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Abstract

Bofedales are azonal peat-forming wetlands located in the tropical and subtropical Andes at high altitudes (approximately 3,200–5,000 m). Motivated by their socio-ecological importance, unique landscape qualities, and increasing vulnerability, scholars have developed a rich research agenda to better understand this ecosystem. We conducted an analysis of the various frameworks used to study bofedales through a systematic review of 119 key academic publications. We observed a range of bofedal naming terminologies, definitions, and descriptions of key threats that sometimes aligned with disciplinary, geographic, or linguistic distinctions between studies. Notably, though the majority of papers employed natural science methods, the social science and multidisciplinary studies were more likely to discuss the role of local communities in helping manage these ecosystems, though many researchers also highlighted the need for further study of these dynamics. This analysis, therefore, demonstrates the need to develop research modalities that are rooted in local contexts and which employ both quantitative and qualitative

methods to investigate and elucidate the complex human-environment dynamics that characterize these ecosystems. By documenting, we aim to support more robust research collaborations and to inform the development of research and conservation agendas that effectively support these landscapes and the myriad socio-ecological services they provide.

Keywords

Bofedales
High altitude wetlands
Andes
Traditional ecological knowledge
Pastoralism

1. Introduction

Bofedales (*ok''os* or *juqhu*, in Aymara, *hoq''o* in Quechua) are azonal high Andean wetlands, distributed along the Andes Mountains from Colombia and Venezuela (Cleef 1981 cit. in Ruthsatz 2012) to Patagonia (Kleinebecker et al. 2007, 2008, Ruthsatz & Villagrán 1991 cit. in Ruthsatz), approximately between 3,200 to 5,000 m. (Squeo et al. 2006; Ruthsatz 2012). They are dominated by cushion plants of the Juncaceae family (e.g. *Oxychloe andina, Distichia muscoides)* and can also contain vascular plants (e.g. Cyperaceae, Plantaginaceae) and grasses (e.g. *Festuca, Deyeuxia*) (Ruthsatz 2012; Meneses et al. 2015). They also have the highest biomass –productivity among the altitude ecosystems of the puna region, forming dense layers of organic matter (peat) (Cooper et al. 2015; Hribljan et al. 2015). Bofedales require permanent water saturation and are located in areas with perennial flow or continuous water recharge, generally provided by a combination of summer rains and the seasonal melting of ice and snow (Squeo et al. 2006; Hribljan et al. 2015). Due to these characteristics, bofedales serve multiple ecosystem functions: they have a high degree of biodiversity and endemism (Coronel et al. 2007; Goitia et al. 2007; Dorador et al. 2013); regulate water flux ensure the stability of the soil, thus controlling erosion (Maldonado 2014/15); and are a key part of the global climate system due to their high carbon sequestration capacity (Hribljan et al. 2015).

Since pre-Hispanic times, these ecosystems have been used by Andean pastoral societies (e.g. Aymaras, Quechuas, Atacameños) as a permanent and highly nutritious source of fodder for domesticated camelids (llamas, *Lama glama*, and alpacas, *Vicugna pacos*) (Capriles and Tripcevich 2016). Bofedal plants, moreover, serve medicinal and spiritual uses, while peat can also be used for fuel and fertilizer

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(e.g. Palacios 1977; Browman 1982; Villagrán and Castro 1997; Gandaríllas et al. 2016). Ethnographic studies among Quechua and Aymara pastoral communities have identified local traditional ecological knowledge and management techniques to conserve, improve, expand, and influence bofedales to reduce erosion (e.g. Palacios 1977; Orlove 1977; Erickson 2000; Yager et al., 2015). The most common management practice is the implementation of community-scale irrigation technologies, including both simple water channels and gullies and more complex networks of irrigation canals, reservoirs, and wells. Some pastoralists also use fire to eliminate dry grasses, as well as to fertilize and strengthen shoots. Additionally, rotating the grazing areas promotes even grass growth and distributes fertilizer and seed via animal droppings (Yager et al. 2008). Finally, in some bofedales, especially in arid environments, herders have adjusted management practices to mitigate the negative effects of changing climate conditions (such practices include, e.g., elevating watercourses and digging wells to ensure water availability during drier periods) (Villarroel et al. 2014; Yager 2015). The beneficial interactions and interdependencies between Andean pastoralist communities and managed bofedal landscapes mean that many of these ecosystems are not strictly *natural* but rather produced through a complex interplay between natural and social dynamics. Bofedales are thus key Andean socio-ecological ecosystems (Yager et al. 2019).

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Bofedales have been increasingly endangered by a number of factors. They are located in an area highly vulnerable to climate change (Urrutia and Vuille 2009) and have been affected by changing precipitation patterns and increasing temperatures (Zimmer et al. 2014; Otto and Gibbons 2017). Bofedales have also been impacted by changing socio-economic conditions, including peat extraction; shifts in land use and grazing practices; water extraction for urban consumption, mining, and large-scale agriculture (e.g. Bury et al. 2013); and broader environmental governance conditions (e.g. Verzijl and Quispe 2013; Struelens et al. 2017).

Motivated by the socio-ecological importance, unique landscape qualities, and increasing vulnerability of bofedales, scholars have developed a rich research agenda to better understand this Andean ecosystem. Yet the resulting publications define, name, and characterize bofedales in varied, often contradicting ways. Indeed, the dominant literature examining these ecosystems adheres to a strict conceptual division between the 'natural' and 'human' worlds, viewing the latter as solely a beneficiary of, and interloper into, a landscape whose original, ideal state is imagined to be devoid of human influence (e.g. Verzijl and Quispe 2013; Prieto 2015). Such interpretations can have material consequences: they can inform or support the development of management practices and public policies that not only endanger bofedales themselves but also, paradoxically, marginalize and even criminalize traditional activities that expand, adapt, and maintain bofedales.

This paper aims to present a synthesized perspective on the variations in the conceptual frameworks and terminology currently used to analyze bofedales in the Central Andes through a systematic review of the existing body of literature on these ecosystems. Taking 119 key academic studies, we examine how each defines bofedales, the synonyms it employs, the key threats it lists, and the way it characterizes the role of local communities. We analyze each of these factors in relation to a study's discipline, stated purpose, research location, and methods in order to map the scope and variation in contemporary bofedal research conducted in different languages, disciplines, and regions. By evaluating the inconsistencies and gaps in this literature, we aim to help illuminate some productive avenues and methodologies for future research. Most importantly, we demonstrate the need to develop research modalities that are rooted in local contexts and which employ both quantitative and qualitative methods to investigate and elucidate the complex human-environment dynamics that characterize these ecosystems. This study, moreover, aims to help facilitate such cross-disciplinary and inter-regional research collaborations by illustrating the range and distribution of bofedal terminology and definitions, as well as the extent, form, and implications of the interactions between these landscapes and human activities. Documenting these variations in terminology and conceptual understandings is key to developing more robust research collaborations and, ultimately, to formulating research and conservation agendas that effectively support these landscapes and the myriad socio-ecological services they provide.

2. Methods

In total, we reviewed 119 publications in English and Spanish (including journal articles, book chapters, and conference presentations) published between 1977 and 2018 that examined bofedal type ecosystems of the Central Andes in Chile, Argentina, Peru, and Bolivia. The findings of articles published in 2019, 2020, and 2021 are not included in this paper, though more recent research has continued to illuminate the species composition and ecological characteristics of bofedales (e.g. Domic et al. 2021). We conducted the analyses using both the core collection of Web of Science (Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Emerging Sources Citation Index) and the SciELO Citation Index, the most important scientific database in South America.

We used a two-stage methodology to select the publications. We first completed comprehensive searches in each database using 18 terms corresponding to commonly-used bofedal synonyms in English, Spanish, and Aymara, as well as five species often indicative of or commonly found in bofedales (See Online Resource 1 for a complete record of database searches). The selection of terms was based on a preliminary analysis of synonyms and other words indicative of bofedales used in 60 academic papers that analyzed true bofedal habitats (see definition by Squeo et al. 2006, below). Employing a variety of

search terms was important because, as discussed in the Results Section, many papers did not use the term "bofedal" to refer to bofedal-type wetland landscapes. After this initial search, we reviewed the bibliographies of key papers found in the initial database searches, adding additional relevant articles.

Once this two-part selection process was completed, documents were filtered to ensure that all those included discussed bofedal-type landscapes as a central theme, were conducted within the geographic limits mentioned above, and were written in English and Spanish. Additionally, we did not include articles that employed the word '*vega*' (which technically indicates a wetland environment distinct from bofedales, but has also been mistakenly used as a synonym for 'bofedal'), unless the landscape analyzed fit the bofedal definition in Squeo et al. (2006), with cushion vegetation and a minimum altitude of 3200 m in the northern ecosystem range or 2800 m in the southern range.

For each paper, the following information was noted: year, full citation, study discipline, role of bofedales in study (as the sole, or as one of multiple, habitats studied), purpose of study, methods, country of research, research site altitude, coordinates (latitude and longitude), bofedal definition used, characterization of people in bofedal management, main threats to bofedales, common vegetation species found, synonyms listed, and number of citations in Google Scholar database (as of March 2018). Where relevant, quotations were also recorded. We coded all papers using keywords that encompassed the range and variation of the sample set. With the exception of the study discipline, date published, and role of bofedales, all coded characteristics were non-exclusive, meaning that multiple keywords could be applied to each paper. This approach allowed for greater nuance within the coding process, as many papers listed multiple characteristics for categories such as threats and synonyms. Online Resource 1 contains a full list and definition of each keyword in all categories analyzed. We used Microsoft Excel to determine the relative frequency of each keyword and to compare keyword use across study discipline and location. Though we examined quantitative metrics where possible, the majority of our review was qualitative.

3. Results

The publications varied not only in language, discipline, and country of study, but also in how bofedales were labelled, defined, and described. The variation in terminology and descriptors of bofedales applied often aligned with disciplinary or geographic differences between papers.

The research locations were distributed approximately equally between Bolivia, Peru, Chile, with a smaller portion in Argentina (Fig. 1). Few studies examined sites in multiple countries, reflecting the influence of geopolitical borders in shaping - and limiting - the scope of comparative research. Within the reviewed publications, 68 ~~percent~~% took bofedales as their main object of study, while 22 ~~percent~~% examined bofedales as one example among multiple ecosystems (Fig. 2). The majority of studies (60

percent%) were published between 2010 and 2018, reflecting an overall increase in published bofedal research over time.

The majority (68 percent%) of papers analyzed were in the Natural Sciences, including Ecology and Botany, Geology and Hydrology, and Archeology papers (Fig. 3a). The proportion of papers in the social sciences, including History, Policy, and Anthropology, was much smaller (18.5 percent%). A small portion of papers, 13.4 percent%, were multidisciplinary, a category that includes Environmental Management, Ethnobotany, and other interdisciplinary collaborations.

When grouped by date and region, more nuanced disciplinary patterns emerged (Fig. 3b). In particular, the papers published between 1977 and 1999 did not hew to these broader trends; during this period social science and multidisciplinary papers were more common in some regions. Among this group overall, 53 percent% of papers were from Natural Sciences and 37 percent% from Social Science. However, though the majority of papers based in Bolivia were in the natural sciences, the majority of those based in Peru used social science methodologies and no papers based in Peru were multidisciplinary. In Chile, publications were split equally between multidisciplinary and natural science papers, with no social science papers. Notably, none of the studies in Argentina were published during this earlier period.

Papers published between 2000 and 2018 more closely reflected the overall disciplinary distributions: the majority of studies in all four countries examined during this period were in the natural sciences, with significantly smaller proportions in the social sciences and multidisciplinary areas. The one exception is Argentina, where no multidisciplinary studies were published during this period. In both categories of grouped years, multidisciplinary studies did not exceed 13 percent% of total publications.

This disciplinary concentration influenced the types of methodologies used, which were predominantly quantitative and biological methods including lab and computational analysis, field sampling, and mapping (Fig. 4). Qualitative methods such as archival research, ethnographic study, and legal analysis were less common.

In total, there were 128 synonyms for bofedales (Fig. 5). Translating Spanish synonyms to their English counterparts reduced the total synonym count to 121. “Bofedal” itself was mentioned in 92 papers. Though these names were primarily words in English and Spanish, 18 studies also mentioned words in Quechua or Aymara. In Quechua, bofedales were referred to as *oqho* (which translates to

cenagal, or bog/marsh), *hoq'ʼo* (saturated wetland), *waylla* (peatland), and *qochawiña* (not a common term; likely a combination of qocha, or 'lake' and wiña, or 'grow'). Bofedales were also referred to by the Aymara names *juqhu* and *jukhu*. Some studies also employed spelling variations of Quechua and Aymara words, including *hok'o*, *hocco*, *j'hoko*, *jockonal*, *jok'os*, and *joqho*. While the 18 papers that used Quechua or Aymara synonyms spanned the natural and social sciences, most were located in Bolivia and Peru, while no papers in Argentina and Chile used indigenous language synonyms.

Though almost every publication reviewed defined bofedales, the papers named different, at times contradicting, features as characteristic of these landscapes. Researchers employed the term bofedal to describe a broad range of ecosystems, including Páramo wetlands, Jalca wetlands, wet Puna, dry Puna, and high Andean wetlands. However, in general, the term (i.e. bofedales) was employed to refer to azonal areas with a constant water source (Buttolph & Coppock, 2004; Dangles et al. 2017; Garcia and Otto 2015; Lane 2009; Lizana 2001; Loza Herrera et al. 2017; Palacios Rios 1996; Pérez and Echevarría 2002; Struelens et al. 2017; Torres et al. 2015; Ovejero 2015) containing peat (Brevedan et al. 2016; Espi et al. 1997; Goitia et al. 2007; Hernández et al. 2018; Herrera et al. 2015; Hribljan et al. 2014; Josens et al. 2017; Meneses et al. 2015; Möller and Muñoz-Pedreros 2014; Munoz-Pedreros et al. 2015; Munoz, et al. 2014, Naoki 2014b; Nieto et al. 2017; Shawet et al. 2012; Torres et al. 2012; Verzijl and Quispe 2013; Villagrán and Castro 1997) and cushion plants (Aguilar et al. 2016; Buttolph and Layne Coppock 2001; Caro et al. 2014; Castellaro et al. 2004; Castellaro et al. 1998; Cochi et al. 2014; Cooper et al. 2010; Cooper et al. 2015; Dorador et al. 2013; Gould et al. 2010; Hartman et al. 2016; Postigo et al. 2008; Prieto 2015; Schittek et al. 2018; Segniniet et al. 2013; Servat et al. 2017), with importance for both ecologies (Acosta and Custodio 2008; Araya-López et al. 2018; Browman 1982, 1983; Budds and Hinojosa 2012; Hoffmann et al. 2014; Izquierdo et al. 2015; Naoki, et al. 2014a; Rundel and Palma 2000; Salvador and Rochefort 2014; Yager 2015) and local inhabitants, for whom they provide, among other services, a food source for livestock (Browman 1982, 1983; Budds and Hinojosa 2012; Erickson 2000; Lane 2006, 2007; Naoki et al. 2014a; Rebaudo and Dangles 2014). Common identifiers included community importance, the presence of water, peaty soils (i.e organic), and location in isolated, harsh environments (Fig. 6). Many studies also defined bofedales by the presence of particular types of vegetation, but the plant species listed varied (Online Resource 1).

The studies reviewed also represented the relationships between herders and bofedal landscapes in a variety of ways. These characterizations were often aligned with disciplinary distinctions; though half

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The citation "Struelens and Pomar 2017" has been changed to "Struelens et al., 2017" to match the author name/date in the reference list. Please check if the change is fine in this occurrence and modify the subsequent occurrences, if necessary.

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of social science and multidisciplinary papers mentioned traditional management practices, one fourth of natural science papers did (Fig. 7). In most papers, the relationship between herders and bofedales was unidirectional: communities benefited from, but did not shape, bofedales (e.g. Wilcox et al. 1986; Earle et al. 2003; Izquierdo et al. 2015; Britto 2017). As Izquierdo et al. stated in a study based in Argentina, "High Andean peatbogs… provide essential ecosystem services to local inhabitants" (2015, 975).

Yet some papers presented evidence that some bofedales are expanded, adapted, and maintained by the communities who use them as pasture. Palacios provided the most detailed description of the relationship between people and bofedales in a qualitative study based on ethnographic research in Chichillapi, Peru,

> Though natural 'bofedales' do exist, they are small...thus it is necessary to prepare them to extend their benefits along large extensions of land. To do this requires permanent and abundant irrigation, which floods large expanses of land (1977, 159–60, our translation).

Through irrigation and other mechanisms, Palacios explained, "The natural landscape is turned and transformed into a cultural landscape" (1977, 169, our translation). Studies that described these interactions also emphasized the lack of understanding of these dynamics within academic communities (e.g. Salvador et al. 2010). As Huanca et al. noted,

> Despite the important positive effect that local communities have had through the irrigation of bofedales, few studies corroborate and attempt to understand the logic behind this activity (2015, 67, our translation).

However, even those studies that did discuss such practices acknowledged that they are poorly understood within both academic and conservation communities (e.g. Verzijl and Quispe 2013; Nina Huanca et al. 2015). Indeed, in our analysis no articles sought to quantify the amount of bofedal area that could be attributed to human expansion and few examined in detail the mechanisms of local maintenance and adaptation activities.

As with bofedal definitions, the factors that different studies named as principal threats to these landscapes varied and often conflicted (Fig. 8). Nearly all papers concurred that bofedales were vulnerable; just five papers listed no threats at all. As with the characterization of human intervention, we

noted a divergence between natural and social science papers in the threats most often listed (Table 1). Among social science and multidisciplinary papers, bofedal degradation was often linked to factors with a geographic and temporal scale that exceeded particular landscapes or communities. Such factors include state policies, market forces, and legacies of colonialism. Many social science papers also listed the loss of local herding traditions, often due to these broader forces, as a main threat. In contrast, among natural science papers a lack of knowledge or poor management practices on the part of local communities were more often mentioned.

4. Discussion

4.1. Bofedal Ssynonyms and Ddefinitions

We observed a range of bofedal naming terminologies, definitions, and descriptions of present-day threats among the papers reviewed. In some cases, these differences aligned with disciplinary, geographic, or linguistic distinctions between studies. These variations reveal the complexity of defining these landscapes, and the need to draw attention to the often overlooked nuances of the terminology applied to describe them. The divergent understandings and approaches among researchers studying these landscapes can lead to contradictory findings, particularly regarding the role of local communities and traditional ecological knowledge. These findings, in turn, can impact recommendations for how to best manage and conserve them.

With respect to bofedal naming terminology, for instance, one synonym often used, *vega*, technically refers to a type of azonal wetland dominated by different vegetation (e.g. Estenssoro 1991; Squeo et al. 2006). Some instances of the use of this synonym use might be due to regional differences in its meaning; Estenssoro states that "Juncaceae-dominated peatlands… receive different local names… in Argentina [they are called] 'high-Andean *vegas*'–"" (1991, 112, our translation; see also Ruthsatz 2012). The papers also presented a range of bofedal definitions. While some publications defined bofedales as wetlands that require rain, for instance, others argued that bofedales cannot be sustained by rain. Most suggested that bofedales are permanent, though a few asserted that bofedales can also be seasonal. In fact, bofedales can be either year-round or seasonal; permanent and seasonal areas are also sometimes found in a single site.

The consequences of these differences in bofedal terminology and characterizations extend beyond impeding cross-disciplinary and inter-regional conversations. Uses of particular synonyms and descriptions of defining qualities, the role of local communities, and key threats, we suggest, can both reflect and reinforce a particular "politics of truth," shaping the way present-day changes in these landscapes are understood -- and, ultimately, how such changes are managed (c.f. Boelens et al. 2016). With respect to synonyms, some of the most common words employed were "wetland," "bog," and

"peatland," terms developed and defined based on the study of landscapes in regions of the Global North with ecological and social histories distinct from those of the Andes. As Earle et al. puts it, "the true bogs in the Northern Hemisphere...are the basis of nearly all knowledge of processes of peat accumulation and peatland development" (2003, 2).

The use of ecological categories developed in the study of Northern Hemisphere landscapes often led authors to characterize bofedales in terms of how they deviated from these standardized types. In some cases these synonyms also obscured the qualities unique to bofedales. Squeo et al., for instance, explained:

> These peatlands are like no other in the world. They have been referred to as "highland bogs"...but they are neither dominated by *Sphagnum* mosses nor are they exclusively ombrogenous, as is typical of true bogs in the Northern Hemisphere. Their only similarity to northern bogs is the microtopographic patterns of pools, lawns, and hummocks" (2006, 246).

Along similar lines, Coronel et al. introduced a description of bofedal characteristics with the phrase, "Unlike many peatlands in the northern hemisphere..." (2004, 85). Salvador et al., meanwhile, asserted, "Contrary to the main characteristic vegetation found in northern hemisphere peatlands…" (2010, 45). Earle et al. (2003), meanwhile, explains that 1 m^2 of *Oxychloe* peat (characteristic of bofedales) sequesters the same amount of atmospheric carbon in one year as at least 10 m^2 of *Sphagnum* peat (characteristic of certain wetlands in the Northern Hemisphere). In one sense, these comparisons describe physical resemblances in and distinctions between the hydrology, ecology, and carbon dynamics of these ecosystems. At the same time, defining bofedales in terms of their deviation from "true bogs" can position knowledge from Northern Hemisphere contexts as more legitimate than ecological classification systems developed in the Andes. Moreover, because Northern Hemisphere bogs and wetlands are not traditional herding sites, these synonyms do not highlight a key distinguishing characteristic of bofedales: the crucial role of local herding communities.

While the use of "bog" and "wetland" can reinforce the authority of ecological knowledge from the Global North and obscure histories of bofedal management, the use of local names can make visible, and validate, situated ecological knowledge. In their review of wetlands in Peru, for instance, Pérez and Echevarría explained:

> The Aymara people, settled in the southern Andes, have managed *oconales* for millennia by creating artificial peatlands (*turberas*), which have maintained the ecosystem (2002, 7, our translation).

The use of Quechua and Spanish words in this English-language article mirrors the authors' emphasis on the importance of localized skills, knowledge, and practices in adapting and sustaining bofedales. Indeed, Peréz and Echevarría (2002), as well as three additional studies, used synonyms that included the word "artificial" (Browman 1983; Erickson 2000; Lane 2009). Erickson, for instance, explained,

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> early hunters would have quickly realized the potential of improving natural wetlands or constructing artificial wetlands (bofedales) to increase populations (2000, 321).

The phrase "artificial wetlands" embeds an assertion that bofedales, though the vast majority form via natural causes, are shaped, managed, or expanded by people. Though this phrasing highlights the mutuality of many human-bofedal relationships, however, it is important to note that not all bofedales are actively managed. Some of the natural wetlands in the Cordillera Real of Bolivia that Ruthsatz (2012), Meneses et al. (2015), and Loza et al. (2015) document are also not managed by Aymara or Quechua communities, and often include those systems that form at high altitudes in less accessible regions near glacier margins.

4.2. Characterization of Tthreats and the Rrole of Llocal Ceommunities

As with bofedal synonyms and defining characteristics, the characterizations of threats not only varied but also sometimes directly conflicted. Some studies, for instance, suggested that population influx into rural areas posed a risk, while others argued that bofedales were endangered by the migration of herders to urban areas. Some authors asserted that bofedales were under threat due to the decline in traditional herding practices, while others contended that these practices have become less effective under current, unprecedented environmental pressures. While many studies cited lack of knowledge as a key obstacle, researchers disagreed about whether this uncertainty stemmed from a loss and marginalization of local management practices or a paucity of scientific study; others suggested it was not knowledge, but political will to act that was lacking. The variations in the key threats emphasized, in turn, shaped recommendations for how bofedales might most effectively be preserved.

While the threats discussed varied widely across all studies, however, disciplinary patterns also emerged. One particularly salient distinction was in the characterization of local communities. In this respect, the reviewed papers diverged in two ways: in whether community activities were considered a threat to bofedales, and in the extent to which key threats, including potentially harmful activities by local communities, were contextualized within broader historical and present-day power dynamics.

Broadly, these divergences aligned with disciplinary differences. Papers drawing on natural science methodologies were more likely to describe bofedales as purely natural, uncultivated landscapes and to highlight local management activities, including the quality and volume of grazing, as a major threat. Few natural science papers, moreover, discussed the role of historical and present-day stressors on local communities and ecosystems, such as state policies or market forces, in endangering bofedales. Studies that used social science methodologies such as ethnography and interviews, meanwhile, were more likely to discuss local communities as key in bofedal management. Social science and multidisciplinary papers were also more likely to list threats that corresponded to extractive activities by external actors, such as mining and large-scale agriculture. Papers employing qualitative methods were also more likely to contextualize shifting local management practices in broader contexts of power and inequality, highlighting the stress that longer-term socioeconomic and political dynamics such as marketization, colonial legacies, and economic inequality had placed on local communities.

This disciplinary distinction may be due, in part, to the limited capacity of some natural science methodologies to make visible the influence of local management practices. As Verzijl and Quispe documented in a multidisciplinary analysis of the irrigation technologies of the community of Ccarhuancho (Peru), Landsat Satellite data, for instance, has a resolution that is

> too crude to reveal local complexities and thus help[s] create the image of wetlands as natural expanses (2013, 287).

Moreover, methods that do not engage the knowledge of local actors, the authors further explained, may not accurately measure the influence of human activities on landscapes over historical timescales:

> over time, it becomes hard to distinguish between peatland produced by human intervention and that produced by natural processes...The history of a bofedal is known only to its makers" (Verzijl and Quispe 2013, 287).

As with the synonyms used, the classification of threats can shape understandings about which agents and processes sustain or harm bofedales. These conclusions, in turn, can influence both bofedal management and conservation policies and institutions. Frameworks that position local communities as a key threat, for instance, can lead to conservation approaches that exclude these communities from bofedales and even criminalize traditional management activities. Meanwhile, understandings that emphasize the risks of disruptions to traditional herding practices might inform a conservation strategy that supports and prioritizes local communities.

The relationship between a study's understanding of key threats and the management practices that emerged as promising was exemplified in the papers we reviewed by the varied characterizations of overgrazing. Overgrazing is an intensifying phenomenon that poses a significant threat to bofedal ecosystems and, in turn, to the communities that sustain and rely on them. Yet we observed distinctions in the level of risk attributed to overgrazing as compared with other threats such as climate change and mining, as well as with the factors to which overgrazing was attributed. Among natural science papers, overgrazing was tied with climate change as the most listed threat. In social science papers, however, overgrazing was the seventh most discussed risk -- behind state policy, market forces, mining, loss of tradition, climate change, and colonial legacies. Furthermore, we observed, some papers attributed bofedal degradation to "overgrazing" without clearly defining the term or describing its specific causes. When not clearly contextualized and delineated from traditional herding practices, descriptions of overgrazing in some cases implicitly implicated the ancestral practices of local communities in bofedal degradation. This interpretation can lead to policies that seek to terminate or limit access by herders.

Though many papers we reviewed presented overgrazing as fairly straightforward -- as too much grazing in one spot (e.g. Coronel et al. 2004, 85; Meza and Díaz 2014, 654) -- a few questioned the term's objectivity and validity. Some authors stressed that a base level of grazing can increase productivity and even be beneficial to bofedal environments (Browman 1982; Garcia et al. 2014). Browman, for instance, in a study of the impacts of ~~20th~~twentieth-century agricultural reforms in Peru and Bolivia, argued,

> the grasslands that exist today have been modified from their 'original' state, that abstract state in which there would have been no grazing selection on plant communities… In arid and alpine regions, the most effective method of exploiting the primary productivity of grasslands for human consumption is by grazing herd animals" (1983, 242).

Moreover, given that even healthy "Grazing by domesticated animals inevitably modifies the vegetation in comparison with its pristine state," the term "overgrazing," Preston et al~~et. al~~. argued, "is

misleading because any grazing removes plants that would otherwise be undisturbed, and this might constitute overgrazing" (Preston et al. 2003, 144–45).

The word "overgrazing" makes an implicit comparison, indicating a landscape's deterioration from an "original" or "pristine" state imagined to have existed in the past. Yet such a state, as Browman observed, is "abstract." As Baied and Wheeler asserted, under current ecological and climatic conditions the Andean plateau has never existed without human activity; "Twelve thousand years of continuous human occupation preceded European contact, and during this period natural resources were used, managed, and modified" (1993, 146; see also Denevan 1992). Thus, as Erickson argued in an archeology of human-environment interactions around Lake Titicaca over the past 8000 years, the distinction between "grazing" and "overgrazing" is not pregiven: "to argue whether human activities are environmental enhancements, sustainable land use, or environmental degradation requires subjective value judgments" (2000, 348).

Management practices based on the assumption that all human intervention is harmful to ecosystems can have counterintuitive effects, in some cases causing further social and environmental damage to bofedales. One striking example is "Project Alpaca," a 1990s initiative to privatize previously communal-access bofedales in the Bolivian Andes by providing fencing to herders. The rationale behind this project, that providing fencing to protect vegetation against grazing would sustain bofedales, echoed the characterizations of "overgrazing" that we observed in many of the other studies reviewed (Buttolph and Coppock 2001, 10). However, in the end, fencing provided few benefits for crop production and diminished ecological diversity - though in some cases it did decrease alpaca mortality rates. In the long term, moreover, the project shifted traditional social relationships, norms, and institutions in ways that diminished overall community resilience and heightened inequality, improving the conditions for larger-scale herders while leaving smaller herders more vulnerable to extreme weather events. The authors who assessed the project concluded that efforts to boost productivity via technological fixes can cause unanticipated impacts when existing social relations are ignored.

Crucially, the long history of human engagement with bofedales does not make all interventions equivalent. The ecological devastation inflicted by Spanish colonizers was vastly different from the sustaining practices of indigenous communities (Baied and Wheeler 1993). Today, meanwhile, practices like mining, agriculture, and in some cases intensifying land use practices are causing bofedales to change, and even disappear, at historically unprecedented rates. Setting aside binary conceptual models of "pristine" versus "degraded" environments, some studies have sought to engage a more participatory and historically-attuned inquiry into bofedal landscape changes. These analyses have made visible a diverse but intertwined set of possible causes for these shifts, including many threats to local management practices. These factors include the introduction of exotic grazing species by Spanish colonizers (e.g.

Hribljan et al. 2015; Struelens et al. 2017), market and migration pressures leading to changes in the availability of local herders (e.g. Yager 2015), behavioral shifts catalyzed by anthropogenic climate changes (e.g. Postigo et al. 2008; Villarroel et al. 2014), and increased erosion (e.g. Hartman 1996). Attending to local contexts and histories, as these studies have done, offers one means to assess bofedal sustainability while acknowledging the political nature of the categories and metrics such evaluations draw on.

5. Conclusions

This analysis has shown that different studies of bofedales in the Central Andes are grounded in a range of distinct definitions, synonyms, and interpretations of key threats. These at times conflicting understandings indicate the lack of a common research framework, which may impede the sharing of findings across local studies, disciplinary approaches, and languages of publication. Just as crucially, though the majority of papers reviewed employed natural science methods, the social science and multidisciplinary studies were more likely to explore the mutual relationship between bofedales and local herding communities -- to characterize bofedales as not purely *natural* but rather as complex cultural landscapes. Many of these papers, however, highlighted the crucial need for further study of these practices, as well as the threat posed by both socioeconomic shifts and conservation strategies that fail to recognize and support the vital role of indigenous pastoral communities in expanding, maintaining, and adapting these landscapes. Indeed, no studies thus far have sought to quantify the area of bofedal land that can be attributed to the expansion of human activities, and few have examined in depth the effect of human maintenance and adaptation activities on bofedal biology. These are questions that can best be answered using methodologies from the natural sciences.

These observations lead us to recommend, first, that future studies incorporate participatory, qualitative methods where possible. Second, we suggest that researchers begin to employ natural science methods to examine and quantify the effects of human activities on sustaining bofedales over time, adapting bofedales to climatic shifts and variabilities, and expanding these ecosystems across space. Third, we propose that researchers continue to develop frameworks for assessing and classifying bofedales that are grounded in socio-ecological systems. Ultimately, how bofedales are characterized shapes both academic findings and conservation practices. Only by developing research modalities that attend to complex human-environment dynamics and are rooted in local contexts can academic inquiry help support these landscapes and sustain their vital roles in ecosystems, carbon cycles, and communities.

The existence of these conflicting understandings has been recognized anecdotally by many bofedal researchers in both the natural and social sciences. However, this is the first paper to

systematically examine studies of bofedales across multiple languages, countries, and disciplines. This study, therefore, offers evidence to quantify and elucidate the range and distribution of definitions of bofedales in order to help facilitate more effective cross-disciplinary collaboration. These results may also help better attune researchers who study wetlands in other contexts to the ways in which the classifications and characterizations of wetland types can reflect not only physical characteristics but also the linguistic and disciplinary contexts of the research itself. –A shared framework of understanding of these landscapes would help facilitate more fruitful cross-national comparisons between bofedales and other wetlands.

For those who study bofedales, meanwhile, this data may help provide evidence to support and specify recommendations for future research and conservation. Solidifying a common framework of understanding is increasingly crucial as the field of bofedal research continues to grow -- and as the myriad threats to these ecosystems intensify.

Contributions

Study conception and design were performed by CW, MP, KY, RIM. Data were collected by CW. Data analysis was performed by CW, MP, KY, RIM. The first draft of the manuscript was written by CW and MP and revised by KY and RIM. This study was supervised by MP and KY. All authors read and approved the final manuscript.

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Data Availability

Not applicable.

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Code availability

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Declarations

Conflicts of Interest/Competing Interests

Not applicable.

Ethics Approval

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Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

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Fig. 1 **a)** Number of studies with research sites in each country included in analysis. Studies with multiple locations were also listed under each of the countries in which study sites were located **b)** Distribution of studied bofedales in papers reviewed, categorized by year

Fig. 2 Role of bofedales (as the central, primary field site or as one of multiple ecosystems examined) within papers reviewed

Fig. 3 Disciplinary and political distribution of papers reviewed, grouped by natural sciences, social sciences, and multidisciplinary studies. **a)** Overall disciplinary distribution. **b)** Distribution of disciplines by country and year

Fig. 4 Number of times each method was used in the papers reviewed, including ethnographic techniques (such as interviews, surveys, and participatory activities), natural science field methods (such as sampling and analysis of bofedal vegetation), computer modelling and statistical analysis, archival research, legal analysis, and use of satellite mapping. Note that many papers employed multiple methods

Fig. 5 Cloud diagram showing relative frequency of synonyms for "bofedal" used in studies in a) Argentina; b) Bolivia; c) Chile; d) Peru. Synonyms in studies with research sites in more than one location have not been included in the count. For all images, word size corresponds to the number of studies that employed each word or phrase. Spanish for commonly applied terms have been translated into English and added to English-language synonym counts; Quechua and Aymara words have been left in original languages. "Bofedal", a word used in 92 of the papers, is not included in the diagram. Spanish words have been translated as follows: turbera: peatland; humedal: wet meadow; cenegal: marsh; ciénega: swamp; pastizal: pasture; pasto: pasture; planicie: plain; pradera: meadow; pantanoso: marshy; humedal: wet; altoandino: high Andean; de altura: high altitude

Fig. 6 Defining characteristics of bofedales organized by the number of papers that mentioned them (the majority of studies listed more than one defining characteristic). Blue indicates characteristics related to water; red indicates geochemical features; green indicates vegetation composition; yellow indicates environment where bofedales are found; purple indicates ecosystem importance and consistency; grey indicates no definition provided

Fig. 7 Percentage of papers that did and did not mention community management of bofedales grouped by discipline

Fig. 8 Number of papers that mentioned each of the 22 categories of threats to bofedales (the majority of studies listed more than one threat). Yellow indicates past or present stressors to local communities; red indicates overgrazing and other forms of poor management on the part of local communities; blue indicates pressures from industry, agriculture, and urbanization; green indicates other environmental factors

Table 1 Top eight threats to bofedales listed for each study discipline (natural science, social science, or multidisciplinary). The number of times each risk was listed within each discipline is displayed in parentheses after each threat. Yellow indicates past or present stressors to local communities; red indicates overgrazing and other forms of poor management on the part of local communities; blue indicates pressures from industry, agriculture, and urbanization; green indicates other environmental factors

Natural Science	Social Science	Multidisciplinary
Overgrazing (38)	State policy (14)	Climate change (9)

Climate change (38)	Market (9)	Mining (8)
Mining (26)	Mining (8)	Overgrazing (8)
Water use (18)	Loss of tradition (7)	Nonnative grazers (6)
Lack of knowledge (17)	Climate change (6)	Loss of tradition (5)
Champeo (17)	Colonialism (6)	Market (5)
Weather (14)	Overgrazing (5)	State policy (5)
Poor management (12)	Weather (4)	Out-migration (5)

A. Supplementary Information

ESM 1 (DOCX 56 kb)

References

Baied, Carlos A., and Jane C. Wheeler. 1993. "Evolution of High Andean Puna Ecosystems: Environment, Climate, and Culture Change over the Last 12,000 Years in the Central Andes." Mountain Research and Development, 145–156.

Boelens, Rutgerd, Jaime Hoogesteger, Erik Swyngedouw, Jeroen Vos, and Philippus Wester. 2016. Hydrosocial Territories: A Political Ecology PerspectiveHydrosocial Territories: A Political Ecology Perspective. Taylor & Francis.

Britto, Berni. 2017. "Actualización de Las Ecorregiones Terrestres de Perú Propuestas En El Libro Rojo de Plantas Endémicas Del Perú." Gayana. Botánica 74 (1): 15–29.

Browman, David. 1982. "Agrarian Reform Impact on Llama and Alpaca Pastoralism in the Andes." Contemporary Nomadic and Pastoral Peoples: Africa and Latin America., 137–152.

Browman, D.L. 1983. "Andean Arid Ll and pPastoralism and dDevelopment." Mountain Research and Development, 241–252.

Bury, Jeffrey, Bryan G. Mark, Mark Carey, Kenneth R. Young, Jeffrey M. McKenzie, Michel Baraer, Adam French, and Molly H. Polk. 2013. "New Geographies of Water and Climate Change in Peru: Coupled Natural and Social Transformations in the Santa River Watershed." Annals of the Association of American Geographers 103 (2): 363–374.

Buttolph, Lita P., and D. Layne Coppock. 2001. "Project Alpaca: Intensified Alpaca Production

lLeads to pPrivatization of kKey gGrazing rResources in Bolivia." Rangelands Archives 23 (2): 10–13.

Capriles, José M., and Nicholas Tripcevich. 2016. The Archaeology of Andean PastoralismThe Archaeology of Andean Pastoralism. UNM Press.

Carevic, Felipe S., Ermindo Barrientos, and Maira Anderson. 2017. "Peatlands in nNorthern Chile: aAn oOverview from the pPerspective of pPlant hHydraulic tTraits for bBiological cConservation." IDESIA (Chile) 35 (3): 109–114.

Cooper, David J., Evan C. Wolf, Christopher Colson, Walter Vering, Arturo Granda, and Michael Meyer. 2010. "Alpine pPeatlands of the Andes, Cajamarca, Peru." Arctic, Antarctic, and Alpine Research 42 (1): 19–33.

Cooper, David J., Kristen Kaczynski, Daniel Slayback, and Karina Yager. 2015. "Growth and oOrganic cCarbon pProduction in pPeatlands dDominated by Distichia Muscoides, Bolivia, South America." Arctic, Antarctic, and Alpine Research 47 (3): 505–510.

Coronel, Jorge Santiago, Steven Declerck, Mabel Maldonado, Frans Ollevier, and Luc Brendonck. 2004. "Temporary sShallow pPools in hHigh-Andes 'Bofedal'Peatlands." Archives des SciencesArchives Des Sciences 57: 85–96.

Coronel, Jorge S., Steven Declerck, and Luc Brendonck. 2007. "High-aAltitude pPeatland tTemporary pPools in Bolivia hHouse a hHigh Cladoceran dDiversity." Wetlands 27 (4): 1166.

Denevan, William M. 1992. "The pPristine mMyth: tThe lLandscape of the Americas in 1492." Annals of the Association of American Geographers 82 (3): 369–385.

Domic, Alejandra I., José M. Capriles, Rosa Isela Meneses, and Paula Pacheco. 2021. "Plant community assembly is predicted by an environmental gradient in high-altitude wetlands in the semiarid western Bolivian Andes." Mires and Peat 27: 1–12.

Dorador, Cristina, Irma Vila, Karl-Paul Witzel, and Johannes F. Imhoff. 2013. "Bacterial and aArchaeal dDiversity in hHigh aAltitude wWetlands of the Chilean Altiplano." Fundamental and Applied Limnology/Archiv Für Hydrobiologie 182 (2): 135–159.

Earle, Lisa R., Barry G. Warner, and Ramon Aravena. 2003. "Rapid dDevelopment of an uUnusual pPeat-aAccumulating eEcosystem in the Chilean Altiplano." Quaternary Research 59 (1): 2–11.

Erickson, Clark. 2000. "The Lake Titicaca Basin: A Pre-Columbian Built Landscape." In Imperfect Balance: Landscape Transformations in the Precolumbian Americas, edited by D. Lentz, 311–56. New York: Columbia University Press.

https://repository.upenn.edu/anthro_papers/10.

Estenssoro, S. 1991. "Los Bofedales de La Cuenca Alta Del Valle de La Paz." Historia Natural de Un Valle En Los Andes: La Paz. Instituto de Ecología, Universidad Mayor de San Andrés, La PazHistoria Natural de Un Valle En Los Andes: La Paz. Instituto de Ecología, Universidad Mayor de San Andrés, La Paz, 109–121.

Flores, Mercedes, José Alegría, and Arturo Granda. 2005. "Diversidad Florística Asociada a Las Lagunas Andinas Pomacocha y Habascocha, Junín, Perú." Revista Peruana de Biología 12 (1): 125–134.

Gandarillas, Vanessa, Yong Jiang, and Kenneth Irvine. 2016. "Assessing the Services of High Mountain Wetlands in tTropical Andes: aA cCase sStudy of Caripe wWetlands at Bolivian Altiplano." Ecosystem Services 19: 51–64.

Garcia, Erick, and Marco Otto. 2015. "Caracterización Ecohidrológica de Humedales Alto Andinos Usando Imágenes de Satélite Multitemporales En La Cabecera de Cuenca Del Río Santa, Ancash, Perú." Ecología Aplicada 14 (2): 115–125.

Garcia, Mary Carolina, Rosa Isela Meneses, Kazuya Naoki, and Fabien Anthelme. 2014. "Métodos Para Evaluar El Efecto Del Pastoreo Sobre Las Comunidades Vegetales de Bofedales." Ecología En Bolivia 49 (3): 91–103.

Goitia, E., M. Maldonado, F. Acosta, N. de La Barra, M. Cadima, J. Coronel, and A. Salvatierra. 2007. "Tipificación de Humedales Altoandinos de Bolivia: Biocenosis Acuática de Los Bofedales." In Memorias Del Congreso Internacional Sobre Desarrollo, Medio Ambiente y Recursos Naturales, 2:1125–1129.

Hartman, B. D. 1996. "Sociocultural cConstraints to lLand mManagement dDecisions: tThe cCase of Bofedal rRestoration in Bolivia." Tropical Resources Institute 15 (1): 24–28.

Hribljan, J. A., D. J. Cooper, J. Sueltenfuss, E. C. Wolf, K. A. Heckman, E. A. Lilleskov, and R. A. Chimner. 2015. "Carbon sStorage and lLong-tTerm rRate of aAccumulation in hHigh-aAltitude Andean pPeatlands of Bolivia." Mires and Peat 15: 12.

Izquierdo, Andrea E., Javier Foguet, and H. Ricardo Grau. 2015. "Mapping and sSpatial cCharacterization of aArgentine hHigh Andean Peatbogs." Wetlands Ecology and Management 23 (5): 963–976.

Lane, Kevin. 2009. "Engineered hHighlands: tThe sSocial Organization of Water in the aAncient nNorth-Central Andes (AD 1000-1480)." World Archaeology 41 (1): 169–90. 41 (1): 169–90. https://doi.org/10.1080/00438240802655245.

Loza Herrera S., R. I. Meneses & F. Anthelme 2015. Comunidades vegetales de los bofedales de la

Cordillera Real (Bolivia) bajo el calentamiento global. Ecología en Bolivia 50(1): 39–56.

Maldonado, MS Fonkén. 2014. "An introduction to the bofedales of the Peruvian High Andes." Mires and Peat 15 (5): 1–13.

Meneses, Rosa I., Susi Loza Herrera, Alejandra Domic, Arely Palabral-Aguilera, Gabriel Zeballos, and Teresa Ortuño. 2015. "Bofedales Altoandinos." In Historia Natural de Un Valle En Los Andes: La Paz, edited by Isabel Moya, Rosa I. Meneses, and J. Sarmiento, Museo Nacional de Historia Natural., 191–205.

Meza, M., and Y. Díaz. 2014. "Effects of climate variability on water level fluctuations and farming practices in Andean highland wetlands." Interciencia 39 (9): 651–58.

Nina Huanca, G. S., S. Loza Herrera, R. K. Gonzales Pomar, and François Rebaudo. 2015. "El ser humano: un actor de la dinámica de los ecosistemas altoandinos de la Cordillera Real." In La Cordillera Real y sus plantas, edited by R.I. Meneses, S. Beck, and F. Anthelme. La Paz, Bolivia: IRD, FFEM and FRB.

Orlove, Benjamin S. 1977. Alpacas, Sheep, and Men: The Wool Export Economy and Regional Society. New York, NY: Academic Press.

Otto, Marco, and Richard E. Gibbons. 2017. "Potential Effects of Projected Decrease in Annual Rainfall on Spatial Distribution of High Andean Wetlands in Southern Peru." Wetlands 37 (4): 647–59. https://doi.org/10.1007/s13157-017-0896-2. 37 (4): 647–59. 10.1007/s13157-017-0896-2.

Palacios, Félix. 1977. "Pastizales de regadío para alpacas." In Pastores de puna: Uywamichiq PunarunakunaPastores de puna: Uywamichiq Punarunakuna, edited by J.A. Flores, 155–170. Lima, Peru: Instituto de estudios Peruanos.

Salvador Pérez, Flor, and Christhian Monsalve López. 2002. "Lagunas y Oconales : Los Humedales Del Trópico Andino." Cuadernos de Biodiversidad 11 (January). https://doi.org/10.14198/cdbio.2002.11.01. 11 (January). 10.14198/cdbio.2002.11.01.

Postigo, Julio C., Kenneth R. Young, and Kelley A. Crews. 2008. "Change and Continuity in a Pastoralist Community in the High Peruvian Andes." Human Ecology 36 (4): 535–51. https://doi.org/10.1007/s10745-008-9186-1. 36 (4): 535–51 10.1007/s10745-008-9186-1.

Preston, D., J. Fairbairn, N. Paniagua, G. Maas, M. Yevara, and S. Beck. 2003. "Grazing and eEnvironmental cChange on the Tarija Altiplano, Bolivia." Mountain Research and Development 23 (2): 141–48. https://doi.org/10.1659/0276-4741(2003)023[0141:GAECOT]2.0.CO;2.

Prieto, Manuel. 2015. "Privatizing wWater in the Chilean Andes: tThe cCase of Las Vegas de Chiu-Chiu." Mountain Research and Development 35 (3): 220–29. 10.1659/MRD-JOURNAL-D-14-00033.1.

Ruthsatz, Barbara. 2012. "Vegetación y Ecología de Los Bofedales Altoandinos de Bolivia." Phytocoenologia 42 (3–4): 133–179.

Salvador, F., J. Monerris, and L. Rochefort. 2010. "Peruvian pPeatlands (Bofedales): fFrom Andean tTraditional mManagement to mModern eEnvironmental iImpacts." Peatlands International 2: 42–48.

Squeo, Francisco A., Barry G. Warner, Ramon Aravena, and Diana Espinoza. 2006. "Bofedales: hHigh aAltitude pPeatlands of the Central Andes." Revista Chilena de Historia NaturalRevista Chilena De Historia Natural 79 (2): 245–55.

Struelens, Quentin, Karina Gonzales Pomar, Susi Loza Herrera, Gaby Nina Huanca, Olivier Dangles, and Francois Rebaudo. 2017. "Market aAccess and cCommunity sSize iInfluence pPastoral Management of Native and Exotic Livestock Species: aA cCase sStudy in cCommunities of the cCordillera rReal in Bolivia's hHigh Andean wWetlands." PLoS OnePlos One 12 (12): e0189409. https://doi.org/10.1371/journal.pone.0189409. 12 (12): e0189409. 10.1371/journal.pone.0189409.

Urrutia, Rocío, and Mathias Vuille. 2009. "Climate cChange pProjections for the tTropical Andes uUsing a rRegional cClimate mModel: tTemperature and pPrecipitation sSimulations for the eEnd of the 21st cCentury." Journal of Geophysical Research: Atmospheres 114 (D2). https://doi.org/10.1029/2008JD011021. 114 (D2). 10.1029/2008JD011021.

Verzijl, Andres, and Silvano Quispe. 2013. "The sSystem nNobody sSees: iIrrigated wWetland mManagement and aAlpaca hHerding in the Peruvian Andes." Mountain Research and Development 33 (3): 280–93. https://doi.org/10.1659/MRD-JOURNAL-D-12-00123.1. 33 (3): 280–93. 10.1659/MRD-JOURNAL-D-12-00123.1.

Villagrán, C, and V Castro. 1997. "Etnobotánica y Manejo Ganadero de Las Vegas, Bofedales y Quebradas En El Loa Superior, Andes de Antofagasta, Segunda Región, Chile."

Chungara, 275–304.

Villarroel, Elena K., Paula Lady Pacheco Mollinedo, Alejandra I. Domic, Jose M. Capriles, and Carlos Espinoza. 2014. "Local Management of Andean Wetlands in Sajama National Park, Bolivia." Mountain Research and Development 34 (4): 356–68. https://doi.org/10.1659/MRD-JOURNAL-D-14-00024.1. 34 (4): 356–68. 10.1659/MRD-JOURNAL-D-14-00024.1.

Wilcox, B. P., F. C. Bryant, D. Wester, and B. L. Allen. 1986. "Grassland cCommunities and sSoils on a hHigh eElevation gGrassland of Central Peru." Phytologia (USA).

Yager, Karina. 2015. "Satellite iImagery and cCommunity pPerceptions of cClimate cChange Impacts and lLandscape cChange." Climate Cultures: Anthropological Perspectives on Climate Change, 146–146.

Yager, Karina, H. Resnikowski, and Stephan Halloy. 2008. "Grazing and cClimatic vVariability in Sajama National Park, Bolivia." Pirineos : Revista de Ecología de MontañaPirineos : Revista de Ecología de Montaña 163 (December). 10.3989/pirineos.2008.v163.25.

Yager, Karina, Corinne Valdivia, Daniel Slayback, Elizabeth Jimenez, Rosa Isela Meneses, Arely Palabral, Mary Bracho, et al. 2019. "Socio-eEcological dDimensions of Andean pPastoral lLandscape cChange: bBridging tTraditional eEcological kKnowledge and sSatellite iImage aAnalysis in Sajama National Park, Bolivia." Regional Environmental Change 19 (5): 1353–69. 10.1007/s10113-019-01466-y.

Zimmer, Anaïs, Rosa I. Meneses, Antoine Rabatel, Alvaro Soruco, and Fabien Anthelme. 2014. "Caracterizar La Migración Altitudinal de Las Comunidades Vegetales Altoandinas Frente al Calentamiento Global Mediante Cronosecuencias Post-Glaciales Recientes." Ecología En Bolivia 49 (3): 27–41.