



NATURAL HISTORY NOTE

First record of the invasive algae *Didymosphenia geminata*
in the Lake Nahuel Huapi: Argentina, PatagoniaPrimera detección del alga invasiva *Didymosphenia geminata*
en el lago Nahuel Huapi: Argentina, Patagonia

GUADALUPE BEAMUD*, GUSTAVO BAFFICO, FERNANDO PEDROZO & MÓNICA DIAZ

Grupo de Calidad de Aguas y Recursos Acuáticos (GECARA), Instituto de Biodiversidad y Medio Ambiente (INIBIOMA),
CONICET - Universidad Nacional del Comahue, Quintral 1250, (8400) San Carlos de Bariloche, Río Negro, Argentina

*Corresponding author: beamudsg@comahue-conicet.gob.ar

The benthic diatom *Didymosphenia geminata* (Lyngbye) M. Schmidt is a very aggressive invasive species found in rivers and streams in different parts of the world. It has become a major concern for its tendency to form conspicuous blooms in oligotrophic aquatic systems with potential for detrimental impacts on recreational fishing.

The first blooms of *D. geminata* in South America were found in May 2010 in the River Futaleufú (Los Lagos Region, Chile) (CIEP 2010). Subsequently, the species was detected upstream, in the River Futaleufú (Chubut Province, Argentina), in August 2010 (Sastre et al. 2013). In November 2011 the diatom was recorded in the River Manso (Río Negro Province, Argentina) (M Alemanni, comm. pers. 2011), and in Chimehuin and Collon Cura rivers (Neuquén Province, Argentina) (Abelli Bonardi et al. 2012¹). Given its explosive development and the notable appearance in Lake Nahuel Huapi during the austral summer of 2013, our aim was to document the first record for a large (557 km²) lentic waterbody in the Andean Patagonia region.

On January 29, 2013, samples were collected at three sites spaced 20 m apart along the

shoreline of Lake Nahuel Huapi (41°06' 20.1" S, 71°26' 9.6" W, Fig. 1) in the area known as Bahía Serena (BS 1 and BS 2), and from a small stream that connects a wetland ("Mallín") with Lake Nahuel Huapi. Water temperature, pH (Orion 3Star pH meter) and electrical

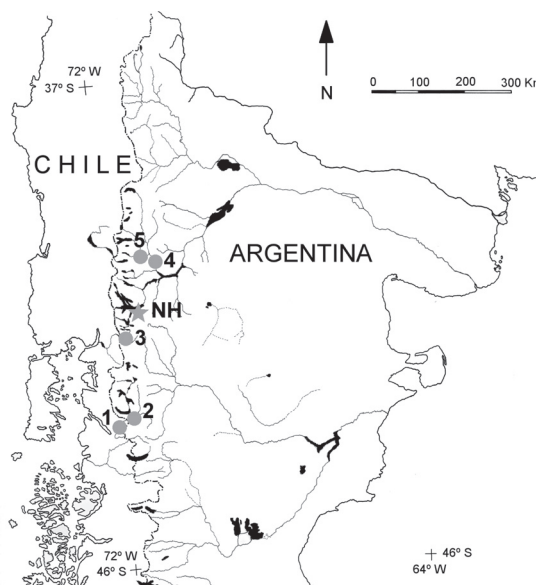


Fig. 1: Map of Northern Patagonia showing sites where *D. geminata* was found. 1: River Futaleufú (Chile), 2: River Futaleufú (Argentina), 3: River Manso (Argentina), 4: River Collon Cura (Argentina), 5: River Chimehuin (Argentina), NH: Lake Nahuel Huapi (Argentina, this study).

Mapa de Patagonia Norte mostrando los sitios donde se encontró *D. geminata*. 1: Río Futaleufú (Chile), 2: Río Futaleufú (Argentina), 3: Río Manso (Argentina), 4: Río Collon Cura (Argentina), 5: Río Chimehuin (Argentina), NH: Lago Nahuel Huapi (Argentina, este estudio).

1 ABELLI BONARDI M, G BAFFICO, G BEAMUD, L CASTIÑEIRA, DÍAZ M, LAFFITTE L, LAURENZANO B, MORZENTI P, MUÑIZ SAAVEDRA J, PEDROZO F, RIVERA D & P TEMPORETTI (2012a) Programa de vigilancia, seguimiento y control de *Didymosphenia geminata* (Lyngbye) Schmidt 1899 en la Provincia del Neuquén. 5th Argentinean Congress of Limnology, November 2012, Santa Fé, Argentina.

conductivity (ORION 3Star) were determined in situ. Samples for water chemistry were collected at 0.2 m depth and were stored in cleaned plastic bottles. The samples were transported to the laboratory where the following determinations were performed using methods outlined by APHA (1992): silicate (SiO_2), total iron (total Fe), sulphate (SO_4^{2-}), total phosphorus (TP), soluble reactive phosphorus (SRP), nitrate (NO_3^-), and total nitrogen (TN). The total organic phosphorus (TOP) was estimated as the difference between TP and SRP. The N:P ratio was calculated as TN:TP. The Si:P was calculated as the ratio of the Si- SiO_2 and SRP. Algal samples were collected directly from rock substrates with a spatula and placed in plastic vials. Immediately on arrival in the laboratory, subsamples were mounted on slides for identification under a microscope (Olympus BX51) at x1000 magnification. The maximum linear dimension

(MLD) of the cells was determined according to Reynolds (2006).

Didymosphenia geminata bloomed on the shore of Lake Nahuel Huapi in the public beach at Bahía Serena area (Fig. 2). The littoral zone has two different areas: one is an entirely volcanic bed-rock (Fig. 2A-B) and the other one is composed of sand and cobbles. The species was detected only in the lake and not in the effluent of the wetland (Mallín). The average (\pm standard deviation) MLD of *D. geminata* cells in Lake Nahuel Huapi samples was $120 \mu\text{m}$ ($\pm 12.7 \mu\text{m}$ SD) and the average width measured was $37.5 \mu\text{m}$ ($\pm 3.5 \mu\text{m}$ SD) (Fig. 2C). The stalks of *D. geminata* were profusely covered by small diatoms, mainly *Achnanthisdium* sp. but also *Navicula* sp. and *Tabellaria* sp. The morphology of the cells of *D. geminata* found in Bahía Serena is consistent with that described by other authors as Sastre et al. (2013) in samples from River Futaleufú in the province of Chubut,

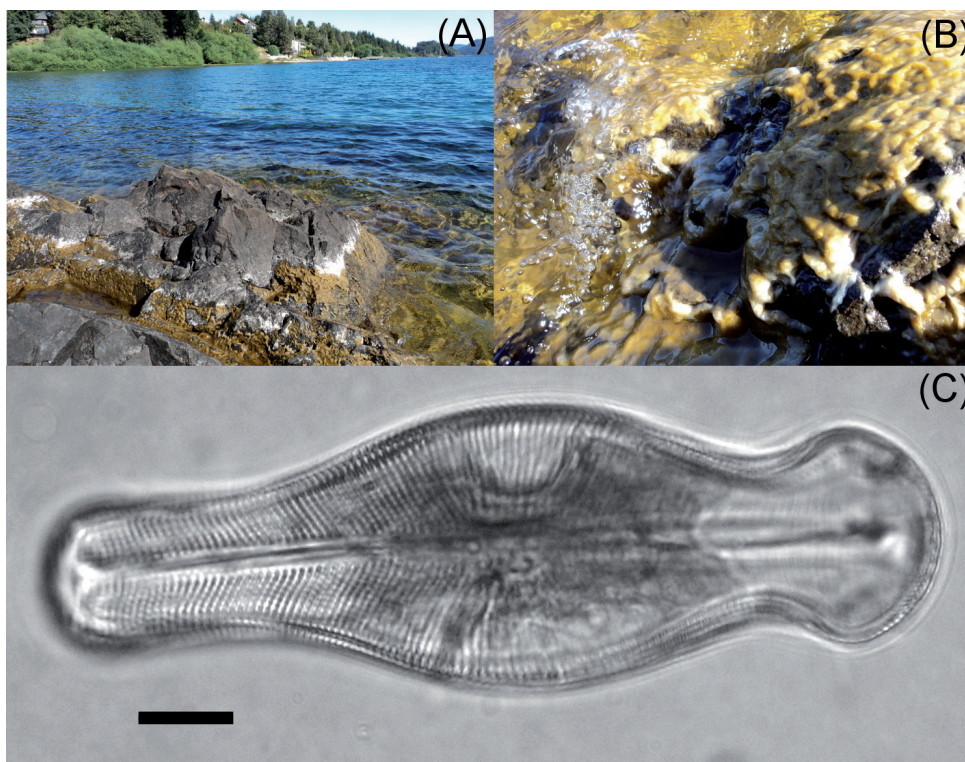


Fig. 2: (A) Detail of the proliferation of *D. geminata*, (B) Close up of the development of *D. geminata* on stones, (C) *D. geminata* cell. Scale bar = $10 \mu\text{m}$.

(A) Detalle de la proliferación de *D. geminata*, (B) Primer plano del desarrollo de *D. geminata* sobre las piedras, (C) célula de *D. geminata*. Escala = $10 \mu\text{m}$.

and Kilroy (2004) in rivers of the South Island of New Zealand, among others.

The pH of the sampling sites was neutral and conductivity and P were both low (Table 1). Total organic P, was higher than the inorganic fraction. N concentrations (dissolved and total) were higher than P and SiO₂ values. Sulphate concentrations and total Fe were near or below the detection limit of the methods. The effluent from Mallín had higher salt content and nutrients than the lake (Table 1). Lake Nahuel Huapi is in the headwaters of an important hydrological catchment of 4260 km² and is a waterbody that has been described as ultraoligotrophic (Diaz et al. 2007), a characterization that can be applied broadly to the lake. Because this waterbody is located in a National Park, the uses of the water are mainly recreational. Sport fishing is an important economic activity in the region. River Limay originates in Lake Nahuel Huapi, and 5 reservoirs built along its watercourse, are used for electrical generation, irrigation, recreational purposes, sport fishing and drinking water.

The presence of *Didymosphenia geminata* in lakes is little known. The species have been described in detail for Lake Baikal (Whitton et al. 2009) and also part of the epilithic community of lentic environments in Turkey (Sahin 2000), Russia (Medvedeva 2001) and the lake District in England (Godward 1937 in Whitton et al. 2009). Our identification in the Lake Nahuel Huapi is the first confirmation of *D. geminata* blooms for a South American lake. The first blooms of *D. geminata* in rivers of South America were reported in Chile's Futaleufú watershed. Likewise the first bloom found in Patagonia Argentina occurred in the River Futaleufú. These watersheds including Lake Nahuel Huapi are located along a 600 km North-South axis of Patagonia (Fig. 1) and have similar chemical, physical and biological characteristics (Diaz et al. 2007). The pH, nutrients (Phosphorus and Nitrogen) and the N:P ratio of Lake Nahuel Huapi agree with those reported by Reid & Torres (2013) for the Baker and Aysen Rivers (Chile), where *D. geminata* mats occur. These Chilean rivers are also oligotrophic, with neutral pH (7.05-

TABLE 1
Environmental conditions of Lake Nahuel Huapi in the coastal area of Bahía Serena (BS1 and BS2) and Mallín effluent at the sampling date.

Condiciones ambientales para la fecha de muestreo en dos sitios de la zona costera de Bahía Serena (BS1 y BS2) y en el efuente del Mallín en el Lago Nahuel Huapi

	Units	Mallín	BS 1	BS 2
pH		7.16	7.23	7.22
Conductivity	µS cm ⁻¹	185.2	43.6	43.1
Temperature	°C	14.0	18.0	16.0
SiO ₂	mg l ⁻¹	23.8	7.1	8.7
SO ₄ ⁻	mg l ⁻¹	< 2	< 2	< 2
Total Fe	mg l ⁻¹	0.07	0.02	< 0.02
TP	µg P l ⁻¹	53.2	17.1	14.5
SRP	µg P l ⁻¹	6.5	< 2	< 2
TOP	µg P l ⁻¹	46.7	16.1	13.5
TN	µg N l ⁻¹	3500	47	74
NO ₃ ⁻	µg N l ⁻¹		12.3	13.3
N:P		65.8	2.8	5.1
Si:P		1700	3313	4060

7.8) and low conductivity (34.3-62.3 $\mu\text{S cm}^{-1}$) (Reid & Torres 2013). They also share environmental characteristics with other rivers, where massive blooms of this species have also been detected, such as rivers in New Zealand. In these rivers, the conductivity varied over a wide range, between 29.8 and 1,612 $\mu\text{S cm}^{-1}$ and the ratio DIN: inorganic P between 3.7 and 98.0 (Larned et al. 2007). Furthermore, in lakes of Turkey with pH values ranging from 7.03-7.15 and values of DIN less than 53 $\mu\text{g N l}^{-1}$ (Sahin 2000), *D. geminata* was present in the environment without forming blooms. On Lake Nahuel Huapi, the Si:P ratio was high, situation in which diatoms are more efficient and have a competitive advantage compared to other algal groups (Hecky & Kilham 1988). The success of the initial colonization of *D. geminata* and the potential for future blooms is defined not only by the introduction of the cells, but also by potential controls that define a suitable window habitat for survival (Cullis et al. 2012). Such controls include: high light availability (Whitton et al. 2009), low nutrient concentrations (Spaulding & Elwell 2007), and low temperatures (Kumar et al. 2009). The chemical characteristics of Lake Nahuel Huapi and the rivers of Patagonia where *D. geminata* has been found correspond to potential controls that define the window habitat. Thus, the study of these environments and distribution of *D. geminata* should be a key element of the research efforts in the future to predict the possible occurrence of massive blooms.

ACKNOWLEDGMENTS: This study was supported by funds from the Universidad Nacional del Comahue (Programme 04B166) to Dr. Mónica M. Diaz. We are very grateful to Max Bothwell for the English improvement of the manuscript.

LITERATURE CITED

- APHA (1992) Standard methods for the examination of water and wastewaters. 17th edition, American Public Health Association, Washington DC, USA.
- CIEP (2010) Evaluación preliminar sobre la diatomea invasora exótica *Didymosphenia geminata* en cuencas de Futaleufú y Provincia de Palena, Región de Los Lagos, Chile. Preliminary Report, Centro de Investigación en Ecosistemas de la Patagonia, Coyhaique, Chile.
- CULLIS JDS, C-A GILLIS, ML BOTHWELL, C KILROY, A PACKMAN & M HASSAN (2012) A conceptual model for the blooming behavior and persistence of the benthic mat-forming diatom *Didymosphenia geminata* in oligotrophic streams. *Journal of Geophysical Research*, doi: 10.1029/2011JG001891.
- DIAZ MM, FL PEDROZO, C REYNOLDS & P TEMPORETTI (2007) Chemical composition and the nitrogen-regulated trophic state of Patagonian lakes. *Limnologia* 37: 37-48.
- HECKY RE & P KILHAM (1988) Nutrient limitation of phytoplankton in freshwater and marine environments: a review of recent evidence on the effects of enrichment. *Limnology and Oceanography* 33: 796-822.
- KILROY C (2004) A new alien diatom, *Didymosphenia geminata* (Lyngbye) Schmidt: its biology, distribution, effects and potential risks for New Zealand fresh waters. Prepared for Environment Southland. NIWA Client report CHC2004-128, Auckland, New Zealand.
- KILROY C & M UNWIN (2011) The arrival and spread of the bloom-forming, freshwater diatom, *Didymosphenia geminata*, in New Zealand. *Aquatic Invasions* 6: 249-262.
- KUMAR S, S SPAULDING, TJ STOHLGREN, KA HERMANN, TS SCHMIDT & L BAHLS (2009) Potential habitat distribution for freshwater diatom *Didymosphenia geminata* in the continental US. *Frontiers in Ecology and the Environment* 7: 415-420.
- LARNED S, D ARSCOTT, N BLAIR, B JARVIE, D JELLYMAN, K LISTER, M SCHALLENBERG, S SUTHERLAND, K VOPEL & B WILCOCK (2007) Ecological studies of *Didymosphenia geminata* in New Zealand, 2006–2007. NIWA Client Report CHC2007-070, NIWA Project MAF07507, New Zealand.
- MEDVEDEVA LA (2001) Biodiversity of aquatic algal communities in the Sikhote-Alin biosphere reserve (Russia). *Cryptogamie Algologie* 22: 65-100.
- REID B & R TORRES (2013) *Didymosphenia geminata* invasion in South America: Ecosystem impacts and potential biogeochemical state change in Patagonian rivers. *Acta Oecologica*, doi:10.1016/j.actao.2013.05.003.
- REYNOLDS C (2006) Ecology of phytoplankton. Cambridge University Press, Cambridge, England.
- ŞAHIN B (2000) Algal flora of Lakes Aygir and Balikli (Trabzon, Turkey). *Turkish Journal of Botany* 24: 35-45.
- SASTRE AV, NH SANTINELLI, GA BAUER, MG AYESTARÁN & NM UYUA (2013) First record of the invasive diatom *Didymosphenia geminata* (Lyngbye) Schmidt in a Patagonian Andean river of Argentina. *BioInvasions Records* 2: 11-17.
- SPAULDING S & L ELWELL (2007) Increase in nuisance blooms and geographic expansion of the freshwater diatom *Didymosphenia geminata*. USGS Open File Report 2007-1425, Reston, Virginia, USA.
- WHITTON B, N ELLWOOD & BKAWECKA (2009) Biology of the freshwater diatom *Didymosphenia*: A review. *Hydrobiologia* 630: 1-37.