Orestias cf. agassizii (Peces, Cyprinodontidae) in the Area of Influence of the PERU LNG Pipeline

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Orestias cf. *agassizii* (Peces, Cyprinodontidae) in the Area of Influence of the PERU LNG Pipeline

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ABSTRACT. We studied *Orestias* cf. *agassizii* (Peces, Cyprinodontidae) in the area of influence of the PERU LNG pipeline. The study was conducted in water systems within the Mantaro and Apurímac River Basins, at sites located between 3,800 and 4,400 m in the high plateau and watershed divide of Vischongo–Huamanga, in the high puna of Apacheta and Huaytará–Rumichaca. We gathered basic data to determine the possible effects of the construction and operation of the pipeline on *Orestias* species. Specifically, we determine the distribution and abundance of *O.* cf. *agassizii* in the study area, the demography and population structure (by size and sex), the biotic and abiotic parameters that determine their presence, and the potential impacts that the pipeline may cause to its populations. Our results indicate that although *O.* cf. *agassizii* seems to prefer lentic systems elsewhere, in our study it was very abundant in the Leche Leche River. Their presence seems to be related to the dry season, when the population seems to congregate in pools and sites with slow water flow. The population structure of *O.* cf. *agassizii* in terms of size has a normal distribution, with the most abundant size class being between 30 and 49 mm for individuals sampled in the river, creeks, and lagoons. For those sampled in bofedales, the most abundant size class ranged from 20 to 29 mm. The sex ratio found for *O.* cf. *agassizii* was 1:2 (males:females). The water physicochemical parameters measured were within the expected range with *O.* cf. *agassizii* present at locations with high oxygen and conductivity values. Conductivity, however, was not a predictor of abundance, as habitats with the greatest abundance of *O.* cf. *agassizii* were highly variable in this parameter. All sites where *O.* cf. *agassizii* was present had high primary and secondary productivity. Water quality indexes showed that the species is found in places with good water quality conditions. Future studies should be guided to study the impact that the introduction of exotic species is having on the distribution and abundance of *O.* cf. *agassizii*.

KEY WORDS: *Orestias* cf. *agassizii,* endemism, high Andes, lotic, lentic.

Introduction

Fish of the genus *Orestias* (order Cyprinodontiformes, family Cyprinodontidae) are among the most emblematic of the high Andes of Peru because of its diversity (38 species) and high levels of endemism (Ortega and Hidalgo, 2008); only in the Titicaca Basin is it possible to find 31 species, most of them restricted to this water system. The range of distribution of *Orestias* in Peru goes from the upper basin of the Río Santa (in the department of Ancash; Parenti, 1984) to the high Andean Plateau (in the department of Puno) at elevations above 3,500 m. The genus Orestias in South America, unlike other genera of Andean fish such as *Astrolephus* and *Trichomycterus*, is only found in the central Andes of Peru and northern Chile (Reis et al., 2003; Vila et al., 2007).

Orestias fish are characterized by having an upward superior oral region, an absence of pelvic fins, scales with very noticeable channels and pores, and a variable size pattern of scales throughout the body. The size of adult individuals varies between 9 and 22 cm in length, with females being larger (Parenti, 1984; Pinto et al., 1991). Their color can vary from a spotted or mottled pattern in juveniles to a uniform color, except for the ventral region, which is white in juveniles and yellowish in adults.

Orestias can be found in both lotic (rivers and streams) and lentic (ponds and wetlands) habitats and

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have a great variety of eating habits (from plankton eaters to carnivores). Some species are important commercially (e.g., Lake Titicaca) since they are consumed by humans.

Species in the genus *Orestias* are poorly known, except for those found at Lake Titicaca, even though some species are being affected by humans to a great degree and others are already considered locally extinct (*Orestias pentandli* and *O. cuvieri*). One of the main concerns with *Orestias* is the negative effect that introduced alien species are having, such as *Odontesthes bonariensis* (pejerrey argentino) and *Oncorhynchus mykiss* (rainbow trout; de Sostoa et al. 2010). The lack of knowledge, the high degree of endemism, and the threat of extinction make *Orestias* species a conservation priority, hence the need for monitoring programs and conservation plans for these fish.

Within the biodiversity monitoring and assessment program led by the Center for Conservation Education and Sustainability of the Smithsonian Institution and supported by the company PERU LNG, we gathered basic biological data to determine the possible effects that construction and maintenance activities of establishing a gas pipeline may have on *Orestias* species. Specifically, this study aims to determine (1) the distribution and abundance of *Orestias* species present in the study area, (2) demographics on population structure (by size and sex), (3) biotic and abiotic parameters that determine the presence of *Orestias* species, and (4) potential impacts that the pipeline may have on its populations.

Methods

We studied the water systems within the Mantaro and Apurímac River Basins, at sites located between 3,800 and 4,400 m in the high plateau and watershed divide of the Vischongo–Huamanga system, in the high puna of Apacheta and Huaytará–Rumichaca (in the departments of Ayacucho and Huancavelica, in the jurisdictions of Huamanga, Huaytará, and Pilpichaca; Figure 1). We evaluated 12 sampling stations located within ecological landscape units 6, 8, and 10 (Langstroth et al., this volume), covering approximately 90 km. The sampling sites were distributed in five lagoons (Corazón, Tagraccocha, Ccochaccocha,

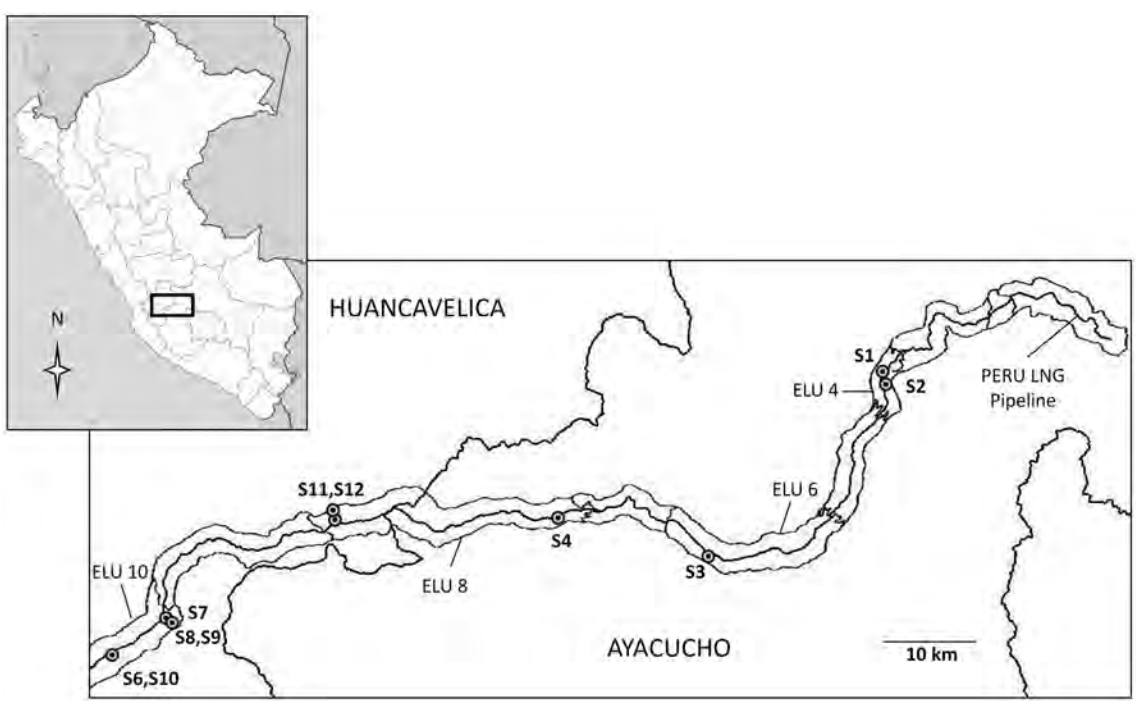

FIGURE 1. Map of the sampling locations where *Orestias* cf. *agassizii* was studied. E1, ORES02 (Corazón Lagoon); E2, Corazón Lagoon; E3, ORES01 (unnamed lagoon); E4, ORES02 (Vizcachayocc Creek, up); E5, ORES03 (Vizcachayocc Creek, down); E6, ORES07 (Leche Leche River); E7, ORES05 (Tagraccocha Lagoon); E8, ORES06 (bofedal 1); E9, ORES04 (bofedal 2); E10, bofedal 3 (head of the Leche Leche River); E11, Ccochaccocha Lagoon; E12: Azulccocha Lagoon. Image © 2009 Google, © 2009 GeoEye, © 2009 Europa Technologies, and © 2009 TerraMetrics.

Azulccocha, and one without known name), two streams, the Leche Leche River, and three bofedales (i.e., high-altitude wetlands; Table 1).

To identify the species, quantify the abundance, and obtain demographic data by age and sex, we captured *Orestias* at each sampling site using drift nets (5 × 10 × 2 m^3, with mesh aperture of 5 mm) and gill nets (15 m length × 1.5 m height, and mesh size of 19.1 mm). Voucher specimens were fixed in formalin in a 10% solution "for further taxonomic studies and were deposited at the Museo de Historia Natural de San Marcos; the rest of the specimens captured were released on site." At each sampling station we placed nets on the basis of fish abundance (more sets in those habitats with low abundance). The initial sampling effort helped us to determine the overall sampling scheme since there were no previous abundance data.

To determine the parameters that influence the presence or absence of *Orestias* at particular sites, we characterized 12 sampling sites (upstream and downstream) with abiotic and biotic parameters. We measured structural parameters (i.e., habitat and substrate type, apparent water color, associated vegetation, bank type, and width and depth of water body; Table 2), physicochemical characteristics of the water (i.e., conductivity, salinity, dissolved oxygen, and water temperature), and biotic indicators of water quality (i.e., abundance of plankton and benthos).

To sample plankton, we filtered 40 L of water using standard plankton nets (20 µm) and a Surber sampler with a 30 × 30 cm^2 metal frame and 1 mm opening to evaluate benthos in lotic waters in three replicates per sampling point. In lentic habitats with depths between 1.5 and 8 m, we used the Eckman dredge (one replicate per sampling point). Plankton was preserved in a solution of 10% formalin and benthos in 70% alcohol. We selected indicator species of water quality for plankton and benthos and calculated the richness and abundance at each site. To analyze data, we used water quality biotic indices such as the generic diatomic index (GDI) and biological monitoring working party (BMWP; Prescott, 1951; Hellawell, 1978; Alba-Tercedor and Sánchez Ortega, 1988; Roldán, 1996, 2001, 2003).

To determine the potential effect of the pipeline on *Orestias* populations, we used sampling localities that were dissected by the pipeline and classified the area above the pipeline (upstream) as control and below the pipeline (downstream) as impacted. For lagoons, we used the slope to classify downhill areas as impacted and uphill as control.

Results

We distinguished three *Orestias* morphotypes for *Orestias* cf. *agassizii* (see Plate 23, I). We included the abbreviation cf. because the species name needs to

TABLE 1. Sampling sites along the PERU LNG pipeline and abundance of *Orestias* cf. *agassizii*. Abbreviations: UTM, Universal Transverse Mercator; ELU, ecological landscape unit; KP, kilometer point of the pipeline; ORES, *Orestias*; No ORE, no *Orestias* present; n/d, not determined; n/a, not applicable.

		UTM Coordinates						
Code	Locality	South	West	ELU	KP	Treatment	Size	Number of individuals
ORES01	Yanaccocha Lagoon	581734	8525215	6	98	Impact	2.5 ha	453
ORES02-03	Vizcachahuaycco Creek	559701	8530866	8	~124	Control/ impact	Mean width of 1.5 m	74/24
ORES04	Bofedal	501970	8516434	10	197	Impact	Channels 0.20–0.50 m wide	40
ORES05	Tagraccocha Lagoon	502965	8515698	10	~197–200	Control	35 ha	156
ORES06	Bofedal	502965	8515698	10	197	Control	Channels 1–5 m wide	236
ORES07	Leche Leche River	494019	8510916	10	~206	Impact	n/d	560
No ORE	Corazón Lagoon	607439	8552121	4	50	n/a	n/a	0
	Corazón Lagoon 2	607815	8550339	4	50–52	n/a	n/a	0
	Leche Leche River head	527002	8530516	8	163	n/a	n/a	0
	Quebrada	0604881	8516189	n/a	n/a	n/a	n/a	0
	Ccochaccocha Lagoon	0526766	8532205	8	n/a	n/a	n/a	0

TABLE 2. Structural parameters of water in sampling sites with *Orestias* cf. *agassizii*.

Code	Locality	Depth (m)	Type, color	Substrate	Shore	Vegetation
ORES01	Yanaccocha Lagoon	8	Clear, dark green	Hard, underwater vegetation	Moderate to high slope	Puna grassland
ORES02/ ORES03	Vizcachahuaycco Creek	1	Clear, dark brown	Rocks with periphyton, underwater vegetation soft, muddy	Narrow, dissected by bofedal	Bofedal
ORES04	Bofedal	No data	Clear, light brown	Muddy	Narrow, dissected by bofedal	Bofedal
ORES05	Tagraccocha Lagoon	1–5	Clear, dark blue	Muddy, underwater vegetation	Wide with mixed vegetation	Puna grassland (north and south), bofedal (east)
ORES06	Bofedal	0.50–0.80	Clear, light brown	Muddy, sandy	No data	Bofedal
ORES07	Leche Leche River	60 (main channel)	Clear, green pools	Channel with rocks, pools muddy, underwater vegetation	No data	Bofedal

be confirmed. We found *O.* cf. *agassizii* in the high Andes (puna) between 3,800 and 4,500 m in the tributaries of the Vinchos River Basin (Mantaro Basin) and the Pampas River Basin (Apurímac Basin). *Orestias* cf. *agassizii* was absent in the lagoons and bofedales above 4,500 m in the Abra Apacheta and the western slope of the Andes.

The Vizcachahuaycco Creek downstream sampling point (impact) had the lowest abundance of *O.* cf. *agassizii* (24 individuals), whereas the upstream sampling point had the highest abundance (74 individuals). Yanaccocha Lagoon had 453 individuals, Tagracoccha Lagoon had 156, the two bofedales had 40 and 236, respectively, and the Leche Leche River had 560. *Orestias* cf. *agassizii* range in size from 10 to 110 mm, but most of them are within 20–59 mm (n = 3,086). The population modal size class for total length was 30–49 mm (Figure 2). We did not find a significant difference in the mean size of fish found in lagoons, bofedales, creeks, and rivers (Figure 2).

The overall sex ratio for males to females was 1:2; however, some samples of the Yanaccocha Lagoon and Leche Leche River had a ratio of 1:5, and other samples in Yanaccocha Lagoon and in one of the bofedales the ratio was 1:1. One percent of individuals examined had immature gonads, and their sex was not determined.

Dissolved oxygen values were between 3.52 and 6.20 mg/L, with percentage saturation between 33% and 58%, which are considered acceptable for aquatic life. Yanaccocha Lagoon and the Leche Leche River had relatively higher values (>6 mg/L dissolved oxygen and >55% oxygen saturation). Azulccocha Lagoon had the lowest relative values (3.52 mg/L; Table 3).

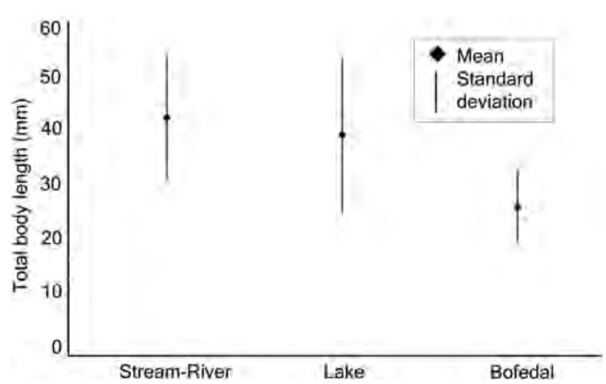

FIGURE 2. Total body length (mm) of *Orestias* cf. *agassizii* in three habitats.

The average water temperature was 13°C (range 11–18).The highest value was recorded in bofedal ORES06 (Table 3). That bofedal had the lowest average depth, and data were taken at 2 PM (the hottest time of the day).

Salinity values at almost all the points were zero, and only Vizcachahuaycco Creek and the Leche Leche River (localities with high relative conductivity values) reached 0.1 and 0.2 parts per trillion (ppt), respectively. The electrical conductivity was less than 100 µS/cm at all sampling sites except the Leche Leche River, which

TABLE 3. Average values of abiotic (water physicochemical) parameters and biotic indices (phytoplankton and zooplankton) at sampling localities with *Orestias* cf. *agassizii*. *H'*, Shannon-Wiener diversity index; GDI, generic diatomic index.

	Orestias cf. *agassizii*	
Parameter	Present	Absent
Water chemical parameters		
Dissolved oxygen (%)	45.28	40.93
Dissolved oxygen (mg/L)	4.74	4.32
Water temperature (°C)	14.55	12.36
Salinity (ppm)	0.04	0
Conductivity (µS/cm)	102.52[a]	36.58
Biotic parameter and water quality		
Phytoplankton richness (individuals/ml)	27	11
Phytoplankton abundance (individuals/ml)	39,171	17,420
Phytoplankton diversity index (*H'*)	4.5	3.2
Zooplankton richness (individuals/ml)	6	4
Zooplankton abundance (individuals/ml)	54	37
Zooplankton diversity index (*H'*)	2.11	1.57
GDI	4.05 (normal)	3.67 (moderate)

[a] The value increased because of a single sampling location (Leche Leche River).

ranged between 22 and 364 µS/cm. Dissolved oxygen, water temperature, and salinity were similar in all locations (with and without *O.* cf. *agassizii*; Table 3).

Principal component analysis showed that the first component explains 55.2% of the variability, with dissolved oxygen (0.525) and conductivity (0.493) having the largest coefficients (Figure 3). Adding a second component increased the explanation of variability to 81%, with salinity as the most influential factor (0.549).

We identified 156 species of algae, phytoplankton, and zooplankton, indicating a relatively high diversity. Phytoplankton and zooplankton species richness and abundance were higher where *O.* cf. *agassizii* was present (Table 3).The GDI varied from 3.5–3.67 (moderate pollution) in Vizcachahuayco Creek, Azulccocha Lagoon, and the Leche Leche River to normal (4.0–4.38) in all remaining sites. Basically, the GDI index shows better water quality where *O.* cf. *agassizii* was present.

Discussion

The present study extends the distribution of *Orestias* to the northern region of the Mantaro River Basin in an area that was considered as data deficient by Parenti (1984). *Orestias agassizii* Valenciennes, 1846 is the most widely distributed species in Peru (Ortega and Vari, 1986), having its northern distributional limit in the Urubamba River Basin (Parenti, 1984). We also confirmed that *O.* cf. *agassizii*, with its relatively wide distribution in the Andes (Parenti, 1984; Villwock, 1986), was absent from some water drainages where the pipeline crosses, but it was found in Carialluna Creek (12 km away from the pipeline) during the environmental impact assessment (EIA) for the Transportadora de Gas del Peru (M. H. Hidalgo, unpublished). Therefore, not finding the species in our study where the pipeline crosses does not mean that the species is not present in the broader catchment area.

Although *Orestias* seems to prefer lentic water systems such as lagoons (Reis and Lima, 2009), it was very abundant in the Leche Leche River. *Orestias* could have been using pools and areas with slow flow, but we cannot be certain because we sampled during the dry season (September 2009).

We found that the population structure of *O.* cf. *agassizii* based on the size of the individuals sampled corresponds to a normal distribution, as reported for other *Orestias* species in Chile (Pinto et al., 1991). The most abundant size class was 30–49 mm for specimens sampled in rivers, creeks, and lagoons. For those sampled in bofedales, the most abundant size class ranged from 20 to 29 mm.

The sex ratio found for *O.* cf. *agassizii* was 2:1 (males:females) and is contrary to studies by Pinto et al. (1991), who indicate that the number of male *Orestias* can be 70% greater than the number of females during certain times of year. Lauzanne (1991), however, reported *O. luteus* (carachi amarillo) in Lake Titicaca with a sex ratio of 1:1. This variation may be due to the time of sampling and the state of the *Orestias* reproductive cycle since some species have fractional spawning, resulting in a greater proportion of males to females at certain times in the annual cycle (Pinto et al., 1991). In addition, the environmental conditions of each study site may influence the outcome. For example, the conditions at Lake Titicaca are very different (e.g., more pollution and a greater presence of introduced predatory species such as trout and pejerrey argentino) from those in our study sites and thus could be affecting the size and population structure of *Orestias*.

The values of the physicochemical parameters obtained in this study are within the expected range,

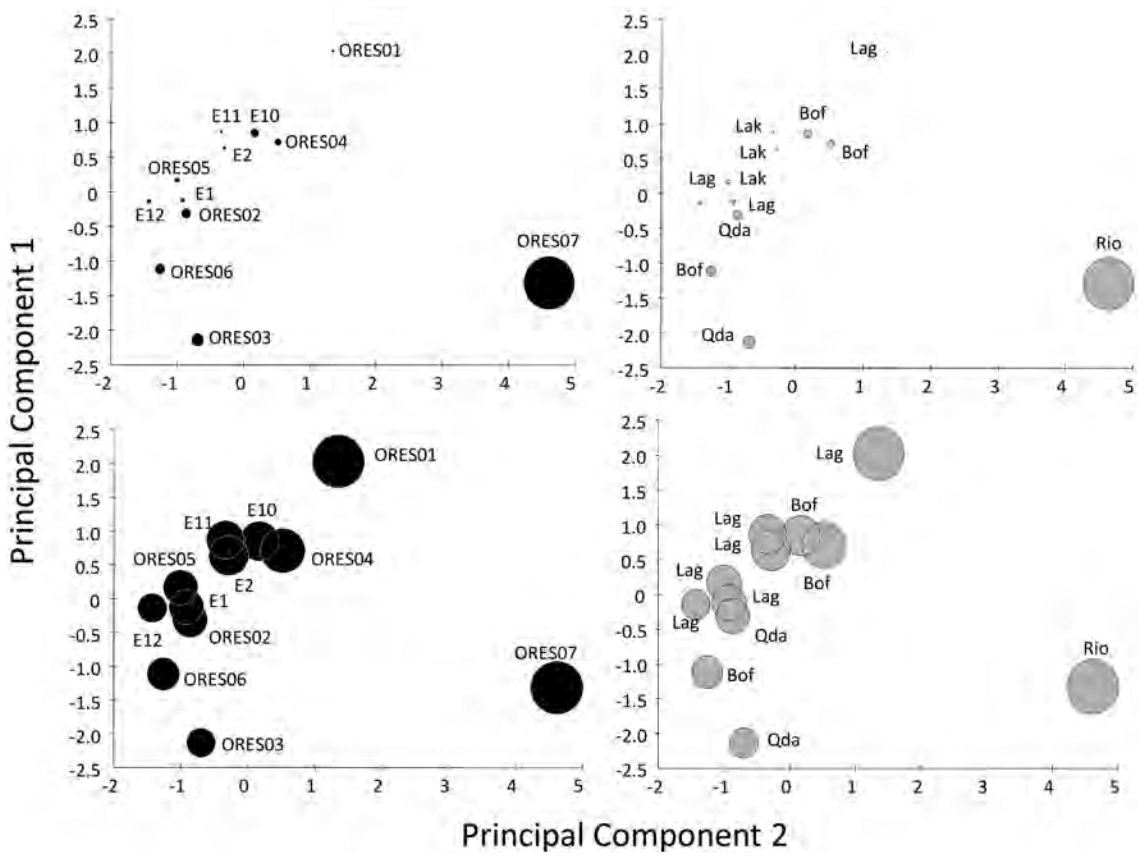

FIGURE 3. Principal component analyses of *Orestias* cf. *agassizii* populations and habitat types with position of water parameters superimposed: top left, dissolved oxygen and populations; bottom left, habitat type; top right, conductivity, water temperature, and populations; bottom right, habitat type. E1, ORES02 (Corazón Lagoon); E2, Corazón Lagoon; E3, ORES01 (unnamed lagoon); E4, ORES02 (Vizcachahuaycco Creek, up); E5, ORES03 (Vizcachahuaycco Creek, down); E6, ORES07 (Leche Leche River); E7, ORES05 (Tagraccocha Lagoon); E8, ORES06 (bofedal 1); E9, ORES04 (bofedal 2); E10, bofedal 3 (head of the Leche Leche River); E11, Ccochaccocha Lagoon; E12, Azulccocha Lagoon.

with daily fluctuations due to solar radiation (Allan, 1995). Overall, our results indicate that the presence of *O.* cf. *agassizii* shows a trend for locations with high oxygen and conductivity values, although conductivity was not a predictor of abundance because habitats with the greatest abundance of *O.* cf. *agassizii* (ORES01 and ORES07) had the largest variation in this parameter (Table 3).

All studied sites were characterized by having high primary and secondary productivity, and the plankton species richness was higher than those reported in the EIA and environmental field study (Walsh Perú, 2005; Domus Consultoria Ambiental, 2007). In addition, the species richness and abundance of phytoplankton, zooplankton, and benthos was higher where *O.* cf. *agassizii* was present. Similarly, the water quality GDI and BMWP indexes showed that *O.* cf. *agassizii* is only found in places with good water quality conditions. Future studies should be guided to understand the impacts that the introduction of exotic species is having on the distribution and abundance of *O.* cf. *agassizii*, a major threat identified in this study.

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