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Fish remains from the Formative Period (1000 BC–AD 400) of Lake Titicaca, Bolivia: Zooarchaeology and taphonomy

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Abstract

This paper presents a detailed zooarchaeological study of fish remains from the site of Kala Uyuni, Bolivia. The fish remains of 31 flotation samples from different archaeological contexts and dated to the Formative Period (1000 BC–AD 400) are described in terms of frequency, weight, taxa distribution, sizes, skeletal representations, and exposure to heat. The results confirm the importance of fish in the diet of the inhabitants of the site and provide insights about the particularities of their exploitation, consumption, and differential discard across the site throughout time. A strong decline in the procurement and consumption of fish is observed for the Late Formative which seems to be a consequence of both environmental and social processes.
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1. Introduction

The Neotropics are among the richest regions of the world in terms of landscape geography, biodiversity, and socio-cultural variation. It is also one of the biogeographic regions with highest diversity of bony fishes. Throughout the human occupation of the Neotropics, a number of societies developed complex economic systems focused on the exploitation and consumption of fishes and other aquatic resources (Moseley, 1975; Falabella et al., 1994; Lavallée et al., 1999; Shady Solis et al., 2001; Parsons, 2006). Nevertheless, there are still numerous questions about the nature of these economies and their articulation with larger processes of social and environmental change.

The complex osteology of fishes and taphonomy in addition to their usually small size have together contributed for long to their limited zooarchaeological study (Casteel, 1976; Colley, 1990; Lyman, 1994; Stahl, 1996; Gifford-Gonzalez et al., 1999; Reitz and Wing, 1999; Zohar et al., 2001). Nevertheless, recent studies have provided good examples of the significance of aquatic fish resources for several societies and their primary role for the organization of social complexity (Sandweiss, 1996; Marcus et al., 1999; Reitz, 2001; Roselló et al., 2001; Barrett et al., 2004; Fagan, 2006).

This paper presents a detailed zooarchaeological assessment of fish use during the Formative Period (1000 BC–AD 400) at the site of Kala Uyuni, located on the shores of Lake Titicaca, Bolivia. Specific focus is on the evaluation of the role of fish exploitation and consumption in the development of increasing social complexity in the southern Titicaca Basin prior to the emergence of the Tiwanaku state (AD 400–1100).

Although it is generally assumed that fish were an important resource for the inhabitants of the region, several recent syntheses imply that their exploitation remained for the most part unchanged even throughout significant periods of environmental and social change (e.g., Kolata, 1993; Stanish, 2003; Janusek, 2004). Zooarchaeological and contextual evidence is presented to support possible effects of drought on fish availability as well as changes in the location of ritual consumption patterns and “sociopolitical development” associated with greater reliance on agriculture and herding during the Late Formative.

1.1. Aquatic resources and fish in the Lake Titicaca Basin

Lake Titicaca is located in the south central Andes, approximately at 15°50′S and 69°25′W and at an elevation

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of 3810 m. It is the highest large lake in the world. The lake itself currently covers a surface area of 8400 km^2, and its surrounding basin integrates a region of over 143,300 km^2 (Revollo, 2001) (Fig. 1). The southern portion of the lake has a complex history of human occupation including the development of multi-communal polities during the Late Formative Period and subsequently the independent formation of the Tiwanaku state (Albarracin-Jordan, 1999; Stanish, 2003; Janusek, 2004; Bandy, 2005). Scholars agree that control of the exploitation of farming, camelid herding, and aquatic resources were key economic factors in the development of complex societies in this region (Albarracin-Jordan, 1996; Bandy, 2001; Hastorf et al., 2001). Recent studies have allowed a better understanding of agricultural intensification (Kolata, 1993; Bruno and Whitehead, 2003; Janusek and Kolata, 2004) and camelid management (Kent, 1982; Webster, 1993; Browman, 1998; Webster and Janusek, 2003). However, the systematic study of the aquatic resources is still a work in progress (Horn, 1984; Moore et al., 1999; Capriles, 2006).

Fish along with totora reeds (*Schoenoplectus tatora*, Cyperacae) are considered the most important aquatic resources in the basin (Orlove, 2002). Two genera and about 26 species of native fish have been described for this region (Tchernavin, 1944; Parenti, 1984; Lauzanne, 1992) (Fig. 2). The catfish genus *Trichomycterus* (Siluriformes, Trichomycteridae) is represented by two bottom-dwelling species: *Trichomycterus rivulatus* or *suche* and *Trichomycterus dispar* or *mauri* (Tchernavin, 1944). The former is usually distributed on the bottom of the rivers that flow into the lake as well as the shoreline and littoral zones, whereas the latter is distributed in more demersal zones of the lake.

The killifish genus *Orestias* (Cyprinodontiformes, Cyprinodontidae) includes at least 24 endemic highly specialized species adapted to a variety of very specific micro-ecosystems of the lake (Parenti, 1984; Vaux et al., 1988; Lauzanne, 1992; Sarmiento and Barrera, 2004). Most of them are small (rarely exceeding 20 cm of standard length (SL)) and their natural history is not well understood (Lüssen et al., 2003).

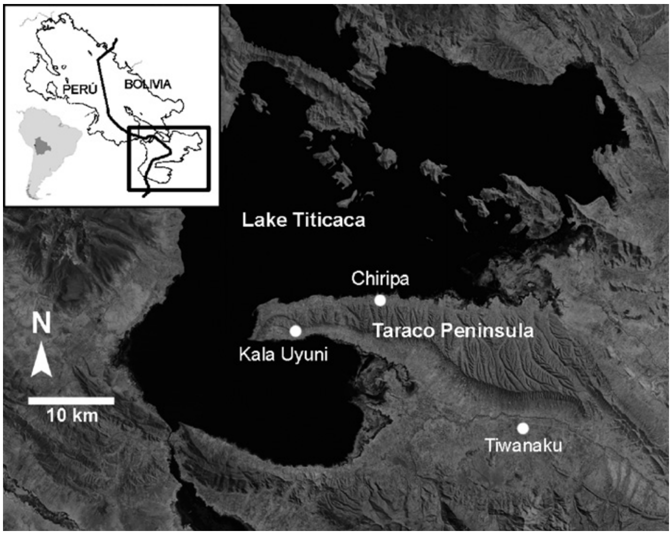

Fig. 1. Lake Titicaca southern basin showing the location of Kala Uyuni and the study area.

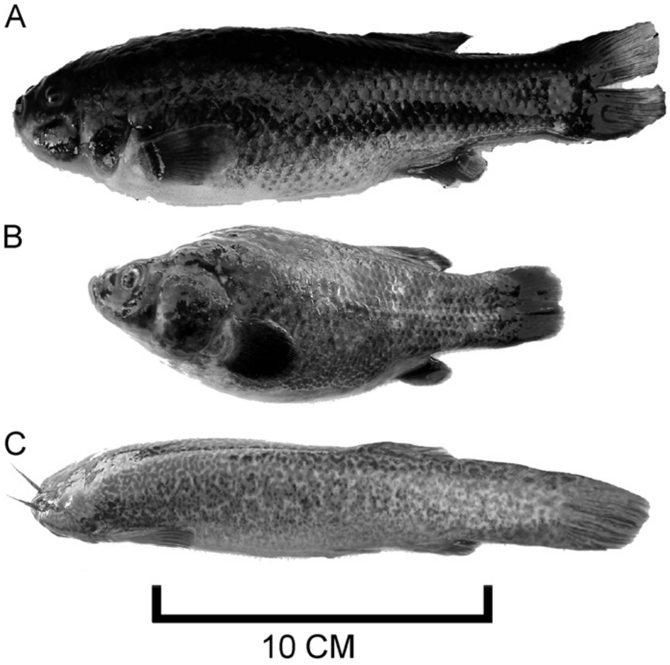

Fig. 2. Native fishes of the study area caught on the Taraco Peninsula. A: *Orestias agassii*, B: *Orestias luteus*, C: *Trichomycterus rivulatus*.

2. Materials and methods

2.1. Archaeological excavations at Kala Uyuni

Kala Uyuni is a large multi-component site located near the southern end of the Taraco Peninsula and has been interpreted as the possible center of a multi-communal polity that, for the first time, integrated the region during the Late Formative Period (Bandy, 2001, 2005) (Fig. 1). Three separate areas were tested during the 2003 excavations at the sites: AQ, AC, and KU (Bandy et al., 2004). The AQ area consisted of a large residential midden area dated to the Middle Formative Period (800–100 BC) with an initial Early Formative (1000–800 BC) occupation. The AC area corresponds to the hilltop of the site, where two separate sunken courts and an associated ritual midden area were discovered. A number of primary refuse pits were discovered in the outside of the courts, often containing very high densities of fish bone remains. A number of stratigraphic events associated with the construction and use of the courts were dated to the Middle Formative; however, the midden contained evidence of Early Formative Period activities. The KU excavation area included mostly Late Formative (100 BC–AD 400) features. Several middens, trash pits, and human burials associated with this phase were encountered and sampled as well as an impressive rectangular U-shaped structure with thick stone cobble foundations.

2.2. Field sampling and flotation recovery procedure

The fish archaeofaunal assemblages analyzed for this study were recovered and processed following the standard collection and flotation protocols developed by the Taraco Archaeological Project (Hastorf et al., 2001; Bandy et al., 2004). Ten liter flotation samples were systematically taken and mapped from every locus (i.e., unit of provenience) excavated and ideally from every depositional stratigraphic event encountered. The analyzed samples were processed with a mechanized water flotation system, a modified version of SMAP (Watson, 1976; Bandy et al., 2004). This particular machine consisted of a 55 gallon drum used as water container coupled with a gasoline mechanic oil water pump. Water was pumped into the machine from a local source of water and moved upward through a submerged shower head. An inner barrel with a half-millimeter brass mesh bottom was partially flooded inside the drum and over the shower head. Then, the soil was poured inside the inner barrel.

Usually, the sediment was soaked prior to its submersion in water to facilitate the process of flotation recovery by the disaggregation of clay. While the sediment was being floated, charred plants remain floated up to the surface of the water and were recovered in a fine fabric and using a tea strainer. A gravel siphon was used to recover finer remains floating below the surface of water. In this way, light and heavy fractions were obtained. The light fraction was composed of the material that floated, while the heavy fraction consisted of the material obtained in the inner bucket and contained animal bones, lithics, and ceramic artifacts. The cloth with these remains then was left to dry under the sun. In the present study, only the heavy fraction materials were analyzed, but it should be noted that the light fractions also contain very few fish remains, particularly tiny scales. Once dry, the heavy fractions were sorted with the help of geological mesh screens up to the 1 mm screen size (bagging and storing the rest as residue). The cultural materials were sorted in different artifact classes including animal bones.

2.3. Laboratory analysis

A sample consisting of 31 flotation heavy fractions from different loci were independently analyzed for this study (see Capriles, 2006, for a more detailed description of the sample and the identification procedure). Samples were selected based on investigation priority as defined by excavators and analysts (Bandy et al., 2004) (Table 1). The analysis included sorting the fish bones from other animal bones and classifying the former into groups of identifiable cranial bones, vertebrae, ribs, rays, scales, and unidentifiable specimens. In addition, each one of the resulting groups was further sorted according to the following burning stages: unmodified (unburned, UMO), and modified (MO) which was subdivided into partially burned (brown or partially black), burned (black), and calcified (gray, blue, and white). Each of these groups was then counted and weighed.

Additional modifications to the materials were also recorded when observed, including bent scales, merged scales or other bones, carbonate incrustations, flattening, thinning, weathering, and staining. Bent scales, were used as a signature of boiling, based on the preliminary experimental observations (Moore et al., 2007).

Cranial bones were identified, counted, weighed, and grouped by genus (i.e., *Orestias* or *Trichomycterus*), skeletal element, and side based on morphological characteristics and the use of reference specimens. The best preserved bones were sided and measured using a digital caliper with a precision of 0.02 mm at the specific features formulated by Morales and Rosenlund (1979). Because *Trichomycterus* do not produce scales, counting scales would only enhance the proportion of *Orestias* and, as a result, the comparisons between genera were only made with identifiable cranial bones. Considering that *Orestias luteus* can be identified by the presence of rough scales, scales were sorted into fractions of rough and plain scales. Each of these fractions was then subdivided into size classes of less than 5 mm (<5 mm), from 5 to 9 mm (>5 mm), and 10 mm (>10 mm) as an estimate for the distribution of sizes in the different samples, counted, and weighed. The basic units of quantification units used in this study were the number of identified specimens (NISP) and weight (using a scale of 0.01 g of precision).

Minimum number of individuals (MNI) was calculated as secondary data based on the siding of the most frequent paired cranial element, or the urostyle, of each genus per sample. Biomass estimations were calculated based on Reitz et al. (1987) allometric equations for the class Osteichtyes ($\text{body weight} = 0.90 * \text{bone weight}^{0.81}$, $N = 393$, $R^2 = 0.80$). Estimations of *Orestias* specimen SL were determined using the operculum greatest height (OH) (*sensu* Morales and Rosenlund, 1979, pp. 34–35) by applying a power regression transfer function ($\text{SL} = 22.2036 * \text{OH}^{0.627}$, $N = 38$, $R^2 = 0.304$, $P < 0.001$). The regression was determined by recalculating the raw values of an experimental collection of modern individuals composed of the species *Orestias agassii*, *Orestias albus*, *O. luteus*, and *Orestias pentlandii* (Capriles, 2003).

2.4. Data analysis

All the observations were recorded and quantified in Excel spreadsheets which were subsequently used for descriptive and inferential statistic treatments. For parametric tests, all the units of quantification were log transformed. One-way analysis of variance (ANOVA) was used to determine if modified bones, and estimated SL, changed among periods. *Post hoc* comparisons were performed using the Tukey test. Non-parametric tests were

Table 1
Flotation samples analyzed for the present study including NISP, MNI, weight, skeletal representations, and contextual information

Float #	Locus	Area	Period	Context	Flot volume (l)	Fish NISP	Fish weight (g)	Fish MNI	*Orestias* MNI	*Trichomycterus* MNI	*Orestias* cranial NISP	*Trichomycterus* cranial NISP	Fish ribs NISP	Fish vertebrae NISP	Fish rays NISP	*Orestias* scales NISP	Fish unidentifiable NISP
13166	5233/1	AC	Early Formative	Midden	10	3242	17.75	12	8	4	117	17	160	190	23	2051	684
13167	5234/1	AC	Early Formative	Midden	10	1694	6.42	6	4	2	33	16	13	63	21	1193	355
13200	5238/1	AC	Early Formative	Midden	9	6597	42.03	29	25	4	188	19	283	766	18	2056	3267
13204	5240/1	AC	Early Formative	Midden	10	2256	14.87	17	10	7	112	11	134	244	44	1180	531
13038	5015/1	AC	Middle Formative	Fill over floor	10	851	3.95	9	5	4	29	8	65	29	32	345	343
13118	5134/1	AC	Middle Formative	Surface	10	740	3.45	5	3	2	6	4	141	61	28	246	254
13120	5178/1	AC	Middle Formative	Pit	10	8193	61.36	31	30	1	562	2	877	764	0	2674	3314
13123	5178/2	AC	Middle Formative	Pit	10	2142	16.42	10	7	3	83	11	108	229	38	868	805
13115	5180/1	AC	Middle Formative	Fill over floor	9	495	3.6	3	2	1	15	1	8	62	4	227	178
13156	5192/2	AC	Middle Formative	Pit	10	4930	34.39	19	13	6	127	11	207	390	54	2437	1704
13175	5193/1	AC	Middle Formative	Pit	9	5017	40.79	19	15	4	155	12	512	550	35	2498	1255
13188	5228/1	AC	Middle Formative	Midden	8	57	0.29	1	1	0	1	0	6	6	3	19	22
13163	5229/1	AC	Middle Formative	Pit	3	746	5.26	4	4	0	45	0	11	92	1	371	226
13159	5230/1	AC	Middle Formative	Pit	2	654	4.75	4	3	1	36	2	22	114	0	187	293
13171	5231/4	AC	Middle Formative	Midden	9	10,465	78.64	36	28	8	366	33	712	500	60	4929	3865
13172	5232/1	AC	Middle Formative	Midden	9	1812	14.15	9	4	5	71	13	37	171	20	1155	345
13025	5063/1	AQ	Middle Formative	Midden	10	4413	15.2	8	4	4	65	32	159	177	170	1486	2324
13035	5065/1	AQ	Middle Formative	Midden	11	4046	27.11	18	10	8	170	44	137	346	45	2001	1303
13055	5075/1	AQ	Middle Formative	Midden	9	1345	5.32	11	6	5	37	16	65	107	56	390	674
13093	5080/1	AQ	Middle Formative	Midden	9	313	3	3	2	1	9	5	42	60	3	75	119
13122	5086/1	AQ	Middle Formative	Midden	9	2661	16.99	9	5	4	96	23	99	385	54	714	1290
13131	5088/1	AQ	Middle Formative	Midden	10	1694	12.74	7	5	2	58	9	11	329	5	556	726
13140	5091/1	AQ	Middle Formative	Midden	9	2937	18.81	16	10	6	182	32	127	291	2	1409	894
13220	5164/10	KU	Late Formative	Surface	7	66	0.38	1	1	0	1	0	3	11	2	32	17
13223	5167/1	KU	Late Formative	Fill over floor	9	235	1.91	3	3	0	14	0	18	35	1	89	78
13226	5270/1	KU	Late Formative	Pit	9	173	1.72	4	3	1	10	1	7	10	10	55	80
13232	5274/1	KU	Late Formative	Midden	10	464	3.04	2	2	0	7	0	33	48	16	159	201
13230	5300/1	KU	Late Formative	Pit	1	136	1.19	1	1	0	6	0	11	17	0	46	56
13245	5305/1	KU	Late Formative	Midden	9	387	3.29	5	3	2	13	7	2	46	0	258	61
13249	5307/1	KU	Late Formative	Pit	10	247	1.98	3	3	0	24	0	6	29	0	87	101
13359	5317/6	KU	Late Formative	Midden	9	832	6.91	8	7	1	34	3	153	84	4	291	263
Total					269	69,840	467.71	313	227	86	2672	332	4169	6206	749	30,084	25,628

used when data were not normally distributed and when the variances were not equal. A Mann–Whitney U test was used to determine significant differences between modified bones (i.e., partially burned, burned, and calcified). A Kruskal–Wallis test was conducted to establish the heterogeneity of the estimated body weight, MNI, NISP, and weight tendencies through different periods. *Post hoc* comparisons were performed using a non-parametric Tukey-type test for unequal samples as suggested by Zar (1999). The significance level was set at $P<0.05$ to detect significant differences considering the reduced sample size.

3. Results

3.1. General patterns

Almost 69,840 fish specimens, weighing 467.7 g, from 31 heavy fractions were analyzed (Table 1). From those, 44,212 specimens (357.2 g) were identified to genus level. This is approximately 63.3% of the sample and it comprises 76.4% of the weight. Overall, the most important limiting factors during the identification process were the small size of the specimens and the level of fragmentation; larger bones were generally easier to identify. In contrast, only 917 fish specimens (59.27 g) were identified from loci ($N=16$) which had corresponding 0.63 cm screened fractions. These results, supported by several studies (Wheeler and Jones, 1989; Moore et al., 1999), show that the 0.63 cm screen fractions under-represent the fish remains from any given provenience.

From a total of 3004 cranial specimens, 2672 were identified as *Orestias* and 332 as *Trichomycterus*, with an MNI of 227 and 86, respectively. The genus *Orestias* was the most consumed and preferred since it conforms more than the 80% of the total sample.

3.2. Changes through time

The chronological distribution of the specimens and samples throughout the sequence is not equivalent. The three units of analysis (NISP, MNI, and weight) vary in proportion between periods (Fig. 3). NISP showed significant changes among periods (Kruskal–Wallis: $\chi^2=12.81$, $N=30$, $\mathrm{df}=2$, $P<0.001$) as well as the MNI (Kruskal–Wallis: $\chi^2=10.32$, $N=30$, $\mathrm{df}=2$, $P<0.001$) and weight (Kruskal–Wallis: $\chi^2=11.70$, $N=29$, $\mathrm{df}=2$, $P<0.001$). Non-parametric *post hoc* comparisons indicate that NISP and MNI decreased significantly from the Early

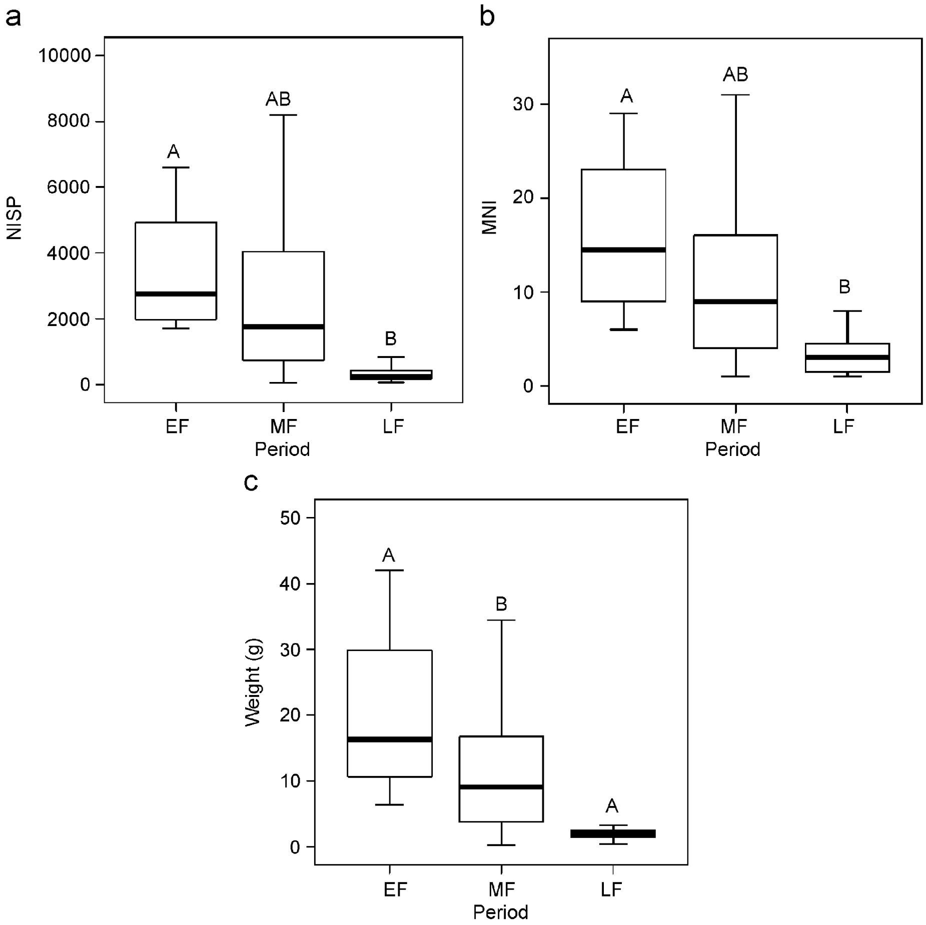

Fig. 3. Box plots of units of quantification between periods, Early Formative (EF), Middle Formative (MF), and Late Formative (LF). (a) NISP, (b) MNI, and (c) weight. Different letters denote significant differences (*post hoc* non-parametric Tukey test: $P\leqslant 0.05$).

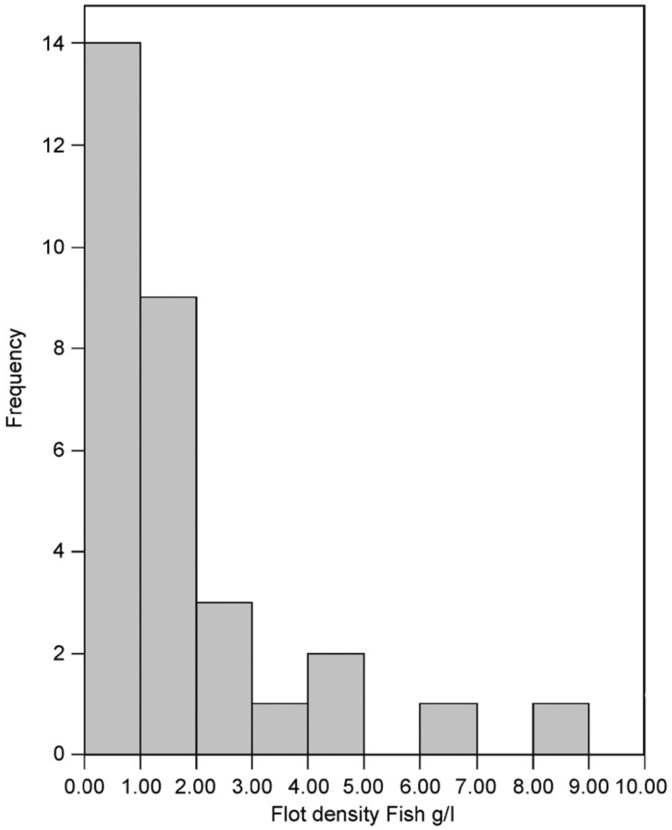

Fig. 4. Frequencies of densities (g/l) of fish bone remains for the 31 heavy fraction flotation samples analyzed.

to the Late Formative (non-parametric Tukey test: $Q = 2.395$, $P < 0.01$).

Weight decreased significantly between the Middle Formative and the Late Formative (non-parametric Tukey test: $Q = 2.394$, $P < 0.05$). Differences among periods might be attributed to a combination of quantification, aggregation, and contextual factors which will be discussed later.

Even though some selected samples with high quantities of fish remains were intentionally selected for this study, the distribution of the frequencies of densities (grams of fish remains per liter of soil) shows a distribution skewed to the right (i.e., a gradient from several samples with smaller densities to fewer samples with higher densities) (skewness = 2.05, kurtosis = 4.71), with most of the samples having densities of less than 2 g/l (Fig. 4). From the information above and the 0.63 cm screen fractions, the following density categories of fish remains for Kala Uyuni can be suggested: very low: >0.01 g/l, low 0.01–0.1 g/l, moderate 0.1–0.2 g/l, high 0.2–0.3, and very high >0.3 g/l. Moreover, significant changes in density through time were detected (Kruskal–Wallis: $\chi^2 = 12.2$, $N = 31$, df = 2, $P < 0.01$) (Fig. 5). Early Formative Period ($N = 4$) has moderate to high densities, the Middle Formative Period ($N = 17$) has a slightly broader range including samples of low to very high densities, and, finally, the Late Formative Period ($N = 3$) samples have restrictively low to moderate densities. A considerable decrease in the density was detected between the Early and the Late Formative (non-parametric Tukey test: $Q = 2.39$, $P < 0.05$).

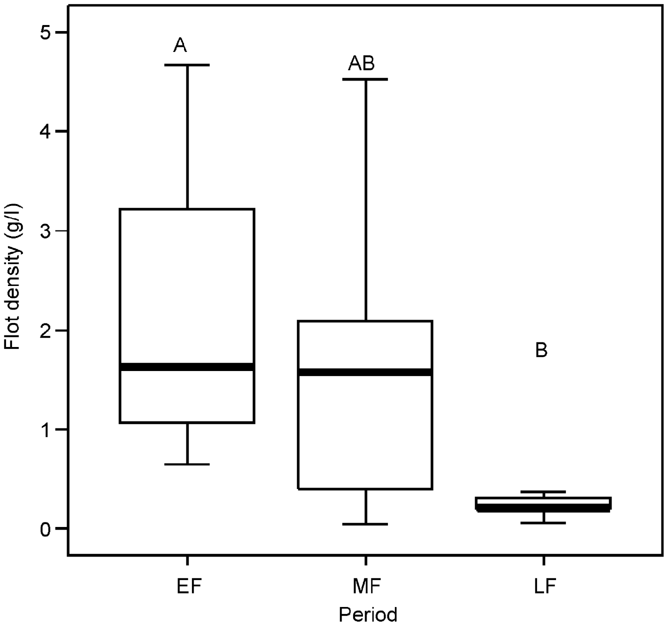

Fig. 5. Box plots of fish bone density (g/l) between periods. Different letters denote significant differences (*post hoc* non-parametric Tukey test: $P \leqslant 0.05$).

The range of estimated body weight calculated for each period suggests a strong decreasing pattern through time (Fig. 6) (Kruskal–Wallis: $\chi^2 = 12.28$, $N = 31$, df = 2, $P < 0.01$; non-parametric Tukey test: $Q = 3.14$, $P < 0.01$). As suggested above, the sampling procedure explains part of this relationship, but it is notable that the relative contribution of fish in terms of weight decreases significantly through time, and is particularly low in the Late Formative samples.

Estimations of the size of fishes were calculated using a regression formula derived from an experimental modern collection. Well-preserved operculum bones from screen and flotation samples were used to estimate the SLs of the fishes. The analysis shows that the size range of the consumed fishes decreased significantly throughout time (Fig. 7). The largest fishes were present during the Early Formative and they diminished significantly during the Middle Formative (one-way ANOVA: $F = 4.61$, $N = 112$, df = 2, $P < 0.01$), although the medium size remains largely the same.

The outliers of the Early Formative and the Middle Formative (data not shown) suggest the consumption of larger and smaller than average *Orestias* species, respectively. Sample sizes are uneven between the three periods; however, the highest range is observed for the Early Formative. The evidence suggests a greater diversity of fish sizes consumed during the first period and a trend towards standardization through time.

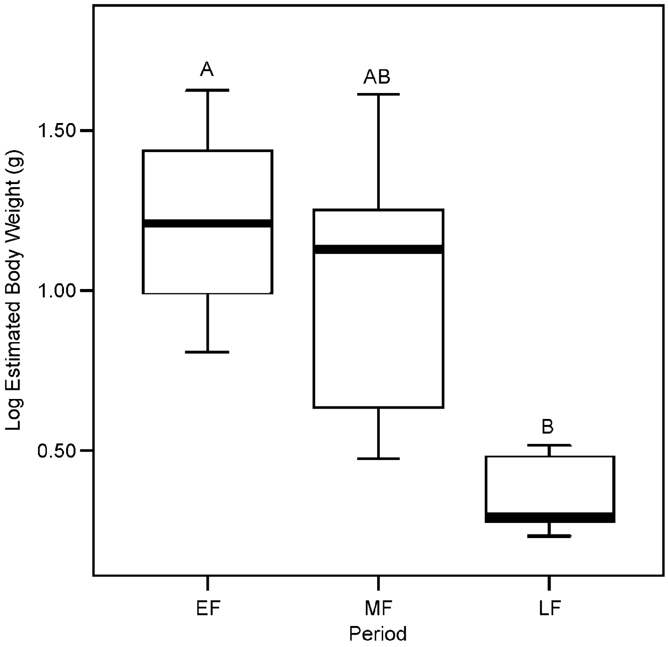

Fig. 6. Box plots of logarithmic body weight estimations of fish bone remains calculated for the entire stratigraphic depositional event associated with each analyzed flotation sample using a bony fishes allometric power regression (Reitz et al., 1987). Different letters denote significant differences (*post hoc* non-parametric Tukey test: $P \leqslant 0.05$).

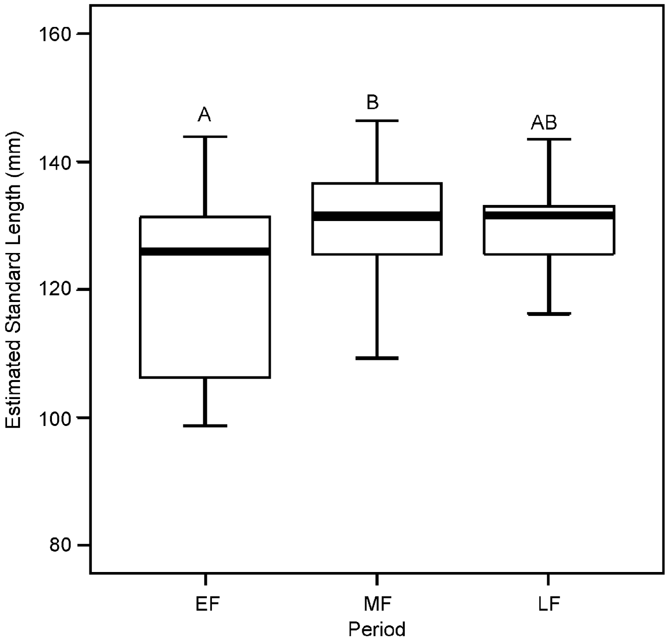

Fig. 7. Box plots of the estimated standard length in mm of the *Orestias* specimens using the operculum greatest height (Morales and Rosenlund, 1979). Screen and flotation specimens from both the left and the right sides were used for the analysis ($N = 75$). Different letters denote significant differences (*post hoc* parametric Tukey test: $P \leqslant 0.05$).

3.3. Modified fish remains

Even though it is assumed that most of the fish bones and scales are the remains of cooked food, only about 14% showed visible signs of heat treatment. This pattern is fairly consistent between NISP and weight frequencies. One-way ANOVA showed that modified (MO) and unmodified (UMO) bones tend to decrease between periods (MO: $F = 5.0$, $N = 31$, $\mathrm{df} = 2$, $P < 0.01$; UMO: $F = 7.02$, $N = 31$, $\mathrm{df} = 2$, $P < 0.01$). In order to understand the variation between modified skeletal bones, proportions of the different kinds of modifications (i.e., burned, partially burned, and calcified) during the Middle Formative were compared. Most of the modified bones were burned (79.1%), while partially burned (10.2%) and calcined (14.4%) were found less frequently. Most of the partially burned and burned specimens were undetermined fragments (<5 mm). Calcified bones were represented mainly by scales and small fragments. The least frequent elements were rays and cranial bones in all the cases.

The heterogeneity of modified bones was compared between pits and middens during the Middle Formative. Differences in the quantity of partially burned, burned, and calcified bones were found between contexts. A Mann–Whitney U test detected a higher amount of burned and calcified bones in middens than in pits (partially burned: $\chi^2 = 1.02$, $N = 133$, $\mathrm{df} = 5$, $P = 0.31$; burned: $\chi^2 = 6.06$, $N = 133$, $\mathrm{df} = 5$, $P < 0.01$; calcified: $\chi^2 = 8.71$, $N = 133$, $\mathrm{df} = 5$, $P < 0.01$).

4. Discussion

4.1. Early Formative Period (1000–800 BC)

All of the fish remains dating to the Early Formative Period belong to the stratified midden excavated on the hilltop AC area. It is interesting to note that no architecture dating to this phase was uncovered from this area. The two trapezoidal sunken courts located during the 2003 excavations were apparently built during the following Middle Formative Period. Nevertheless, judging by the high densities of fish remains and other artifact remains, it appears that ritual and/or other types of activities were carried out in this area before the construction of the buildings. Presently, there is uncertainty if some type of architecture was associated with these activities and perhaps destroyed with the construction of the Middle Formative courts. However, the information that fish remains provide is potentially useful to further understand some of the (probably ritual) activities carried out in this area during the Early Formative Period.

The four loci of the midden have particularly high densities of fish remains (2.14 g/l). This suggests that high quantities of fish were consumed and discarded at the site. The assemblage is particularly robust, since the densities of NISP are equally high and several bones were sufficiently well preserved to make osteometric measurements. Moreover, the screen samples from these loci were equally dense, and, in the case of locus 5238, the highest screen MNI ($N = 297$) for the entire sequence was recorded. This area is interpreted as containing secondary refuse from consumption activities subsequently undisturbed except by limited mechanical and bioturbation processes.

Following Nicholson's (1998) experimental results, biochemical processes enhanced by rapid burial might have consolidated the formation of good conditions for cross-linking of fish bone collagen fibers with the humic content of the soil. Indeterminate bones have a high proportion of burned and partially burned specimens, possibly associated with *in situ* burning activities. From this pattern, it might be speculated that some activities involved burning, although it is not clear if cooking related activities took place near this location. The proportions of skeletal representations suggest that there was not a clear bias in the survival of any specific group of skeletal elements. Moreover, the near absence of burned identified cranial specimens suggests that the firing might have occurred after discard and, consequently, not caused by cooking processing activities.

In relation to species distribution, the cranial information suggests that one out of 10 individuals dated to this phase was *Trichomycterus* and the rest *Orestias*. NISP, weight, and MNI are consistent with this proportion. Coincidentally, the ratio between plain and rough scales favors the former 9–1 as well. This suggests that while the bulk of the fishes consumed were indeed *Orestias*, most of them were not *O. luteus*. Fishing was probably performed near the shore because the diversity of fishes consumed was rather high, probably as a consequence of using diverse types of net fishing. Bone net gauges have been recovered from excavations at Kala Uyuni, and the highest densities of these artifacts are roughly associated with cultural contexts of high densities of fish remains. Both very large and very small specimens are present, including a fair amount of *Trichomycterus*. Interestingly, *O. luteus* was not as popular as in the later phases. There appears to have been a diversity in consumption and possibly in processing.

4.2. *Middle Formative Period (800–100 BC)*

The Middle Formative Period is the best time frame represented in the analyzed sample and, unlike other periods, segregated space as well as diverse contextual information is available from the studied loci. It is apparent that the ritual activities amplified extensively in the AC area. The construction of the two trapezoidal courts is dated to this period, as well as several events of reconstruction and maintenance that are still not well understood (Cohen and Roddick, 2007). Consequently, fish remains provide a glimpse of the activities carried out in this area during the whole span of the Middle Formative Period.

As in the case of the previous Early Formative samples, the Middle Formative midden samples from the AC area are particularly dense in fish remains (3.45 g/l), although there is a wide range between these three samples, the largest having a density of 8.74 g/l and the smallest one 0.04 g/l. It seems clear that the midden continued to be in use during this phase. Considering all the activities held in the courts, it is expected that the quantity and the heterogeneity of the refuse deposited in the midden would be correspondingly high; however, during this period there are new secondary refuse contexts such as trash pits. While the proportion of nine *Orestias* to one *Trichomycterus* persists from the previous phase, interestingly, around half of the *Trichomycterus* specimens found in the AC area were located in midden contexts.

The skeletal representation includes a particularly high concentration of scales followed by ribs, vertebrae, cranial bones (with the broadest diversity and the number of elements identified), and rays. It is worth noting that vertebrae are not particularly well represented. Relatively low percentages of modifications produced by exposure to heat were recorded. This might be signaling that cooking activities took place somewhere else, and that they might have not included roasting fishes, but perhaps boiling them. This is supported by a high percentage of bent scales present in the midden samples.

A total of four pits comprising six loci were analyzed from the Middle Formative Period. Two specifically defined "fish pits" (depositional events A26 and A29) contained high densities of fish bones and ash and were associated with the outside surface of the lower sunken courts. It is unclear if these were offerings made in or to this ritual space or if they were specific discrete deposition events of consumption activities associated with the court. In addition, two pits were identified inside the matrix of the AC midden. The contents of these pits were more heterogeneous than the ones associated with the court.

The pits of the AC area are characterized as having overall good preservation of fish remains. Several of them include an important quantity of specimens exposed to heat. Differences between the fish pits associated with the courts and those of the midden were present. An interpretation of the fish pits from the lower court as specific discrete events of ritual deposition associated with consumption activities is favored. In contrast to other pits and midden deposition events, which were also associated with consumption activities, the fish pits of the lower court also signal purposeful ritual offering, not of fishes themselves (with the possible exception of the remains of locus 5178/1), but of processed (i.e., cooked) fish meals, some of them, perhaps not even consumed.

In addition to the midden and pit contexts, two fill over floor events and one surface sample were analyzed from the Middle Formative AC area. These contexts have comparatively fewer specimens of fish remains. Their relatively poor preservation prohibits further interpretations of their characteristics, although these remains confirm that fish consumption occurred throughout the hilltop.

The analysis of fish remains dated to the Middle Formative also includes a domestic component, which corresponds to the AQ excavation area. Seven loci from the stratified domestic midden of this sector were analyzed. The overall density for AQ is moderate (1.45 g/l) although the lowest levels tend to be denser than the higher ones, as well as in comparison with other contexts. Since all of the analyzed samples from this area are midden samples, they were associated with quite extensive depositional events that grouped together provide a strong indication of the nature of the domestic refuse discarded during the Middle Formative Period at Kala Uyuni.

The fish bones recovered from the AQ area are not extensively modified by fire. Less than 10% of the total analyzed specimens had evidence of some type of burning. Most of them were unidentified specimens, suggesting that the processing techniques did not involve substantial exposure of the bones to fire. The skeletal representation of the bones shows a clear predominance of scales in the remains recovered from the AQ domestic area. This evidence supports the interpretation of the area as a domestic midden.

Moreover, the discarded remains reflect more activities of fish processing and specifically fish scaling rather than consumption. Perhaps boiling the fishes was more common than roasting them. Moreover, the high frequency of burned undetermined specimens as well as the other identified ones might have been produced through unintentional exposure to heat in hearths or during occasional roasting events. The high frequency of domestic cooking pots discarded in the analyzed loci (Steadman, 2007) further reinforces the possibility of boiling as the most important processing practice for fish. In addition, the AQ area is the location where some of the highest frequencies of *Trichomycterus* specimens were found. In fact, for all the Middle Formative, the highest frequency of *Trichomycterus* bones is located in these loci. This information has a great significance, since it suggests that *Trichomycterus* was consumed in the domestic areas of the site. On the other hand, it seems that in the ritual and possibly more public space of the hilltop, the fish consumption was more standardized and *Orestias* was preferred.

Standardized *Orestias* consumption in the hilltop might be related to cuisine and specific cooking preferences and purposefully prepared meals for rituals and festive consumption events on the ceremonial area as well as to increasing status differences. Since few *Trichomycterus* were identified in the hilltop, it would not be warranted to hypothesize that *Trichomycterus* consumption was not carried out in this area. Standardized consumption would imply that a limited number of types of meals were consumed and eventually discarded. Since currently *Trichomycterus* is not a particularly abundant fish and usually is poorly represented in the archaeological record (Capriles, 2003; Sarmiento and Barrera, 2003), it is more logical to use *Orestias*, the more abundant and readily available fish, where middle to large-scale consumption is required.

There are reasons to suspect a different symbolic meaning for *Trichomycterus*, particularly using ethnographic and iconographic information, which suggests a ritual connection with this genus during the Formative Period and a greater relevance of *Orestias* during the following Tiwanaku Period (Capriles, 2003).

The large midden sector along with the fish pits and the characteristics of the fish remains they contain seems to be suggesting that middle to large, possibly community scale meals, were consumed and discarded in the AC area. The possibility that these meals were also processed in the hilltop area requires more evidence than that provided in the present study, but even in the case of decentralized processing and cooking, standardized meals seem to be prevalent. The reduction in the size ranges of measured fish through time also supports this possibility shimmer.

4.3. Late Formative Period (100 BC–AD 400)

Eight samples dating to the Late Formative Period were analyzed. All of them correspond to the KU excavation area, but they include a diverse set of archaeological contexts. The nature and function of the structure excavated in this location as well as of its surrounding area is not entirely clear. Consequently, the implications for the interpretation of the fish remains analyzed from this area can vary. The size and the shape of the structure in addition to its artifact contents (including a large volume of fine ware and decorated serving bowls) as well as the presence of burials in its vicinity might indicate that the KU area was used for special purposes, perhaps as a part of a larger complex of public buildings. However, the possibility that it was a domestic structure has not been completely ruled out.

An initial observation is that fish in all of the KU contexts seem to be less important than in the previous phases. Most of the samples contain very few fish remains and the average density for the phase is low (0.41 g/l), with only one sample having a density higher than 1 g/l (locus 5300/1).

Although a tendency towards the reduction of the number of *Trichomycterus* between periods seems apparent, it is not very strong. Some *Trichomycterus* are present in the Late Formative Period samples, particularly in the midden contexts. What seems to be more evident is the change in the mean size of the *Orestias* individuals, which are statistically significantly larger than those of the Early Formative Period and show a considerably smaller range than those of the Middle Formative. This can be interpreted as more effective fishing techniques emphasizing a particular size class of fishes or a change in fishing strategies or grounds.

Pits tend to be denser in fish remains than midden contexts, although midden samples have a slightly broader diversity of skeletal elements identified and more bones within them were identifiable. These samples also include a significant percentage of burned specimens. The presence of bent and merged scales were greater in this period, and could indicate boiling activities and processing of fish remains near the deposition contexts. Once again, plain scales predominate in the assemblage (~80%) with fewer scales larger than 5 mm, and none larger than 10 mm. This might indicate that even though the average size of the *Orestias* specimens is larger, there is less diversity in the catch, supporting the hypothesis of standardized exploitation processes (Capriles, 2003, 2006). The distribution of the scales further suggests the diversity in the depositional contexts.

Midden samples have a higher proportion of scales, particularly those of the smaller size classes. Pits were among the very few contexts where the quantity of indeterminate remains was higher than scales. The higher quantities of calcified specimens suggest high temperatures of burning, perhaps impacting the identification of the remains. Most calcified specimens were located in the midden contexts.

The additional two contexts, a surface and a fill over floor, are particularly low in fish remains. It seems that the surface of the KU structure was kept particularly clean with a very low density 0.05 g/l, and, even though several fish specimens were recovered from this context, the information provided is rather low. This evidence might support the idea that the structure was not a house. The fill under the surface of the structure was identified over a second floor and includes a moderate density of fish remains (0.21 g/l). Most of the fish specimens from this sample (locus 5167/1) were composed of scales and indeterminate fish bone fragments. The nature of this particular deposition is still not well understood, but erosion of the adobe of the structure as well as sediment redeposited from other parts of the area might be included. Interestingly, burned specimens are few and most of them were not identified, suggesting that the area was kept relatively clean and was not particularly dense in fish remains.

Assuming that the KU structure and its surrounding area had domestic functions, the analysis suggests that fish preparation and consumption were very limited. Nevertheless, the observed pattern might be the result of a reduction in the availability of fish produced by the drought periods recorded in the paleoenvironmental reconstructions of Lake Titicaca (Binford et al., 1997). At least three hypothesized lake-level reductions that dried the southern portion of the lake occurred throughout the Formative Period, of which the greatest occurred during the Late Formative (Abbott et al., 1997). If, in fact, the lake dried during this period, it would have had a major impact on the fishing and household economy of Kala Uyuni and other sites. Maria Bruno (pers. comm., 2006) sees an increase in the diversity of the plant taxa during this same time period, which could have been related to a more extensive use of the agricultural landscape, and in particular the use of the new fertile land opened with the retreat of the lake. The Late Formative Period deposits from KU also indicate a much higher percentage of bird bone than the Middle Formative, suggesting a different local environment (Moore et al., 2007).

On the other hand, if the structure and its surrounding area had a special purpose, possibly associated with the new sociopolitical activities that Kala Uyuni incorporated as it grew to become the possible center of the multi-community polity of the entire Taraco Peninsula, then a functional interpretation might be suggested. Consequently, the low density of fish remains could be reflecting an area not dedicated to intensive processing, serving, or consumption of fishes. At this point it seems fair to suggest that there is a decrease in the consumption and the deposition of fish remains during the Late Formative, and paleoenvironmental as well as contextual differences might account for this pattern.

5. Conclusions

The specific properties of the studied fish samples and their analytical treatment provided relevant information with regard to the osteoarchaeology and taphonomy of fish remains from Lake Titicaca archaeological sites. Subsistence data including the results of this study suggest that throughout the Formative Period there is a tendency of reduction in the importance of aquatic resources. During the Early Formative Period, the inhabitants of the Taraco Peninsula had a diversified economic strategy that included extensive fishing, limited agriculture, possibly incipient camelid herding, and opportunistic hunting of waterfowl and wild mammals (Kent et al., 1999; Moore et al., 1999). The southern Titicaca Basin was a particularly advantageous environment for all of these activities. A tendency towards standardization in the procurement and the preparation of fishes is seen throughout the Middle Formative in correspondence with increasing intensification of *Chenopodium* cultivation practices (Bruno and Whitehead, 2003). By the Late Formative, however, the situation seems to have changed dramatically, and, while the intensification of the domesticates continues to prevail, a clear reduction in the importance of fish is noted.

The sharp decline in fish consumption and discard was a possible consequence of several factors including a greater variability in the water regime (Abbott et al., 1997), an increasing human population pressure (Bandy, 2001), and the possible depletion of wild resources. The rise and the integration of multi-community polities have been interpreted as a response to these complex factors in terms of sociopolitical organization (Bandy, 2001, 2005). The fish remains from the Kala Uyuni site further suggest that the corresponding economical response to this process was a decreasing reliance on fishing and aquatic resources and a possible increment in intensification of the agricultural production and camelid herding. Even though paucity on the exploitation of aquatic resources is observed throughout the Late Formative Period, it is only when these resources reestablished their significance (during the emergency of the Tiwanaku state) that a truly expansive and integrative social system emerged and prevailed over the entire Lake Titicaca Basin.

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