of this species' contributions to people. On one hand, llamas are loaded with woven llama fiber sacks that are tied to the animal using llama fiber ropes, to carry llama fiber across the Andean mountains on a 6 day journey to a local market. On the other, high-tech molecular engineering of llama nanobodies is used for biomedical research purposes in the most prestigious laboratories and institutions in the world. Llamas are incredibly versatile animals that connect the past and the future and foster telecouplings between such diverse actors as subsistence fiber producers in

Table 3 Main components and drivers of llama caravans in Santa Catalina

Components	Case study	Value	Description	Other
Nature	Llamas	Intrinsic Relational Instrumental	Domestic animal co-created 5000 years ago in the Central Andes	A white llama, Napa, was sacred in the Inca empire
Nature contribution to people	Llama caravans that transport llama fiber and dry llama meat in llama fiber woven sacks secured by llama ropes	Relational Instrumental	Caravan llamas are castrated. They are young males called <i>pakarane</i> or <i>orco llamita</i> in Quechua	Llamas can carry 25 kg (2 arrobas) each Groups of 30 to 80 llamas are driven by 3 to 5 people
Anthropogenic assets	Ancestral techniques for loading, driving and unpacking the animals Traditional local fair that includes trading and social activities ones (football, music) Extra-Andean market of fiber and processed food	Intrinsic Relational Instrumental relational	<i>Llameros</i> use ropes and sacks made of llama wool to load the animals The main exchange is llama fiber for 50-kg sacks of flour, To determine the price of the fiber	The <i>llameros</i> manage the animals with postures and special sounds Peasants brings their yearly production
Institutions and Governance and other indirect drivers	Traders and export food companies	Instrumental	Trucks carrying processed food arrive to the fair from large cities and leave with fiber to sell to export companies	<i>Llameros</i> can move between the capitalist economy and the traditional exchange structures Drought can be an obstacle to travel
Direct natural drivers	Climate Natural vegetation/ pastures	Relational intrinsic Intrinsic relational	Lightning Storms. (e.g. the leader of the caravan was killed by lightning) The food of llamas is based on natural vegetation	If there are not sufficient pastures along the way, they cannot travel
Direct anthropogenic driver	Vehicles	Instrumental Relational	10 h in the vehicle equals 5 days walking in the caravan	Vehicle are increasing as mode of transport
Good quality of life	A safe trip with good interchanges. Bring food to the <i>llameros</i> families for one year	Relational instrumental	The caravan's management techniques have a huge cultural value as caravans started more than 3000 years ago and have little changes	Andean culture, since the Inca times, recognized the llama an iconic and sacred animal

Table 4 Main actors and role of the anthropogenic drivers described in the CF for the llama caravans case study

Component	Stakeholder	Role/description
Institutions and other indirect drivers of change	Nor Lipez herders' communities <i>llameros</i>	The caravans depart from the <i>llameros</i> ' homes in Bolivia. A propitiatory ritual is carried out at departure, which consists of smoking the animals by burning coa, a local plant. Then, they guide the caravans on a six-day journey across the mountains to Santa Catalina
	Santa Catalina local authorities	Administrative, Religious and recreative activities in town
	Santa Catalina Fair organizers. Local people associated with the authorities	Place of exchange Social activities, music, food, football
	Border authorities	Allow the passage of animals, people and goods from Bolivia to Argentina and back
	Traders and Truckers with information on Fibre market export companies and processed food wholesaler	Determine fibre to flour exchange rate, which is the main exchange of the fair
Anthropogenic direct drivers	<i>Llameros</i> transition to transport by motor vehicles	Extinction of caravans and caravan technologies
	Non-IPLC individuals breeding pack llamas and training them to walk	Using llamas' caravans as touristic attraction
Anthropogenic assets	<i>Llameros</i>	<i>Quechua</i> -speaking IPLCs with knowledge and experience in breeding, training, and travelling with cargo llamas
	Researchers	Observing all the stages of the caravan trip to have a record of the activity after its extinction
	Local schools	Using caravans as a transversal theme for different subjects, such as mathematics, geography, history, and natural sciences
	Local people	Visitors, musicians, greengrocers, cooks, shopkeepers, traditional medicine women, among others
	Traders and truckers, textile companies, and processed food wholesaler	Financial capital for the purchase of food or fiber Infrastructure and technology with use of labor

an Andean town and golf players in the UK that use llamas as caddies.

In the Andes, a direct natural driver (lightning) killed the last caravan leader in 2019. No caravans have arrived in Santa Catalina since then, and we can conclude they are now extinct. Fewer people are choosing to remain in the rural Andean Altiplano, which is a local expression of a global pattern of abandonment of traditional livelihoods. Global pastoralist populations have decreased from 10 to 1.5% of the total global population over the last five decades (Faye 2016). Local people attending the Santa Catalina fair in 2018 and 2019 commented on what they considered to be the reasons for the decline in caravan trade at the fair: (a) a growing demand for camelid fiber in Bolivia; (b) the improvement in living conditions, which allowed peasants to use motor vehicles to transport the products; and (c) the drought that affected the area during the 2014–2017 period. In their detailed paper analyzing seven pastoral regions in six continents, Dong et al. (2011) found that three factors—agroecosystem resilience, livelihood options, and institution capacity—are the axes of a three-dimensional vulnerability framework influenced by climate change—the same natural

driver as in our llamas case—and socioeconomic factors—our anthropogenic drivers and assets—that is fracturing large-scale pastoralist ecosystems into spatially isolated systems. This may be happening in our area, with Bolivian *llameros* staying in their territories and ceasing to travel to Argentinean fairs.

We have also suggested that another significant reason is that young local people have little personal interest in caravans as a component of their adult life (Vilá in prep). Since the *llamero* profession is learned as a teenager while travelling in a caravan with adults—usually parents and uncles—it is very important to understand the perceptions and attitudes of young people towards this activity. Teenagers that had travelled in caravans have stated that they were living in the city and studying (finishing secondary school), and that did not see caravanning as a suitable occupation for them. They did it for the experience and the sense of adventure, and to accompany their uncle, rather than as training for the future. Also, children at school stated that they did not enjoy walking for several days and sleeping outdoors, which was a very tiring and boring experience for them. They did not wish to be *llameros* when they grew up.

Table 5 Main CF components in relation to llama nanobodies

Components	Case study	Value	Description	other
Nature	Llamas	Intrinsic relational instrumental	Domestic camelid	Can be used as lab animal
Nature contribution to people	VHH nanobodies	Instrumental	Smaller and simpler than those found in humans	VHH fit into smaller and more recessed binding sites on the viral surface
Anthropogenic assets	Development of llama bio management	Instrumental	Llamas live in a corral near the laboratory	Tamed and trained for special handling (e.g. inoculation, collection of blood samples)
	Laboratories developing therapeutics with llama VHH	Instrumental	State-of-the-art techniques used in molecular biology	
Institutions and Governance and other indirect drivers	International Research institutions National Research Council CONICET, other national institutions (INTA, Milstein, Leloir)	Instrumental	Research to produce biomedical products	Many products can be patented Nagoya protocol
Direct natural drivers	Housing conditions, temperature, food	Instrumental Relational	Llamas must be housed and handled with care	In summer, they need to be shorn
Direct anthropogenic driver	Research on llama blood	Instrumental	Several laboratories around the world	Techniques for blood collection must follow animal welfare protocols
Good quality of life	Can provide the cure for a wide range of diseases, including neurodegenerative ones	Instrumental	Therapeutic approaches based on the novel camelid nanobodies	Many people in the world can receive effective treatments based on the molecules of an animal that they do not know and live thousands of kilometers away. Health telecoupling

On the contrary, the prospect of cutting-edge molecular research of llama nanobodies attracts young scientists from around the world. Llama nanobodies are now in the frontlines of research seeking to improve Coronavirus diagnosis and treatments in several countries.

This raises interesting points to be considered for integration into institutional and governance indirect drivers of change. A strong case could be made that, as co-creators of llamas and stewards of camelids, Andean IPLCs are responsible, at least to some extent, for the existence of llama nanobodies, the 14th of the NCP reporting category (Díaz et al. 2018). In view of increasing international interest, and considering the Nagoya protocol, this could have significant implications for Andean IPLC's rights over the use of llama nanobodies. This is a complex indirect driver to be analyzed in detail in the future.

Conclusions

As the concept of “buen vivir” (good living) was born in Andean altiplano communities, it constitutes a suitable case to analyze the relationship between Andean people and their environment using the IPBES conceptual framework. South American camelids (SACs) provide vital contributions to people that have intrinsic, relational, and instrumental value. There is a wide range of types of contributions depending on the stakeholders and their cultural and social backgrounds. The IPBES conceptual framework is a useful paradigm to approach the study of Andean livelihoods associated with and based on the breed and use of camelids.

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