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Short Communication

Addressing conflict between fishermen and the Titicaca Grebe (*Rollandia microptera*) through diet analysis

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Human–wildlife conflict is often a driver of species declines, and understanding the material basis of this conflict is the first step in addressing it. The Titicaca Grebe *Rollandia microptera* is an endangered endemic species found solely in the Lake Titicaca watershed of Peru and Bolivia, and has experienced population declines due to fisheries bycatch. Human fishers often have negative opinions of the Titicaca Grebe, because they consider it as a competitor for declining fish stocks. We tested that assumption by an analysis of the bird's diet and found that the Titicaca Grebe does not compete with fishers for more lucrative fish species such as trout *Oncorhynchus* sp. and Pejerrey *Odontesthes bonariensis*, but does compete for the less desirable (to human fishers) native *Orestias* sp.

Keywords: diet, grebe, human–wildlife conflict, piscivore, stomach contents.

Human–wildlife conflict is a significant driver of population declines of species the world over (Nyhus 2016). Although human–wildlife conflicts can have many causes, a common one is when animals predate on species in which humans have an economic interest. Usually, this is livestock (Plumer *et al.* 2018, Jacquier *et al.* 2020), but in marine and aquatic species, conflict often stems from wild animals predating on other wild animals that are the target of human fisheries (Guerra 2019, Hoel *et al.* 2022). Perceived conflict with wildlife can be as much of a barrier to conservation as actual conflict (Guerra 2019), and knowledge of the empirical unreality of conflict is often not enough to reduce human–wildlife conflict (Treves *et al.* 2013), but knowledge of the source and extent of conflict is a necessary first step towards mitigation (Toomey 2023). Without knowing the actual basis of the conflict between humans and wildlife, any conservation actions are based purely on hunches, rather than science. Knowing the extent of conflict can also indicate whether education campaigns informing humans that conflict is primarily imaginary can be run, as well as suggesting what behaviour modifications can be reasonably expected of humans.

The Titicaca Grebe *Rollandia microptera* (hereafter referred to as Grebe) is an Evolutionarily Distinct and Globally Endangered (EDGE) species (Jetz *et al.* 2014), endemic to Lake Titicaca and associated water bodies in Peru and Bolivia (Fjeldså 2004, Llimona *et al.* 2020, Villar *et al.* 2023). The Grebe, which is flightless, saw a population decline of around 70% between the 1970s and the early 2000s (Engblom *et al.* 2001). This decline could have multiple causes, including changes to the Lake Titicaca ecosystem caused directly by the introduction of salmonids, but is thought to be primarily driven by mortality due to fisheries bycatch (Martinez *et al.* 2006). However, there is widespread animosity amongst fishers towards the Grebe, because it is seen as competing directly for fish (Quispe *et al.* 2023, Villar *et al.* 2024a). This study aims to find the material basis of this perceived conflict, and then make conservation recommendations on the basis of this material basis. We do not pretend that knowing the extent of dietary niche overlap will resolve conflict between fishers and Grebes and will immediately reduce Grebe bycatch. However, knowledge as to whether this dietary niche overlap is real or imagined can inform what sort of environmental education campaigns should be run to foster Grebe–fisher coexistence, as well as inform whether changes in fishing patterns are likely to be effective at reducing Grebe bycatch. In the latter case, if Grebes and fishers are indeed targeting the same fish species, then it is not reasonable to expect fishers to change where they fish, but it might be possible for them to use visual cues, such as thicker nets, that reduce bycatch while not reducing fisheries catch.

The introduction of fish, especially salmonids, has been associated with the extinctions of at least three species of endemic grebes in the 20th century, the Alaotra Grebe *Tachybaptus rufolavatus*, the Colombian Grebe *Podiceps andinus* and the Atitlan Grebe *Podilymbus gigas* (LaBastille 1983, Fjeldså 1993, Wilmé 1994,

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O'Donnell & Fjeldså 1997). In Lake Titicaca, salmonids *Oncorhynchus* sp. and Pejerrey *Odonesthes bonariensis* were introduced in the mid-20th century (Everett 1973, Laba 1979, Lauzanne *et al.* 1992). The specific causes differ between these species. In some cases, invasive salmonids eat macrozooplankton, depleting either the diet of the Grebe directly, or reducing the number of fish that eat those plankton, so reducing the number of fish that Grebes can predate upon. In other cases, invasive salmonids cause population declines less directly, such as Grebe numbers being reduced by bycatch in nets placed by fishers to catch salmonid fish. Studies of dietary overlap between invasive species and native grebe species has helped wildlife managers and conservationists to protect other species of grebe, such as work on the overlap in the diet between the Hooded Grebe *Podiceps gallardoi* and invasive Rainbow Trout *Oncorhynchus mykiss* in Patagonia (Lancelotti *et al.* 2015). Understanding the diet of the Titicaca Grebe, and how it varies across age classes, can help to indicate by which mechanisms the introduced salmonids influence the Grebe's population, and whether a particular life stage is most affected. Usually, the intersection between demography and human–wildlife conflict focuses on the demographics of the species that problem species target and human values, such as livestock (i.e. De Azevedo & Murray 2007), though in some cases they have focused on the demographic differences in individuals causing said conflict (Mattisson *et al.* 2014). The latter can help target interventions on the particular individuals that are most likely to cause issues in 'problem' species, while the former can help target which individuals need greater preventive measures to be protected. Given that we know that Grebe diet is extremely variable (Fjeldså 1981), we felt that it would benefit not just the understanding of the Grebe's ecology, but also its conservation, to explore at least one source of this variation, and age is one that is readily identifiable, making it theoretically easier to be the subject of education campaigns than more cryptic traits in this species, such as sex.

The Titicaca Grebe is piscivorous, and in the context of Lake Titicaca can be considered an apex predator (Servant-Vildary *et al.* 1992). The one study performed on the diet of this species was an analysis of 12 adult Grebes, caught in Laguna Umayo and near Piata, in the region of Huancané, over 40 years ago (Fjeldså 1981). This found that 94.4% of the diet by weight was *Orestias*, with the remainder being invertebrates, mainly aquatic insects of the genus *Buenoa* and the family Corixidae (Fjeldså 1981). This study also noted that there was significant variation in the diets of individual Grebes, but no attempt was made to determine the cause of this variability.

The objective of this study is to determine the extent of overlap between the target species of fishers and Grebes. As an ancillary to this main objective, we also have the mini-objective of determining if there is any age difference in the overlap between the target species of the Grebe and fishers. Knowledge of the actual dietary overlap between predatory species and species valued by humans is a first step in addressing actual or perceived human–wildlife conflict (Treves *et al.* 2013, Guerra 2019). Knowledge of any age-based variation in this overlap is important in understanding whether conservation efforts should be targeted at specific groupings within a species that causes problems for humans (Mattisson *et al.* 2014).

METHODS

Study sites and site description

Lake Titicaca is the world's highest altitude navigable lake and is shared between Peru and Bolivia (Wirrmann 1992). Lake Titicaca is a freshwater ichthyological diversity hotspot, with over 90% of species being endemic (Albert *et al.* 2011). All save two native species of Lake Titicaca are members of the genus *Orestias*, and the other two are pencil catfish of the genus *Trichomycterus* (Vila *et al.* 2007). Although little is known about the ecology of the fishes of Lake Titicaca before the introduction of invasive species in the 20th century, today, most native species are relatively slow and primarily reside near the shore, particularly in areas with high levels of vegetation (Lauzanne *et al.* 1992, Vila *et al.* 2007). In the 20th century, invasive predatory fish species were introduced, such as Rainbow Trout and Pejerrey, to Lake Titicaca (Everett 1973, Laba 1979, Orlove 2002). These tend to be faster than native species and are found in open water as well as near the shore (Lauzanne *et al.* 1992, Vila *et al.* 2007).

Although the Titicaca Grebe is thought to have experienced significant population decline over the last 50 years, this itself represents a decline from earlier times. Nineteenth century descriptions of Lake Titicaca state that the Titicaca Grebe was one of the most common, or the most common, bird species on the lake (Sclater & Salvin 1869, Squier 1877). This significant population decline is associated with increased fisheries bycatch, which has followed increased fishing intensity in Lake Titicaca over the 20th century (Martinez *et al.* 2006). Fisheries have existed in Lake Titicaca for thousands of years (Capriles *et al.* 2014), but expanded significantly in the mid-20th century with the above-mentioned fish introductions (Everett 1973, Laba 1979, Orlove 2002). These introductions were followed by significant declines of Grebes, as well as of other endemic Lake Titicaca species, such as the Titicaca Giant Frog *Telmatobius culeus* (Angulo 2008), and has been linked with the probable extinction of the Titicaca Orestias *Orestias cuvieri*, an endemic pupfish (Hall & Mills 2000, Vila *et al.* 2007). The capture of Grebes

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as a fishery bycatch has also increased hostility towards it from local fishers, who blame Grebes for competing with them for limited fish stocks and for breaking nets (Quispe *et al.* 2023, Villar *et al.* 2024a).

Samples were collected on the Peruvian side of Lake Titicaca. We distinguish between three areas on the Peruvian side from which we collected samples: Huancané, Huata and Chucuito (Fig. 1). Huancané is on the north side of Lake Titicaca, with little aquatic vegetation and deep water. Huata is on the north side of Puno Bay, and on the edge of a large expanse of thick totorales, or swamp of *Schoenoplectus californicus* subsp. *tatora*, and probably other sub-species or species of the same genus (Paola Velásquez-Noriega, pers. comm.). Chucuito is on the south side of Lake Titicaca, in an area with little aquatic vegetation but shallow waters. These areas are highlighted on the maps in Figure 1.

Fishers' target species

Fishers' target species were gleaned from semi-structured interviews as part of a larger ethnobiological study of fishers in Lake Titicaca that took place in 2022. As part of this larger study, fishers were asked to provide their opinion of the species on a Likert Scale, with 0 being the most negative and 10 the most positive, and then were asked to justify their opinions of the Grebe. For full results and methodologies, see Villar *et al.* (2024a). Fishers were also asked which fish they targeted and were permitted to list multiple species. This free-listing technique is well established in ethnobiology for studying the extent of use of species and the importance of different species to a society (Balée 2013, Silva *et al.* 2019), including for studying the target species of artisanal fisheries (Messias *et al.* 2019, Braga *et al.* 2020). We then calculated the percentage of fishers that targeted each species, to determine what percentage of fishers target the same species as the Grebe. Fishers who said they fished indiscriminately were listed as fishing all species in Lake Titicaca. Furthermore, we surveyed the largest fish market in the Peruvian Altiplano, that of Unión y Dignidad in Puno, to provide an independent control for the target fish species of the fishing industry in Lake Titicaca, although this was not included in the dietary overlap analysis between fishers and Grebes. This survey of the fish market was to validate that the fish species that fishers said that they were targeting were indeed the species being targeted.

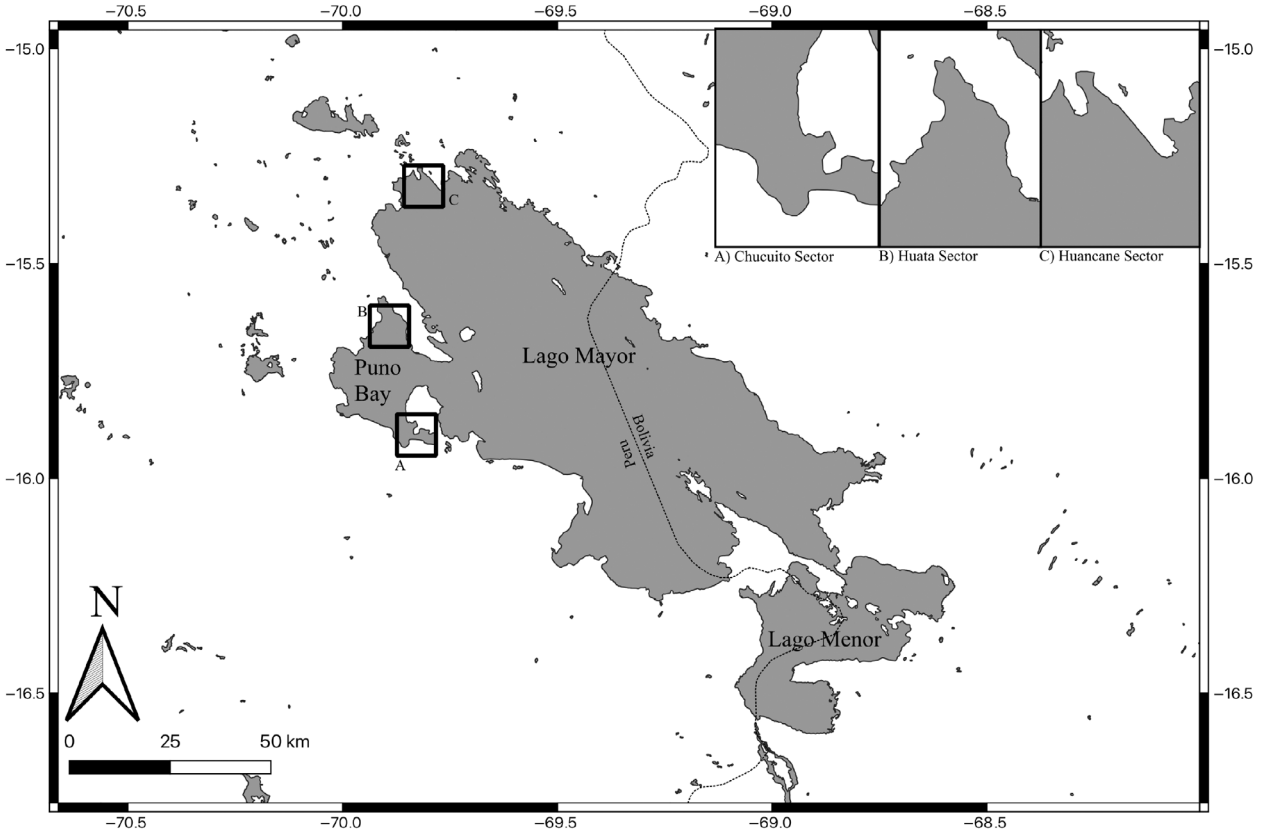

Figure 1. Map of Lake Titicaca, with the Huata, Chucuito and Huancané Sectors, where birds were collected, shown in insets.

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Fishers gave species names using the local taxonomy of fishes that exists in the Altiplano. Although variation exists between the most common folk taxonomy of the region, it places fish in one of six categories. These are: ispi – small native pupfish, primarily *Orestias ispi*; carachi – all pupfish larger than ispi; mauri – pencil catfish, primarily of the species *Trichomycterus rivulatus*; suche – catfish larger than the mauri; Pejerrey and trucha, or trout. Ispi, carachi, mauri and suche are all local vernacular names for these categories, and are shared between Quechua, Aymara and Spanish speakers. For the purposes of this study, we merged the categories of carachi and ispi into a category of *Orestias* sp.

Specimen collection, stomach content analysis and data sources

Our analysis is based on specimens caught as bycatch by fishers. The possible effects of bias caused by this sampling method are considered in the Discussion. We worked with fishers in the summer of 2008 to collect birds caught as bycatch in their nets. All individuals ($n = 45$) were preserved in 40% ethanol while being transported to the Universidad Nacional del Altiplano in Puno, Peru, for stomach-content analysis, which was undertaken on the same day as the collection of specimens. Individuals were identified as either adults or juveniles on the basis of plumage. Juveniles have lighter brown feathers on the upper body and white feathers on the belly, whereas adults have darker brown feathers on the upper body and a more rufous-coloured belly. This difference in plumage between adults and juveniles is characteristic of the species (Fjeldså 2004).

The oesophagus, proventriculus and gizzard were removed from each bird via an incision on its ventral side. We measured volume of the stomach content of each individual, and identified the contents of the stomach by reference to a voucher collection, identifying fish by otoliths. We counted both abundance and presence/absence of prey to the lowest possible taxonomic level, allowing for both 'presence–absence' and 'numerical' analyses (Hyslop 1980). The latter can include counting the number of individual prey items as well as the volume of prey, but following work on the unreliability of volume estimates from guts (Rindorf & Lewy 2004), we have counted the number of prey items for our numerical analysis. Numerical analysis tends to overestimate the importance of small prey due to reporting numerous prey that constitute an energetically insignificant percentage of the species' diet as more important than larger but less numerous species (Crisp *et al.* 1978, Ahlbeck *et al.* 2012), but allows an assessment of the relative importance of different prey species (Hynes 1950). Presence–absence methods tend to be more robust mathematically (Baker *et al.* 2014, Buckland *et al.* 2017), but can underestimate the importance of species in diet, especially for specialist species. Following the recommendation of a recent review on gut content analysis (Amundsen & Sánchez-Hernández 2019), we have combined these approaches to attempt a more complete understanding of the diet of the Titicaca Grebe. Because our interest was on conflict between the Grebe and the fishers, and due to difficulties in identifying semi-digested invertebrate remains, we focused on identifying the fish species in the stomachs of Grebes, and placed invertebrates into four categories: insects, amphipods, molluscs and miscellaneous invertebrates. Due to the local folk taxonomy of fisheries, and the limitations of identifying semi-digested fish remains, we did not identify pupfish to the level of species.

Quantitative analysis

Schoener's Diet Overlap Index (Schoener 1970) was used to measure the diet overlap between juvenile and adult Grebes across all sites, and between juvenile and adult Grebes within sites. Schoener's Overlap Index is calculated as $D = 1 - 0.5\left(\sum_{i=1}^{n} \left| p_{ij} - p_{ik} \right|\right)$, where p_{ij} is the proportion of prey type i in the diet of population j, and p_{ik} is the proportion of prey type i in the diet of population k. The Index, which ranges from 0 (no overlap) to 1 (complete overlap), is generally used to study niche overlap between species (e.g. Ogloff *et al.* 2019, Tesfaye *et al.* 2021), but has been used to study diet overlap of populations within species (e.g. Mabragaña & Giberto 2007, Šantić *et al.* 2012, Anastasopoulou *et al.* 2013). An Index value greater than 0.6 is of biological significance, suggesting that the two populations have the same dietary niche (Wallace 1981). In this instance, the Index measures the overlap in target species by the Grebe and the fishers. This was done both for numerical and for presence–absence counts of prey. In addition to diet overlap between adult and juvenile Grebes, we also used diet overlap between fishers and Grebe, using the response of the target fish species of the fishers as a proxy for fisheries dietary overlap. We did this solely for presence–absence counts, because, although fishers did tell us their average weekly catch, lack of knowledge of the Grebe's digestive system means that we were unsure of the timeframe of their diet that was represented in the stomach samples. For the purposes of the diet overlap analysis between fishers' self-reported catch and Grebe stomach contents, ispi and carachi were merged into one *Orestias* sp. category, and we merged mauri and suche into one *Trichomycterus* sp. category. We performed the analysis both with all prey categories and solely with fish, the latter allowing us to focus on the most likely area of direct competition between fishers and Grebes. We believe that it makes sense to compare all categories between fishers and Grebes even though fishers do not target invertebrates, and their nets do not catch invertebrates, as the goal of

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this study is to look at the overlap between the target species of fishers and Grebes. By definition, this has to involve looking at species that are non-target species for both parties. All quantitative analyses were conducted using R software version 4.3.1, and graphs were made using the ggplot2 library (Wickham 2016, R Core Team 2023).

RESULTS

We interviewed 221 people, of which 63 were fishers. Full detailed results, including the breakdown of the number of individuals interviewed per location, can be found in the supplemental material of Villar *et al.* (2024a). Fishers were not asked for how long they had been involved in fisheries. The most commonly targeted fish species was carachi (66.66% of fishers), followed by Pejerrey (57.14% of fishers), ispi (25.40% of fishers), mauri (20.63%), trout (17.46%) and suche (9.52%). The average score fishers gave to the Grebe was 4.82, suggesting overall slightly more negative opinions than positive ones. The cause of these negative views was that the Grebe is seen as competition for scarce fish resources, and that the Grebe breaks nets when it gets caught as bycatch. Twenty-seven fishers directly mentioned that they viewed the Grebe as competition for fish as a reason for their opinion. Of these, 18 made no species-level distinction of which fish the Titicaca Grebe ate, and five accused the Grebe of eating trout and Pejerrey directly. Although it was not part of the planned semi-structured survey, all save two mentioned declines in fish abundance during their time as fishers. There are seven stands which primarily sell fish from Lake Titicaca in the Unión & Dignidad fish market in Puno. Which fish they sell varies on availability each day, given that most fishmongers are women who get fish from their husbands or buy it from fishers coming to Puno in the early hours of the morning, save for one whose fish solely comes from her husband's fish farm. All, when asked, preferred to sell trout or Pejerrey, but all save the one who solely sold farmed trout sold native species as well. Trout fry were commonly found in the piles of ispi being sold in the fish market, suggesting that fishers are accidently catching many non-target fish in their smaller-mesh nets.

We examined the stomach contents of 45 Grebes, consisting of 19 juveniles and 26 adults. Fifteen Grebes were caught in each sector: in Chucuito, 5 were adults and 10 were juveniles; in Huata, 12 were adults and 3 were juveniles; and in Huancané, 9 were adults and 6 were juveniles. We found that there was no significant difference between the diets of juvenile and adult Grebes. We found no biologically significant dietary overlap between fishers and Grebes when taking non-fish prey items into account (Table 1). However, we found a biologically significant overlap between the target fish species of fishers and adult Grebes, and a near-significant overlap for fishers and juvenile Grebes and when considering all Grebes together. Dietary contributions of prey species for fishers and Grebes and for different age classes of Grebes are summarized in Figures 2 and 3, respectively. We found no evidence of the Grebe eating the fry of either of in the invasive fish species in Lake Titicaca.

Table 1. Schoener's Overlap Index indicating the dietary overlap between adult and juvenile Grebes, and between Grebes and fishers.

Populations being compared	Schoener's Overlap Index
Grebe juveniles and Grebe adults – numerical count, all prey types	**0.811**
Grebe juveniles and Grebe adults – presence–absence count	**0.899**
Fishers and Grebe adults – presence–absence count, all prey types	0.162
Fishers and Grebe juveniles – presence–absence count, all prey types	0.193
Fishers and all Grebes – presence–absence count, all prey types	0.172
Fishers and Grebe adults – presence–absence count, fish only	**0.602**
Fishers and Grebe juveniles – presence–absence count, fish only	0.558
Fishers and all Grebes – presence–absence count, fish only	0.588

Results showing a biologically significant dietary overlap (>0.6) are in bold.

DISCUSSION

We found that fishers have negative attitudes towards the Titicaca Grebe, which are caused by a variety of factors, including perceived overlap in the target species of the Grebe and the fishers. This negative perception of the Grebe is a significant barrier to conservation efforts towards the Grebe. However, previous studies have already highlighted this fisher–Grebe conflict, and its role in the conservation of the Titicaca Grebe (Quispe *et al.* 2023, Villar *et al.* 2024a). This study provides the first empirical test of this perceived overlap in target species of fishers and Grebes and provides the first empirical evidence for ameliorating this source of conflict.

We found mixed evidence for this common assertion among fishers that the Grebe is direct competition for fish species. The Grebe almost certainly targets members of the genus *Orestias* among its fish prey, and does not compete with the fishers for the more commercially lucrative trout or Pejerrey. This is also the case for

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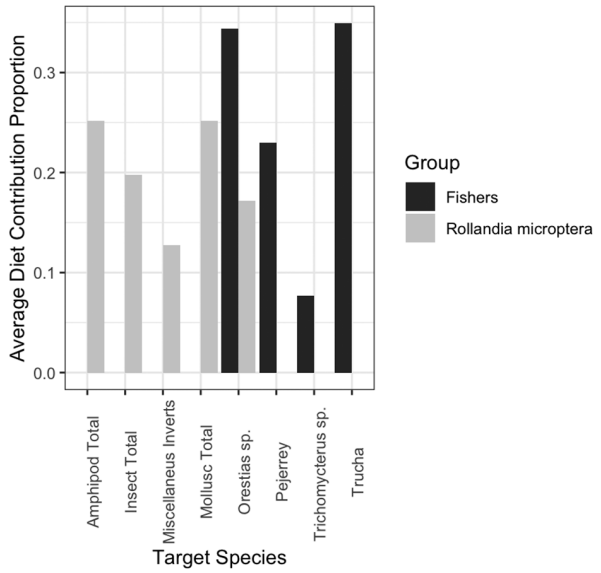

Figure 2. Comparison of average proportion contribution of each prey class to diet using numerical counts of prey items between fishers and Grebes.

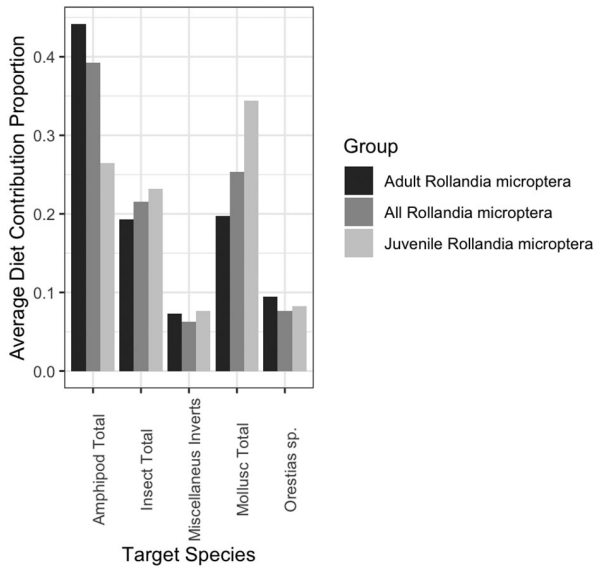

Figure 3. Comparison of average proportion contribution of prey items between Grebe age classes using presence–absence count results for prey items.

juveniles of the latter two, though it remains possible that some Pejerrey or trout fry are eaten by Grebes, given the inherent uncertainties present in identifying small partially digested fish remains (Buckland *et al.* 2017).

As a result of the conservation status of the Titicaca Grebe it would have been unethical to take birds specifically for diet analysis. Nevertheless, it is possible that sampling only from fishery bycatch could produce a bias, as being trapped in a net implies fishing for the same prey. Our analysis may, therefore, have overestimated the degree of diet overlap that exists between fishers and Grebes overall. However, we cannot dismiss the possibility that genuine competition exists between fishers and Grebes. Most fishers target at least some *Orestias* species, even if they indicated that they would rather be targeting rarer Pejerrey and trout.

These results lead us to suggest that there may exist genuine (as opposed to perceived or assumed) competition between fishers and Grebes for *Orestias*. Furthermore, we have to consider the 14-year time difference between the fishing interviews and the dietary analysis. It is possible that the competition could have changed as the result of changes in resource use by fishers or Grebes in that time, due to changing availability of fish in Lake Titicaca. However, if change has occurred, we suspect it would be towards more competition, and not less. We have no reason to believe that Grebes have begun to hunt trout or Pejerrey in the intervening years, but from the interviews with fishers we have reason to believe that there has been a move away from targeting trout and Pejerrey by human fishers, and towards targeting the more abundant, if less economically lucrative, native *Orestias* species.

The importance of *Orestias* indicates that the Grebe has not managed to change its diet following the introduction of salmonids and Pejerrey to Lake Titicaca, making the conservation of the endemic fish fauna crucial for the conservation of the Titicaca Grebe. The endemic fish fauna of Lake Titicaca has undergone significant declines due to invasive salmonids and pollution (Villwock 2001, Vila *et al.* 2007, Monroy *et al.* 2014), including the probable extinction of at least one species, the Titicaca Orestias (Hall & Mills 2000, Vila *et al.* 2007). If the Titicaca Grebe relies primarily on the native *Orestias* as its prey, and the populations of *Orestias* in Lake Titicaca have been reduced irrevocably by invasive species in the 20th century, it might be the case that the carrying capacity of Lake Titicaca for Titicaca Grebes is lower than it had been before these introductions. If this is the case, it might mean that the flocks of 300–400 birds described in the 19th century (Sclater & Salvin 1869) would not be sustainable today even if a fisheries moratorium to reduce bycatch were to be introduced and enforced.

Although the overlap in the 'diet' of the target fishes of Grebe and fishers was only biologically significant for adult Grebes, it was nearly so for juveniles and when considering all Grebes together. It is also interesting to note that juveniles consume many more molluscs compared with adults; in general, other grebe species prefer

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to eat amphipods to molluscs (Fjeldså 2004). This age difference in diet might indicate learning in this species, as adults learn to discriminate between amphipods and molluscs when hunting. However, overall, we found no difference between adult and juvenile Grebes, suggesting that they occupy the same dietary niche in Lake Titicaca.

Future research and conservation actions

Resolving human–wildlife conflict when the conflict is more imagined than real is already very difficult, as the attitudes of affected people can remain unchanged even after education (Treves *et al.* 2017). Resolving human–wildlife conflict when there are factual grounds for said conflict is even more difficult. We suggest that environmental education of fishers is required to teach how Grebes do not compete with them for most fish species in Lake Titicaca, especially not for the more lucrative trout and Pejerrey, though they do compete for the less lucrative native *Orestias*. The conflict occasioned by actual overlap between fishers and Grebes regarding *Orestias* cannot be resolved the way human–wildlife conflict has been dealt with in other contexts where predators hunt species on which humans rely, such as direct compensation schemes for individuals predated (Dickman *et al.* 2011, Ravenelle & Nyhus 2017), for practical reasons, though a compensation scheme for broken nets might be viable if done by the governments of either Peru or Bolivia. Instead, the Grebe must be turned from an economic problem species to one that provides economic value to the community (Woodroffe *et al.* 2005). There are several ways this could be done, including ecotourism (Gössling 1999), though it is likely that several potential models will have to be considered and tested before finding which one is correct for Lake Titicaca. These conservation strategies would have to be particularly mindful to take into consideration the rapid economic and social changes that the region around Lake Titicaca is undergoing, which have considerable impacts on people's uses and attitudes towards the natural environment of the lake (Villar *et al.* 2024b).

Further study of Grebe ecology and feeding habits could lead to more information regarding Grebe–fisher conflict, noting for example the potential for sampling bias through sampling bycatch, although ethical considerations must be in the foreground. Although this study focused on Grebe diet, studies of Grebe bycatch could reveal patterns of net types, net depths or geographical patterns in bycatch that could lead to conservation actions. Estimation of the total human fisheries catch in Lake Titicaca, and of the total Grebe fisheries catch, could help place the competition between fishers and Grebes for *Orestias* in perspective. Previous studies of Grebe diets in other study systems have found that predation by Grebes can be a greater pressure on fish populations than the total fisheries catch (Geiger 1957) or can be insignificant compared with human fishing activity (Markuze 1965), but it is difficult to predict a priori which it is in Lake Titicaca. Dietary isotope studies, which can help explain the finer variations in diet composition, especially when combined with gut contents analysis (Horswill *et al.* 2018), could also more precisely show which species of *Orestias* the Grebes and fishers compete for. The use of historical museum samples could inform on historical Grebe diets and be used to study the diet of life stages not included in this study, such as chicks. Zooarchaeological work on fish stable isotopes suggests that stable isotopes can distinguish between different *Orestias* species (Miller *et al.* 2010). We also recommend work on the effect of pisciculture on Grebe diet and bycatch, given the increasing number of fishers who are transitioning to pisciculture in Lake Titicaca (D. A. V., pers. obs.).

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AUTHOR CONTRIBUTIONS

D. A. Villar: Writing – original draft; writing – review and editing; formal analysis; software; data curation; conceptualization; validation. **Ever Yanes:** Investigation; writing – review and editing; validation; methodology; conceptualization; data curation. **Edwin R. Gutiérrez Tito:** Investigation; methodology; writing – review and editing; formal analysis; data curation. **Andrew G. Gosler:** Writing – review and editing; supervision; methodology.

ETHICAL NOTE

None.

FUNDING STATEMENT

None.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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