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Short Communication

First Observations on Zooplankton and Optical Properties in a Glacial North Patagonian Lake (Tagua Tagua Lake, 41°S Chile)

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Abstract

The Patagonian lakes are of glacial origin and some of these are associated with glaciers that generate specific optical properties such as water colorations due to glacier sediments. These lakes also are oligotrophic with a low crustacean zooplankton species number. The aim of the present study was to analyze potential associations between optical properties and zooplankton communities in Tagua Tagua Lake (41°S). The results revealed inverse associations in reflectance of bands 3 and 7 of LANDSAT TM+ with *Daphnia ambigua*, *Mesocyclops araucanus*, and nauplius, and direct *Neobosmina chilensis* and *Cyclopoids copepodites*, whereas it was inverse relations between bands 5 and 2 with *B. gracilipes* and calanoid copepodites that make this zooplankton assemblage similar to Nord Patagonian oligomesotrophic lakes. These results would agree with few reports for other similar Patagonian lakes of glacial origin reported for Argentinean and Chilean Patagonia. Nevertheless, it is necessary for more studies to find potential associations between limnological characters and optical properties.

Keywords: glacier, optical properties, reflectance, zooplankton

Introduction

The Patagonian lakes located in southern Argentina and Chile (38-51°S) are of glacial origin [1-3], and some of these lakes have associated ice fields in their surrounding basins that generate specific characteristics in landscapes such as that observed in Grey Lake in Torres del Paine National Park [4], or water colorations specific for each lake, for example the greenish bays in General Carrera or Todos los Santos lakes [1, 5]. Also, the Patagonian lakes are characterized by their marked oligotrophy [1] generated in consequence of the low crustacean zooplankton species

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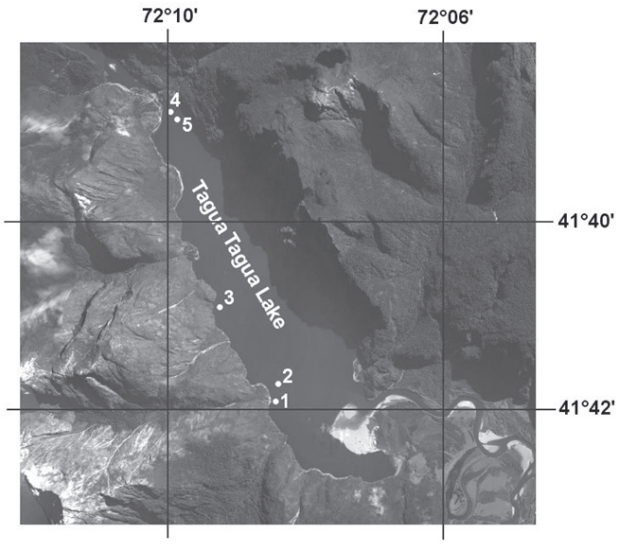

Fig. 1. Satellite image of Tagua Tagua Lake with sampled sites.

richness and marked predominance of calanoids copepods of genus *Boeckella* and *Tumeodiaptomus* [1].

In this scenario, the oligotrophy that can be enhanced by the presence of glacial salts would generate an additional light limitation due to the low penetration of photosintetically active light [1], and this scenario would affect the zooplankton communities such as those observed in preliminary observations of General Carrera Lake in Chile using remote sensing techniques [5]. The aim of the present study is to study the zooplankton assemblage in Tagua Tagua Lake and its potential association with optical properties using remote sensing techniques.

Materials and Methods

Study site: Tagua Tagua Lake belongs to the Puelo Lake system and river basin that involves Argentina and Chile and has numerous lakes and rivers in a mountain zone with difficult access due the mountains and strong winds that complicate sampling work (Fig 1).

Sampling procedures: five sampled sites were georeferenced using a Garmin GPS unit, and zooplankton samples were taken using vertical hauls of 15 m with plankton net of 20 cm diameter and 100 μm mesh size. Zooplankton specimens were fixed in absolute ethanol identified with specialized literature [6, 7] and quantified in laboratory. The site was visited on 10 April 2013. Sechi disk for all sampled sites was 3 m.

Remote sensing procedures: in this step we used a LANDSAT/ETM+ image obtained on April 2013 (Fig. 1) provided by the Land Processess Distributed Active Archive Center (LP DAAC) of the U.S. Geological Survey (http://LPDAAC.usgs.gov). The bands of visible, near, and mid-infrared were calibrated radiometrically to spectral irradiance and then to reflectance with atmospheric correction being applied (Table 1).

Data analysis: reflectance and zooplankton abundances were applied in a principal correspondence analysis to obtain the grouping for sampled sites, and in this analysis a Pearson correlation analysis was considered. This statistical analysis was applied using Xlstat 11.0 software.

Results

The results revealed low species number that varied between two species in sites 2 and 3, three species for sites

Table 1. Geographical location, reflectance, and zooplankton composition for studied sites.

Site	Geographical location	Reflectance					
		B1	B2	B3	B4	B5	B7
1	41° 41’ 58.0” S; 72° 08’ 29.2” W	0.0198	0.0275	0.0010	0.0095	0.0005	0.0013
2	41° 41’ 48.4” S; 72° 08’ 28.1” W	0.0213	0.0277	0.0050	0.0082	0.0059	0.0020
3	41° 40’ 56.1” S; 72° 09’ 18.2” W	0.0216	0.0300	0.0050	0.0050	0.0059	0.0040
4	41° 38’ 50.0” S; 72° 09’ 59.1” W	0.0304	0.0255	0.0058	0.0119	0.0005	0.0031
5	41° 38’ 53.0” S; 72° 09’ 52.9” W	0.0240	0.0255	0.0045	0.0119	0.0005	0.0030

Zooplankton composition (ind/L)						
Site	*D. ambigua*	*N. chilensis*	*B. gracilipes*	Cop. calanoids	*M. araucanus*	Cop. cyclopoids
1	0.0064	0.0382	0.0064	0.0096	0.0318	0.0000
2	0.0000	0.1019	0.0000	0.0000	0.0032	0.0924
3	0.0000	0.0159	0.0000	0.0000	0.0064	0.0096
4	0.0000	0.0478	0.0032	0.0064	0.0127	0.0414
5	0.0000	0.0318	0.0096	0.0096	0.0000	0.0478

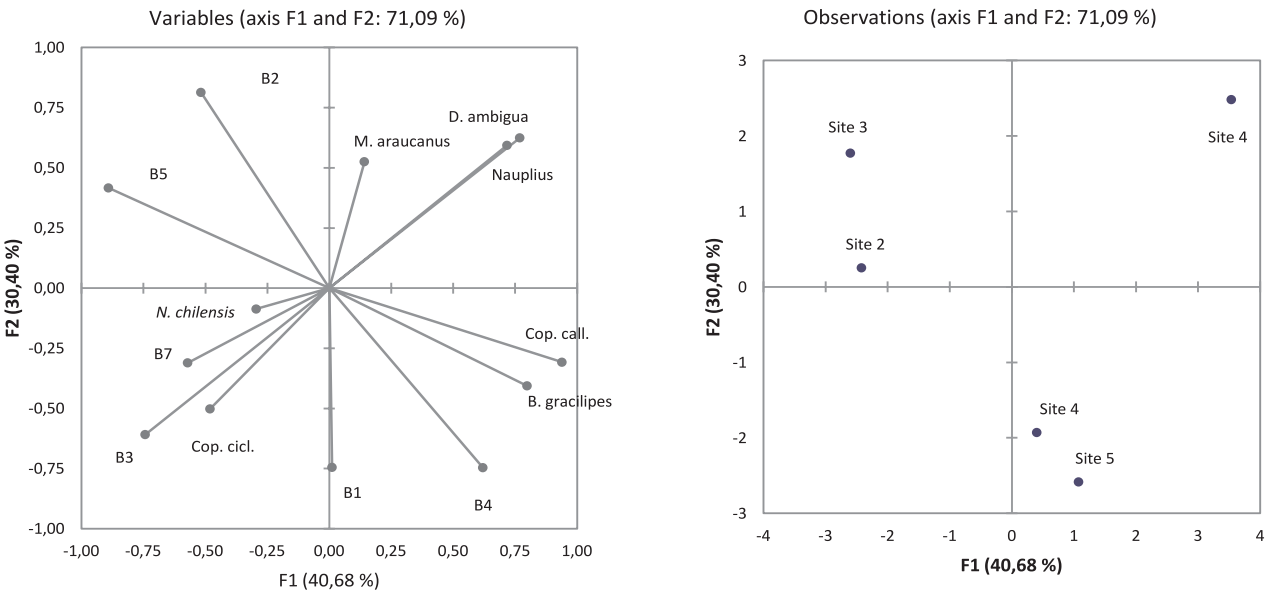

Fig. 2. PCA analysis for variables considered in the present study.

4 and 5, and four species for site 1. The species reported were *Daphnia ambigua, Neobosmina chilensis, Boeckella gracilipes,* and *Mesocyclops araucanus* (Table 1). Sites 1, 2, and 3 have high values for B2 and low values for B7, whereas site 4 has high value for B1 and low value for B5, and site 5 has high value for B2 and low value for B5 (Table 1).

The correlation analysis revealed direct significant correlations between B1 with B3 and B4, B2 with B5, B3 with B7, and B4 with *B. gracilipes* and calanoids copepodites, *D. ambigua* with calanoids copepodites and *M. araucanus*, *B. gracilipes* with calanoid copepodites, and *M. araucanus* with Nauplius. Also we found significant inverse relations between B1 with B2; B2 with B4, *B. gracilipes*, and Calanoids copepodites; B3 with *D. ambigua* and *M. araucanus*; B4 with B5; B5 with *B. gracilipes* with calanoid copepodites; B7 with *D. ambigua, N. chilensis*, and *M. araucanus*; *D. ambigua* with cyclopoids copepodites; and *M. araucanus* with Cyclopoids copepodites (Table 2).

The PCA revealed that the main contributor variables for axis 1 were B3, B5, calanoids copepodites, *B. gracilipes*, and *D. ambigua*, whereas for second axis the main variables where B1, B2, and B4 (Fig. 2, Table 3). Site 1 has low B5 and B7 reflectances and high *D. ambigua*, *M. araucanus*, and nauplius abundance, whereas sites 2 and 3 were high B2 and B5 reflectance and low zooplankton abundance, and finally sites 4 and 5 were high B1

Table 2. Correlation matrix for variables considered in the present study; values in bold denote significant correlation ($p < 0.05$).

Variables	B2	B3	B4	B5	B7	*D. ambigua*	*N. chilensis*	*B. gracilipes*	Cal. Cop.	*M. araucanus*	Cycl. Cop.	Nauplius
B1	**-0.643**	**0.628**	**0.603**	-0.430	0.408	-0.484	-0.057	0.068	0.191	-0.212	0.169	0.107
B2		-0.111	**-0.992**	**0.787**	0.215	0.078	-0.155	**-0.661**	**-0.699**	0.056	-0.317	0.219
B3			-0.001	0.359	0.723	**-0.969**	0.178	-0.434	**-0.524**	**-0.810**	**0.549**	-0.239
B4				**-0.855**	-0.272	0.039	0.090	**0.718**	**0.777**	0.057	0.212	-0.170
B5					0.279	-0.408	0.328	**-0.840**	**-0.963**	-0.435	0.319	0.000
B7						**-0.737**	**-0.516**	-0.253	-0.368	**-0.610**	-0.114	-0.312
D. ambigua							-0.152	0.343	**0.516**	**0.928**	**-0.586**	0.456
N. chilensis								-0.370	-0.359	-0.181	**0.850**	0.140
B. gracilipes									0.936	0.173	-0.235	-0.470
Calanoids cop.										0.447	-0.360	-0.135
M. araucanus											-0.644	0.719
Cyclopoids cop.												-0.303

Table 3. PCA contribution percentage of variables for axis 1 and 2.

	F1	F2
B1	0.003	14.049
B2	5.065	16.739
B3	10.427	9.380
B4	7.273	14.097
B5	15.005	4.386
B7	6.168	2.443
D. ambigua	11.185	9.866
N. chilensis	1.640	0.192
B. gracilipes	12.061	4.177
Calanoids cop.	16.683	2.402
M. araucanus	9.739	8.906
Cyclopoids cop.	4.373	6.380
Nauplius	0.381	6.983

reflectance and *B. gracilipes* and calanoids copepodites abundances (Fig 2).

Discussion

The results described above agree with results obtained for other lakes of glacial origin, for example lakes Sarmiento and Del Toro in the Torres del Paine National Park [8], and General Carrera Lake [6], where the markedly abundant calanoid species *B. gracilipes* Daday, 1901 and/or *B. michaelseni* are associated with low abundances of cyclopoid copepods and the cladoceran *N. chilensis*. Similar results were observed for other glacial oligotrophic lakes in Torres del Paine National Park, such as Nordsdenkjold and Grey, where the zooplankton communities consist of only two species (*B. michaelseni* and *Tropocyclops prasinus* [9]. This situation differs from that of another Patagonian lake with glacial influence, Todos los Santos Lake, which has four species [1].

Zooplankton communities can be affected by glacial influence. In marine environments zooplankton mortality, mainly associated with the chemical properties of the ice, has been found in areas close to ice fields [10, 11]. For Patagonian lakes the glacial influence is water turbidity due to glacier sediments and dissolved organic matter, which prevent light penetration into the water column [12, 13], with the consequences in photosynthesis activity that involve a biogeochemical process of nutrient inputs from phytoplankton that are grazed by zooplankton, such as those observed in Argentinean Patagonian lakes [13]. This would make it similar to some lakes with glacial influence in Torres del Paine National Park, where only two species are found [1, 9]. The results presented indicate that a potential correlation between zooplankton assemblages and optical properties might possibly be found; however, it would be necessary to carry out more intensive studies and obtain more data to be able to confirm or discount the possibility of finding potential correlations.

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