

1 Declining Use of Totora (*Schoenoplectus californicus* subsp  
2 *tatora*) in Lake Titicaca

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17

18 **Abstract**

19

20 Local Ecological Knowledge (LEK) is fast disappearing globally but the drivers of this loss  
21 are not fully understood. We present a a case study of how even long-standing and regulated  
22 forms of LEK are vulnerable to erosion as market forces spread to regions which have  
23 historically been peripheral to global markets. We consider changes in knowledge and use of a  
24 cultural keystone species, totora, in the Altiplano of Bolivia and Peru around Lake Titicaca.

25 Totora has been used for a variety of purposes and historically its cultivation and planting  
26 was regulated by village co-operative councils, called *ayllus*. We argue that a significant  
27 decline in the use of totora in the Altiplano along with the disappearance of the regulatory  
28 power of *ayllus* have primarily been driven by the integration of the Altiplano into the global  
29 market system, which has led to the replacement of totora with industrially manufactured  
30 goods, such as plastics and concrete. It has also undermined social bonds as individuals rather  
31 than the ayllu become the fundamental agents of economic decision-making.

32

33 **Keywords:** Traditional Ecological Knowledge, *ayllu*, Loss of Traditional Knowledge,

34 Totora, Altiplano, Lake Titicaca, Peru, Bolivia

35

36

37 **Introduction**

38 Traditional Ecological Knowledge (TEK) and Local Ecological Knowledge (LEK) both  
39 comprise knowledge of the natural world discerned through direct interaction over extended  
40 periods of time (Berkes et al., 2000; Brook & McLachlan, 2008). Definitions vary  
41 substantially, and whether they can be meaningfully distinguished is the subject of ongoing  
42 academic debate (Souto & Ticktin, 2012). However, there is widespread recognition of their  
43 increasing erosion worldwide (Leony & Voeks, 2004; Aparicio Aparicio et al., 2021). The  
44 drivers of this loss are various, but include formal education (Voeks & Leony, 2004; Aparicio  
45 Aparicio et al., 2021), urbanisation (Sogbohossou et al., 2015; Gosler & Tilling, 2022),  
46 changing gender roles (Souto & Ticktin, 2012; Brandt et al., 2013; Mathez-Stiefel et al.,  
47 2016; Aparicio Aparicio et al., 2021), socio-economic changes (Aparicio Aparicio et al.,  
48 2021), age (Voeks & Leony, 2004; Souto & Ticktin, 2012; Brandt et al., 2013; Mathez-  
49 Stiefel et al., 2016; Aparicio Aparicio et al., 2021), ethnic interactions (Eyssartier et al.,  
50 2008), changes in religious practice (Rist et al., 2003; Gruberg et al., 2022), and migration  
51 patterns (Souto & Ticktin, 2012; Brandt et al., 2013; Aparicio Aparicio et al., 2021). The  
52 most studied drivers of loss of TEK have been the effects of age and education. While most  
53 studies have found that the young have less ethnobotanical knowledge than the old, there is  
54 disagreement about how to interpret these findings. Some argue that it indicates a loss of  
55 ethnobotanical knowledge (Begossi et al., 2002; Aparicio Aparicio, 2021), while others argue  
56 that ethnobotanical knowledge may be gained over a lifetime, making low scores of  
57 ethnobotanical knowledge among the young misleading (Voeks & Leony, 2004; Quinlan &  
58 Quinlan, 2007). There is less debate, however, over the decline in the habitual use of  
59 traditional botanical sources – even among those who know the properties and traditional  
60 uses of plants (Voeks & Leony, 2004; Aparicio Aparicio, 2021).

61

62 Most ethnobotanical studies have focused on a suite of plants that are used or known  
63 about by individuals in one geographic area or ethnic group (Begossi et al., 2002; Mathez-  
64 Stiefel et al., 2012; Aparicio Aparicio et al., 2021; Gruberg et al., 2022). Here, we focus on  
65 the use of one plant: the Totora reed (*Schoenoplectus spp.*). Single species studies have some  
66 disadvantages over multi-species studies, such as not incorporating all types of TEK that exist  
67 within a community, relationships among species, and the inability to compare changes of  
68 use between types of use or species. But they can allow researchers to understand in greater  
69 detail the drivers of changes of use (Banack et al., 2004; Brandt et al., 2013; Sogbohossou et  
70 al., 2015). This is especially useful when studying species that are, or until recently were,  
71 culturally or economically important keystone species, i.e., species particularly important for  
72 ecosystem function (Paine, 1966), or, in the case of cultural keystone species, particularly  
73 central to the functioning of a particular human culture or group (Garibaldi & Turner, 2004).  
74 Focusing on well-documented species can also allow for direct historical comparison of uses.

75  
76 Totora, generally identified as *Schoenoplectus californicus*, subsp. *tatora* (Banack et  
77 al., 2004), but likely to be multiple species of *Schoenoplectus* (PVN, pers. obs.), (Fig. 1) is a  
78 perennial aquatic sedge native to South America but is also now found as far north as  
79 California. It is an invasive plant in other parts of the world, such as New Zealand (Heiser,  
80 1974; de Lange et al., 1998). Totora has been a cultural keystone species for both the coastal  
81 and the lakeside communities of Peru, Bolivia, and Chile for several thousand years (Bruno et  
82 al., 2021; Stanish, 2003; Banack et al., 2004; Erickson, 2000; Macía & Balslev, 2000; Levieil  
83 & Orlove, 1992; Levieil & Orlove, 1990; Heiser, 1978; Forman, 1977; Heiser, 1974; La  
84 Barre, 1948; Mishkin, 1946; Tschopik, 1946; La Barre, 1941; Tutin, 1940; Forbes, 1870).  
85 Historically, totora has been used to create vessels (Stanish, 2003; La Barre, 1948; Mishkin,  
86 1946), for roofing (Forbes, 1870; Gilson, 1938), as animal feed (Banack et al., 2004), and to

87 produce artisanal goods, such as mats and baskets (Mishkin, 1946; La Barre, 1948; Banack et  
88 al., 2004). Totora is especially important culturally in the Altiplano region around Lake  
89 Titicaca. Though totora is not a domesticated plant, it was and is managed by the people of  
90 Lake Titicaca. This includes deliberate plantings where totora is absent, and burnings (Fig. 2)  
91 to encourage the growth of new totora stands during August and September (La Barre, 1948;  
92 Heiser, 1978; Erickson, 2000; Stanish, 2003; Banack et al., 2004). This long-term use,  
93 harvesting, and planting of totora by the indigenous people of the Altiplano gives us  
94 confidence that the communities' knowledge of totora meets the criteria of TEK (Berkes et  
95 al., 2000). We explore the drivers of changing uses of totora in the Lake Titicaca region, and  
96 consider how the decline of a once prominent cultural keystone species may reflect on other  
97 forms of Traditional and Local Ecological Knowledge in the Altiplano region of Peru and  
98 Bolivia.



99  
100 Figure 1 Totora in Lake Titicaca



Figure 2 Smoke from totora burning in Peru in August, 2022

101  
102

103

## 104 **Historical Ecology of the Totora and Altiplano Societies near Lake Titicaca**

### 105 Ecological Importance of Totora

106 In addition to its cultural value, totora is an important ecosystem engineer in Lake Titicaca.

107 Totora wetland is one of the major characteristic aquatic vegetative zones of the Lake (Tutin,  
108 1940), dominating most of the area and a breeding habitat of the endemic Titicaca Grebe

109 (*Rollandia microptera*) and the Titicaca Giant Frog (*Telmatobius culeus*), both of which are

110 listed as endangered by the International Union for the Conservation of Nature (IUCN)

111 (Villar et al., 2023; Fjeldså, 1981; Vellard, 1992). Totora wetlands are also thought to be an

112 important habitat for many of fish, including endemic pupfish of the genus *Orestias* (Vila et

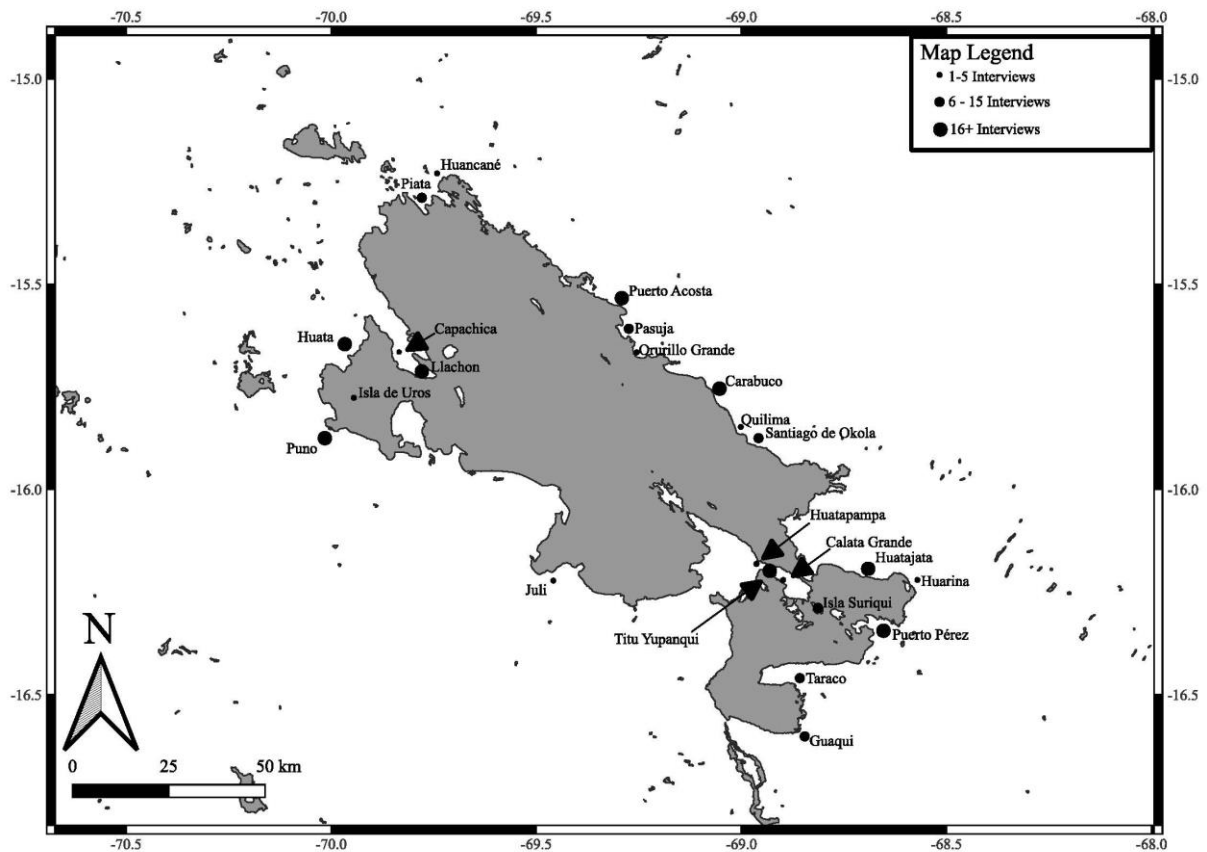
113 al., 2007; Lauzanne, 1992). This ecosystem also provides shelter to many endemic

114 invertebrates, most of which probably remain to be discovered (Jaume et al., 2021; Kroll et

115 al., 2012; Boury-Esnault & Volkmer-Ribiero, 1992; Mourguiart, 1992; Dejoux, 1992). In  
116 addition to hosting these endemics, the totora wetlands of Lake Titicaca are an important  
117 habitat for many species of waterfowl, including the Andean Ruddyduck (*Oxyura*  
118 *ferruginea*), the Puna Teal (*Spatula Puna*), Slate-coloured Coot (*Fulica ardesiaca*), and  
119 White-tufted Grebe (*Rollandia rolland*), amongst others (Pulido Capurro, 2018; Fjeldså &  
120 Krabbe, 1990; Fjeldså, 1981). Despite the high cultural and biological importance of totora  
121 wetlands, it remains, like many high-altitude wetlands, critically understudied from a  
122 biological, ethnobiological, and conservation perspective (Aber et al., 2012; Harden &  
123 Fernández, 2022).

124

## 125 Situating Altiplano Societies



126

127 Figure 3 Map of Lake Titicaca, with locations of interviews highlighted

128

129 Lake Titicaca is the highest altitude navigable lake on earth and is the centre of the broader  
130 Altiplano cultural region, a broadly flat area of the central Andes between 3800 and 4000  
131 m.a.s.l., a landscape that has been heavily modified by agricultural societies since at least  
132 3,500 BP (Fig. 3) (Ellenberg, 1979; Kent et al., 1999). Totora appears to have been  
133 introduced by humans to Lake Titicaca from the Pacific coast around 3,500 BP (Erickson,  
134 2000; Paduano et al., 2003; Bruno et al., 2021) and the paleopalynological record suggests  
135 that it has remained important for the human cultures of the lake. Early anthropological work  
136 showed that totora was most extensively used by the Uro ethnic group (Forbes, 1870; La  
137 Barre, 1948). Until recently, the Uro resided on floating islands of dried totora (La Barre,  
138 1948; Orlove, 1991; Stanish, 2003; Banack et al., 2004), and many still own such islands,  
139 though now they are mainly operated for tourism. The Uro have historically been the poorest  
140 group around Lake Titicaca, and discrimination against them, even by other Indigenous  
141 people such as the Aymara and the Quechua, continues to be documented up to the present  
142 day (Kent, 2013; de Loma et al., 2019). This anti-Uro sentiment has been directly tied to the  
143 Uro's aquatic and semi-nomadic traditional lifestyle, which entails neither land ownership  
144 nor cultivation in the popular manner of the peoples of the Altiplano (La Barre, 1941; de la  
145 Barra Saavedra et al., 2011; Lara Barrientos, 2012). This nomadic and semi-aquatic lifestyle  
146 is so predicated on the use and cultivation of totora, that the Peruvian government has given  
147 special rights to Uro communities to cultivate totoras in what are otherwise protected areas,  
148 including the Reserva Nacional del Titicaca (Orlove, 1991). The Uro have historically been  
149 the ethnic group around Lake Titicaca most reliant on totora, but two other dominant ethnic  
150 groups of the region, the Aymara, and the Quechua, have also historically used totora to make  
151 reed boats, as livestock feed, and for artisanal products (Forbes, 1870; Mishkin, 1946;  
152 Tschopik, 1946).

153           Historically, the management of totora has been communal, and organised through a  
154 clan-based governance system called *ayllu* (La Barre, 1946; Erickson, 2000; Banack et al.,  
155 2004), which has been, for most of the period since the Spanish conquest, the basic form of  
156 organisation of Altiplano society (Mishkin, 1946; Erickson, 2000). Its kinship structure  
157 centres on the extended families in each village and oversees communal properties such as  
158 grazing lands, fishing territories, and totora fields (Tschopik, 1946; Levieil & Orlove, 1990;  
159 Villaroel et al., 2014). Multiple attempts were made to outlaw *ayllus* in both Peru and Bolivia  
160 during the nineteenth and twentieth centuries (Tschopik, 1946; La Barre, 1948), and multiple  
161 failed predictions were made of its imminent collapse as a viable form of collective resource  
162 management (Mishkin, 1946; La Barre, 1948; Rist et al., 2003). Since the Bolivian  
163 Revolution of 1952 and the Peruvian Land Reform of 1969, both countries have officially  
164 recognised the legal rights of *ayllus* (Rist et al., 2003), and since 2009 these have been  
165 enshrined in the Bolivian constitution (Schilling-Vacaflor, 2011). The modern *ayllu* is thus  
166 more of an administrative unit that shares a name with this ancient collective mode of  
167 production (Eisenberg, 2013) than a direct transposition to the present day, and until recently  
168 was the primary means of regulating the use of totora in the Altiplano (Orlove, 2002; Banack  
169 et al., 2004).

170

171           Twenty years ago, Banack et al. (2004) found that totora was beginning to be  
172 harvested at greater intensity around Lake Titicaca than previously, and at levels that they  
173 considered unsustainable. They also documented several sustainable traditional practices of  
174 totora harvest, including annual burnings to remove older plants, and communal control of  
175 totora by *ayllus*, though they also noted an apparent weakening in the power of *ayllus* to  
176 regulate individual totora cultivation. They attributed the increasing intensity of totora harvest  
177 to the increasing population around Lake Titicaca. Since then, a generation has passed that

178 has seen a further weakening of traditional economic structures but capitalistic gain that has  
179 been associated with reduced poverty and increased migration to urban areas in the Altiplano.  
180 The region has also seen significant political change, especially in Bolivia, where a socialist  
181 government has restructured society and the economy since 2006. Our objective was to  
182 determine what has changed in the cultivation and uses of totora, and whether the increased  
183 intensity of traditional harvesting techniques and uses described by Banack et al. have  
184 persisted during this period of rapid poverty reduction in the region as well as urbanisation,  
185 the growth of the tourism sector, the expansion of education, greater freedoms for women,  
186 decline in the birth-rate, and growth in Christian evangelicalism. While these differences  
187 have occurred on both the Peruvian and the Bolivian sides of Lake Titicaca (Webber, 2016),,  
188 there has been greater disruption of traditional patterns of living on the Bolivian side due to  
189 faster economic development in rural Bolivia since 2006.

190

191       Following previous work on demographic factors influencing loss of TEK in rapidly  
192 changing societies (Rist et al., 2003; Voeks & Leony, 2004; Brandt et al., 2013; Sogbohossou  
193 et al., 2015; Mathez-Stiefel et al., 2016; Aparicio Aparicio et al., 2021; Gruberg et al., 2022)  
194 we hypothesised that country, sex, profession, religion, age, ethnicity, education, migrant  
195 status, language use, and family size could all potentially influence the degree of change in  
196 whether and how individuals use totora in the region. We first describe our materials and  
197 mixed methods before presenting our findings. We then discuss the potential effects that the  
198 declining use of totora as a cultural keystone species may have on contemporary Indigenous  
199 culture and knowledge.

## 200 **Materials & Methods**

201 Study Area

202 Lake Titicaca, the highest-altitude navigable lake on earth with a surface altitude of 3,812  
203 metres (Wirrman, 1992), forms the core of the watershed that is the main source of water in  
204 the Altiplano. Lake Titicaca is shared between Peru and Bolivia. The lake is further divided  
205 into two major sub-lakes: Lago Mayor is the larger and includes all the deep-water sections  
206 of the lake, as well as the majority of the totora wetland (Wirrmann, 1992, Villar et al., 2023);  
207 and Lago Menor, a shallow lake with an average depth of nine metres (Wirrmann, 1992) and  
208 a higher degree of primary productivity for its area than Lago Mayor (Richerson et al., 1992).  
209 Lago Menor is also the region of Lake Titicaca with the longest archaeological record of  
210 totora use and fishing by humans (Bruno et al., 2021). The entirety of Lake Titicaca has seen  
211 increases in pollution in the last several decades (Guédron et al., 2017; Guédron et al., 2020),  
212 which might also influence the growth of totora, although the plant has proven resilient to  
213 pollution in other contexts (Blanco, 2019).

214

215         The Altiplano cultural landscape surrounds Lake Titicaca (Ellenberg, 1979; Young,  
216 1997; Brown & Mitchell, 2000). Whether the the region may have been forested before  
217 agriculture remains debated, (Fjeldså, 2002; Kessler, 2002; Paduano et al., 2003; Gosling et  
218 al., 2009; Hanselman et al., 2011), but the naturally occurring vegetation now is Puna  
219 grassland (Pulgar Vidal, 1987; Ibarguchi, 2014), such as *Jarava ichu*, *Azorella compacta*, and  
220 *Festuca dolichophylla*. There are marked wet and dry seasons, with a dry austral winter and a  
221 wet austral summer (Pulgar Vidal, 1987). In addition to the grassland, the Altiplano is also  
222 home to many small lakes that may be important repositories for biodiversity, but remain  
223 understudied. There are also pockets of non-Puna ecosystems around the Altiplano, such as  
224 *bofedales* peatlands (Squeo et al., 2006) and isolated pockets of *Polylepis* (Fjeldså, 2002).

225

226           While Puna grassland is the current naturally occurring landscape around Lake  
227 Titicaca, most of the area remains used for agriculture, primarily by subsistence farmers,  
228 though sheep herding is also common (Morales Garzón, 2007; Rojas et al., 2014; Fagandini  
229 & Bazili, 2016). Most of the land has been used for agriculture since before the Spanish  
230 conquest (Erickson, 2000; Stanish, 2003), when Andes the mountain range was named for its  
231 agricultural terraces (Ellenberg, 1979). However, these terraces are now abandoned and  
232 many villages have become depopulated as young people move to the cities (D. A. V., pers.  
233 obs.). This may be causing a renewed expansion of Puna grassland, as has occurred in other  
234 regions (Poyatos et al., 2003; Navarro & Pereira, 2012), including other parts of the Andes  
235 (Haller & Bender, 2015). To our knowledge, no such study has been done to test whether this  
236 is the case in the Altiplano.

237

#### 238 Data Collection

239 We adopted a mixed methods approach to ethnographic data collection that included semi-  
240 structured interviews, participant observation, and archival research coupled with quantitative  
241 surveys (Creswell and Creswell, 2017). We conducted semi-structured interviews with  
242 individuals in Spanish or, in cases where individuals were monolingual in Aymara, with the  
243 aid of an interpreter. We interviewed a total of 221 individuals from 23 locations: 143 in  
244 Bolivia and 78 in Peru, over the course of six months. Interviews lasted between 15 minutes  
245 and two hours, and were conducted face-to-face, in Bolivia from March to June and in Peru  
246 from June to September in 2022. Responses were digitally recorded and transcribed after  
247 fieldwork by the first author. The interviewees were a convenience sample of the Altiplano  
248 population that we considered necessary due to the dispersed and rural nature of Altiplano  
249 population. Time constraints also prevented the creation of a mechanism to randomly sample  
250 the wider population. While this is not ideal, convenience sampling has been used previously

251 in ethnobiological studies (e.g., Cruz et al. 2014, Gutiérrez Alonso et al., 2020), and is  
252 considered a valid way of collecting information on community ethnobiological knowledge  
253 (Creswell & Creswell 2017). We collected demographic information (age, sex, birthplace,  
254 present community, ethnic group, education, main language & languages spoken, family size,  
255 profession, and family size) (Appendix 1). We then asked about current or prior personal use  
256 of totora and the regulation and cultivation of totora. During the dry season (August) we  
257 engaged in participant observation during totora collection. Ethical approval was obtained  
258 from the Departamento de Biología, Universidad Nacional del Altiplano en Puno (UNAP).

259

#### 260 Quantitative Data Analysis

261 We constructed a Generalised Linear Mixed Model, with binomial distribution using a logit  
262 link function, with the fixed effects of country, gender, age, religion, ethnicity, residence,  
263 education, profession category, primary language, and household size, and the random effect  
264 of the birthplace, current place of residence, and location of the interview, and the dependent  
265 variable being either current or past use of totora. Since questions about totora collection  
266 management elicited a qualitative response, we did not subject it to statistical analysis (see  
267 supplemental materials). We tested for collinearity of these variables by measuring the  
268 variance inflation factor (VIF) of all categories and found all of them to have a VIF of under  
269 5, which means that they could be included without risking multicollinearity (Akinwande et  
270 al., 2015). Since this study grew out of a wider study focused on the interaction between  
271 fishers and non-fishers with the aquatic resources of Lake Titicaca, profession is divided  
272 between those involved in fisheries and those who are not. Statistical analysis was conducted  
273 in SPSS Statistics and in R using the lme4 package (Bates et al., 2015).

274

#### 275 Qualitative Data Analysis

276 We performed a thematic analysis of the qualitative data (Newing, 2011) of the  
277 correspondents' responses to assess how totora is used, and, in cases where individuals no  
278 longer used totora, why they stopped using it. Qualitative analysis involves a close reading of  
279 responses and allows us to tease out the causes of declining totora use as understood by our  
280 informants. DAV recorded daily field notes of participant observation and subsequently  
281 analysed them (Creswell & Creswell, 2017) to compare present use of totora to the results of  
282 previous studies, including harvesting methods during the end of the dry season in August  
283 and September (Banack et al., 2005; Leviel & Orlove, 1992; Heiser, 1978; La Barre, 1948;  
284 Mishkin, 1946; Tschopik, 1946; La Barre, 1941; Tutin, 1940; Forbes, 1870). DAV translated  
285 responses into English, which were verified by the co-authors.

286

## 287 **Results**

288

### 289 Quantitative Results

290

291 One hundred and twelve of the 221 respondents said that they currently used totora, 45 said  
292 they had previously used totora but have now ceased, and 64 said that they had never used  
293 totora. None of our respondents mentioned the collective management of totora as described  
294 by past researchers (Levieil & Orlove, 1990; Banack et al., 2004). However, several did  
295 mention that they were aware of this totora management technique, or that it had been used in  
296 their village in the past. When asked how totora is managed, all respondents, said that there  
297 were individual plots owned by households or individuals and that people had absolute  
298 freedom to do as they wished with those plots. However, there does appear to be some degree  
299 of coordination of totora use between neighbouring plots, especially regarding planting totora  
300 in areas where there previously was none, and the annual burning of old totora in August and

301 September., The most common response (N = 98) to a question about current use of totora  
 302 was for feeding livestock, followed by traditional handicrafts (N = 27), and human  
 303 consumption, especially of its white root, which was likened to cheese (N = 14). Several  
 304 interviewees described multiple uses. Production of traditional handicrafts seems to be  
 305 restricted primarily to areas where tourism has overtaken agriculture as the primary industry,  
 306 such as the floating village of the Uro in Puno Bay, Llachon, in Peru, and Santiago de Okola,  
 307 Huatajata, Guaqui, and Copacabana in Bolivia.

308

309 Of the variables studied, only profession had a statistically significant effect on  
 310 whether individuals still cultivated totora. Those who did not engage in fishing were more  
 311 likely to harvest totora than were other groups. Of these, the majority were agriculturalists,  
 312 who harvest totora as feed for livestock (Table 1).

313

314 Table 1

315 Predictors of current use of totora by individuals (AIC = 314.5252)

Fixed Effect	F	df	Sig.
Country	0.260	1	0.611
Sex	0.011	1	0.989
Age	0.797	1	0.373
Religion	0.121	2	0.997
Ethnicity	0.069	3	0.976
Residence	0.302	1	0.584
Education	0.403	8	0.918
<b>Profession</b>	<b>4.538</b>	<b>1</b>	<b>0.034</b>
Primary Language	0.579	5	0.716

Family Size	0.405	10	0.943
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316

317           Profession and country had a significant effect on whether individuals had abandoned  
318 the use of totora. Bolivians were more likely than Peruvians to have ceased to use totora, and  
319 fishers were more likely to have abandoned the use of totora than other professions (Table 2).

320

321

322 Table 2. Predictors of an individual having ceased to use totora (AIC = 252.5479)

Fixed Effect	F	df	Sig.
<b>Country</b>	<b>4.000</b>	<b>1</b>	<b>0.049</b>
Sex	0.103	1	0.749
Age	0.018	1	0.893
Religion	0.269	8	0.949
Ethnicity	1.795	3	0.174
Residence	0.056	1	0.814
Education	0.736	8	0.807
<b>Profession</b>	<b>6.929</b>	<b>1</b>	<b>0.010</b>
Primary Language	1.488	5	0.215
Family Size	1.097	10	0.376

323

324

### 325 Qualitative Findings

326 Most people in the Altiplano either currently use or previously used totora. However the  
327 number of people who still use totora and the uses to which it is put appear to have declined  
328 since the last published study on totora use in the Lake Titicaca region (Banack et al., 2004).

329 Some respondents indicated that they were nostalgic for some uses of totora. One farmer in  
330 El Muelle, Bolivia, said that he missed “the taste of totora root, which young people today  
331 don’t know”<sup>1</sup>. Some even indicated that they thought that some of the old totora products  
332 were of higher quality than modern products, such as one man in Huatajata, Bolivia, who said  
333 that “totora cushions are more comfortable than the ones you get now”<sup>2</sup>. Despite nostalgia  
334 from some elements of Altiplano society, there appears to be very little effort to restore the  
335 use of totora to its former prominence. The reason for this is perhaps clear enough; a  
336 colleague of the authors, who did not participate in the questionnaire but is a fisherman in the  
337 community of Chimu, Peru, and a park ranger at the Reserva Nacional del Titicaca, said “It’s  
338 a lot of effort to make things from totora, easier to go to Puno and buy them”<sup>3</sup>.

339

340 We found no evidence for the previously well documented collective management of  
341 totora through *ayllus*. Instead, totora management is now highly individualised with  
342 respondents saying that “each person controls their own totora”<sup>4</sup> or that “each person has  
343 their own parcel of totora, and they control it”<sup>5</sup>. Nonetheless, the *ayllu* has not completely  
344 disappeared but rather modernised as in at least some towns it appears to have been replaced  
345 by a town council, with *concejales* and *alcaldes* taking the place of *mallkus*. Interviewees  
346 were still aware of the old collective management of totora, but, as one in Calata Grande,  
347 Bolivia, commented the traditional collective management of totora was something that “used  
348 to exist, back when there was an *ayllu*”<sup>6</sup>. Almost every interviewee who used totora said that  
349 they used it for their own livestock, primarily sheep, cattle, and guinea pigs, though many of  
350 the older respondents said that they knew how to make things out of totora. A few

---

<sup>1</sup> El sabor del queso de totora, que ya los jóvenes no comen.

<sup>2</sup> Los colchones viejos de totora eran más cómodos que los que compras ahora.

<sup>3</sup> Es mucho esfuerzo hacer cosas de totora, más fácil ir de compras en Puno.

<sup>4</sup> Cada uno controla su propia totora.

<sup>5</sup> Cada persona tiene su parcela de totora que lo contrala.

<sup>6</sup> Antes había cuando existía el ayllu.

351 respondents, primarily older fishermen, indicated that they still remembered how to make the  
352 famed totora boats that used to grace Lake Titicaca. However, even those who said that they  
353 knew how to make them indicated that the modern wooden boats, though more expensive,  
354 had significant advantages over the traditional totora boats akin to other forms of passive  
355 acculturation through technological advance (Thomsen et al., 2020), namely, that a totora  
356 boat would rot away and must be replaced every 1-2 years, and that a modern wooden boat  
357 could carry more people and fish.

358

359           Even among people who still use totora, we observed a change in the relationship  
360 with totora. Two brothers interviewed in the village of Huata, Peru, offer an example of how  
361 even traditional agricultural uses of totora have changed over time. Their primary profession  
362 revolves around cutting totora in Huata and selling it as animal feed to other villages, one of  
363 which, Llachon, has developed a communal tourism industry. Another informant in Llachon  
364 was an artisanal crafts maker, who sold totora products to tourists, commented “I don’t know  
365 how totora is harvested, I buy it”<sup>7</sup>. Artisanal uses of totora have also changed. During the  
366 entire study, we saw no practical artisanal objects made of totora apart from some totora  
367 covered couches in the hallways of some town halls, but rather, in regions with plenty of  
368 tourists, objects made with tourists in mind, such as miniature totora boats even although,  
369 ironically, there are no actual boats made of totora. There were, however, modern wooden  
370 boats with totora placed atop for decoration – which immediately marked them apart from  
371 the more common workaday fishing vessels of the region.

372

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<sup>7</sup> No se como se saca o se regula, lo compro.

373 **Discussion**

374

375 Economic Implications of Totora Use

376

377 In the Altiplano, whether an individual uses totora is primarily determined by their economic  
378 situation, with agriculturists being the last population in the region who have a practical  
379 reason to harvest totora as livestock feed in the winter. The other traditional uses of totora,  
380 such as roofing or practical items, seem to have been abandoned by the people of Lake  
381 Titicaca. Like other losses in traditional practices worldwide, this seems to have been driven  
382 by globalisation and materialised locally through rapid urbanisation and (eco)tourism  
383 (Vandebroek & Balick, 2012). In the Altiplano, it is now easier and cheaper to obtain  
384 industrially produced goods, such as corrugated aluminium roofs and plastics, than it is to  
385 produce these goods domestically using totora. This is not the first time that rapid cultural  
386 changes with ecological implications driven by economic changes have been noted in the  
387 Andes (Zimmerer, 1991, 1993). In each case, globalisation changed the incentive structures  
388 that permitted traditional resource uses to maintain themselves, either in the form of cheaper  
389 imported goods, or a greater outflow of labour to industry elsewhere.

390

391 Altiplano agriculture remains small-scale, but as the region develops, we expect that it  
392 will follow the trajectory of other countries and become industrialised, leading to the  
393 concentration into fewer, larger farms (Lianos, 1984; Beckett, 1990; Hobsbawm, 1994;  
394 Singh, 1997; Bryer, 2016). Once this occurs, the last remaining practical use of totora will be  
395 lost, and the use of totora in Lake Titicaca for practical purposes on a large scale will likely  
396 cease. In its place will be a niche market for totora, likely centred around tourism. To a

397 degree, this has already happened for some uses, such as totora handicrafts and faux totora  
398 vessels.

399

400           It should be noted that the scale of loss of use of totora we have documented is likely  
401 an underestimate, since we interviewed only people in the Lake Titicaca area, and none who  
402 have migrated from area to cities, mining districts, the Amazonian agricultural frontier, or  
403 abroad. These migrants represent a significant percentage of the region's young people,  
404 especially young men, and in some villages constitute a majority of those who grew up there  
405 in the last decade and can safely be assumed to have abandoned any use of a plant that does  
406 not grow near their new locations.

407

408           It is perhaps ironic that there were more interviewees self-reporting that they have  
409 ceased using totora in Bolivia than in Peru because since 2006 Bolivia has, with one slight  
410 interruption, been governed by the Movimiento al Socialismo (MAS) a self-described  
411 socialist and Indigenous party. The Altiplano study region has been one of the significant  
412 political bastions of MAS, which since coming to power, strengthened the legal rights of  
413 indigenous institutions (Humphreys, 2017), and enshrined elements of Andean cosmovision,  
414 such as La Pachamama and Sumak Kawsay, into the Bolivian constitution (Barié, 2014;  
415 Humphreys, 2017). Admittedly, the MAS government has not always been honoured this  
416 commitment to Indigenous rights (Hope, 2016; Lalander, 2017; Hope, 2020), and despite  
417 their rhetorical commitment to the Indigenista ideology, it appears that loss of TEK is more  
418 rapid in Bolivia than in Peru, at least concerning totora among our interviewees. This  
419 suggests that economic development and prosperity, independent of ideology, is a significant  
420 driver of the loss of TEK.

421

422 Fishing as Mechanism toward a Market Economy in Lake Titicaca

423 There is evidence of fishing in Lake Titicaca in the archaeological record since the arrival of  
424 humans in the area (Capriles et al., 2008; Capriles et al., 2014). However, it was traditionally  
425 a relatively unimportant economic activity (Young, 1997; Moore, 2011; Miller et al., 2021).  
426 This changed in the twentieth century with the introduction of pejerrey (*Odonesthes*  
427 *bonairensis*) and trout (*Salmo trutta*), which caused a fishing boom (Everett, 1973; Laba,  
428 1979) that led not only to many individuals who had not previously fished becoming fishers,  
429 but also to modernisation of the lake's fishing fleet (Orlove, 2002). While the original fishing  
430 boom collapsed in the 1980s, last decade has seen a second fishing boom, this time with  
431 farmed fish. While both fishing booms have been capital-intensive, the second appears to  
432 require more start-up capital for people to get involved. We therefore suggest that the higher  
433 rate of abandonment of the use of totora by self-described fishermen may be due to them  
434 having sold off livestock to raise the capital needed to invest in fishing and fish farming.

435

436

437 One of our more intriguing findings is the apparent collapse of the *ayllu* as an organising  
438 economic principle over the course of a generation. In not a single village did we find  
439 collective management of totora – our respondents reported at most agreements between  
440 neighbours about the timing of burning, but even that is a significantly lower degree of  
441 cooperative management than described in previous studies (Forbes, 1870; La Barre, 1948;  
442 Levieil & Orlove, 1990; Banack et al., 2004). That is not to say that the *ayllu* has disappeared  
443 across the entire Altiplano – it still serves a local judicial function, though that also seems to  
444 be declining, and many people still identify with their *ayllu*. Furthermore, certain elements of  
445 communal lands appear to remain under the jurisdiction of *ayllus*, such as grazing territories  
446 (Eisenberg, 2013). Despite the *ayllus* having greater legal rights now than at any other time in

447 the post-Spanish history of Peru or Bolivia, their economic power seems to be collapsing as  
448 the Altiplano increasingly integrates into the global market economy. It appears that  
449 capitalism ultimately cannot be resisted by collectively managed modes of production and  
450 that the *ayllu*, which has been praised by communists and anarchists alike as one of the few  
451 remaining examples of collective ownership and management of economic resources (Castro  
452 Pozo, 1924; Mariátegui, 1971 [1928]; Boudin, 1961; Carrière, 2010; Fabricant, 2010), could  
453 only survive as long as the rural Altiplano remained so peripheral to capitalism as to  
454 effectively be excluded from it. As has occurred elsewhere, increased integration with global  
455 markets has weakened the traditional natural resource regulatory functions of the *ayllu*  
456 (Moore, 1970; Brantlinger, 2018; Thomsen et al., 2021) despite theoretically left-of-centre  
457 governments in both Bolivia and Peru.

458

459         Our The aforementioned professional totora cutters are illustrative of the  
460 specialisation of totora use, even amongst those who are still using totora in relatively  
461 traditional ways. The brothers have specialised, and their customers no longer know much  
462 about totora, the plant, or how its harvested. Previous anthropological work on the economy  
463 of the Altiplano suggested that the cutting and cultivation of totora was a communal  
464 activity (Banack et al. 2004; Orlove, 2002; la Barre, 1948; Forbes, 1870). However, our  
465 interviews with the two brothers in Huata, Peru, who now specialise in totora cutting and  
466 with the artisanal crafts maker who buys totora to create products to sell to tourists indicate a  
467 rise of specialisation and division of labour that is a hallmark of the rise of market  
468 relationships over traditional ones (Braverman, 1974). In an increasingly capitalistic  
469 Altiplano, it is therefore unsurprising to see this new professional breed of totora cutters  
470 emerge. It is also not surprising that these men were from Huata, since that village enjoys  
471 quick and good road connections to Juliaca, which is the main market city in the Peruvian

472 Altiplano. The only other person found in the entire study whose primary profession was  
473 cutting totora was in the town of Llachon, also in Peru, which has successfully transitioned to  
474 a tourism-based economy and has become a regular stop on tourist package holidays, and  
475 suggests how totora use may be maintained, at least marginally, through tourism long-term.

476

## 477 **Conclusion**

### 478 Implications of Totora Use on Traditional Ecological Knowledge

479 TEK is not static, and changes in uses of natural resources over time are inevitable, and  
480 undoubtedly the history of the use of totora from its first introduction to the region to the  
481 present day includes significant shifts. Our results suggest that there has been a decline in the  
482 use of totora driven by (global) economic forces. We do not envisage a reversal of these  
483 trends in the near future. This does not mean we think that totora will disappear from Lake  
484 Titicaca – the plant is not domesticated, and it appears to have increased in extent even as  
485 humans have come to rely on it less over the last 20 years (Villar et al., 2023). Nor do we  
486 expect people will cease to use and cultivate totora entirely. Smallholder animal husbandry  
487 will likely survive in some form in the region for decades and will likely continue to rely on  
488 totora for animal feed. The ecological consequences of the decline in totora harvesting are  
489 also difficult to predict, and totora burnings are no doubt harmful for bird species that nest in  
490 it (Villar et al., 2023; Pulido Capurro, 2018). However, the degree to which species of totora  
491 have become adapted to the human modified landscapes of totora wetlands is unclear. Work  
492 elsewhere in the world suggests that many seemingly wild biodiverse ecosystems rely on  
493 long-term human, generally indigenous, modification, to flourish (Bowman, 1998), and that  
494 the suppression or abandonment of those practices can be deleterious to biodiversity (Bliege  
495 Bird & Nimmo, 2018). Further ecological monitoring of the totora wetlands of Lake Titicaca

496 is needed to understand the ecological consequences of this rapid change in human  
497 involvement with this landscape.

498

499           Our most significant finding is perhaps that the *ayllu* system of collective  
500 management of totora, which has existed for at least as long as there are written records for  
501 the region, has effectively been wiped out within a generation. This is not only a change of  
502 economic system but also represents a disruption of social bonds in the Altiplano on a scale  
503 unseen since early nineteenth-century attempts to enclose the commons. Given the reliance  
504 on human propagation of totora wetlands for most of their history in Lake Titicaca, there is  
505 also a question of whether this unique ecosystem that hosts significant numbers of endemic  
506 species can long survive without human aid, and what will happen if it fully disappears.

507

508 Parting Thoughts

509 Alles Ständische und Stehende verdampft – all that is solid melts into air. The use of totora as  
510 a staple plant in the area around Lake Titicaca dates back at least 4000 years, and the *ayllu*  
511 system to regulate it dates back at least 500. The *ayllu* survived the conquest of Pizzaro, the  
512 Bourbon Reforms, the Wars of Independence, and the various republics, dictatorships,  
513 revolutions, and civil wars which engulfed independent Peru and Bolivia – but it has not  
514 survived increasing market integration. While totora use has not disappeared, it has become  
515 more specialised. Market integration has undercut both totora harvesting through reducing the  
516 number of young workers available, totora goods by replacing them with cheaper  
517 manufactured ones, and the *ayllu* system by creating individual rather than communal  
518 economic actors. The full ecological, social, and cultural impacts of these changes are yet to  
519 be determined. For the totora one thing is clear - its role as a cultural keystone species is  
520 diminishing fast .



522 **Declarations**

523 **Ethical Approval**

524 This work received ethical approval from the Institutional Review Board of the Universidad  
525 Nacional del Altiplano, and University of Oxford's CUREC.

526

527 **Competing interests**

528 The authors declare that they have no conflicts of interest.

529 **Authors' contributions**

530 This study was undertaken as part of a doctoral project by D. A. V. at the University of  
531 Oxford, U. K. under the supervision of A. G. G. and J. M., with support from B. T. and  
532 essential local support from E. R. G. T. A. C. P. C., P.V.N., E. M., & M. A. who facilitated  
533 fieldwork. D. A. V. conceived the project, collected data with help from E. R. G. T., A. C. P.  
534 C. and P. V. N., and analysed the data. DAV wrote the first draft with help from B. T. All  
535 authors reviewed and commented extensively on the manuscript.

536

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539

540 **Availability of data and materials**

541 The datasets generated and analysed in this study are not publicly available because they  
542 constitute an excerpt of an ongoing research project, but are available from the corresponding  
543 author at a reasonable request.

544

545

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892 **Supplemental Data**

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<b>Demographic Factor</b>	<b>Possible Response Categories</b>
Country of Residence	Peru, Bolivia
Gender	Male, Female
Age	Any age over 18
Ethnicity	Aymara, Mestizo, Quechua, Uro
Education	None, Incomplete Primary, Complete Primary, Incomplete Secondary, Complete Secondary, Incomplete Technical, Complete Technical, Incomplete University, Complete University
Profession Category	Fishing and non-fishing
Languages Spoken	Aymara, Quechua, Spanish, English, French, German
Primary Language Spoken at Home	Aymara, Quechua, Spanish, Equal Amounts Aymara & Spanish, Equal Amounts Quechua and Spanish, Equal Amounts Quechua and Aymara
Religion	Roman Catholic, Protestant, Miscellaneous

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