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A new collaborative web site to improve the accuracy of dinoflagellate identification: focus on the morphologically-variable genus *Neoceratium* (Schrank) Gomez, Moreira *et* Lopez-Garcia

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Abstract – Identification of dinoflagellates to specific level is sometimes arduous due to high diversity and frequent morphological variability. Focusing on *Neoceratium* genus, often used as ecological indicator, our collaborative web site provides to scientists an accessible and detailed taxonomic tool, allowing accurate identification of its numerous species and varieties. This original web site offers the possibility to visualize several taxa to avoid confusion between infraspecific taxa of the same species and between morphologically close taxa, belonging to different species.

Dinoflagellate / *Neoceratium* / Web Site

While the study of the diversity becomes a first-class issue in our societies, it appears that its estimation remains sometimes problematic. Among the numerous taxonomic impediments that is link to species recognition (Gaston & O'Neill, 2004), species phenotypic plasticity has probably caused many misidentifications. This is particularly true for the dinoflagellates, for which it is difficult for taxonomists or ecologists to categorize specimens from species due to significant morphological variations (Culverhouse *et al.*, 2003).

Within the dinoflagellates, species of genus *Neoceratium* (Schrank) Gómez, Moreira & López-Garcia hold a special place and their morphological plasticity is often treated of "diabolical" (Sournia, 1968). Nevertheless, taxa of the genus *Neoceratium* are very useful. They were recently used as a biological model to examine potential effects of global change on phytoplankton biodiversity (Tunin-Ley *et al.*, 2009). This cosmopolitan genus includes numerous species apparently easy to identify and often representing the main part of thecate and

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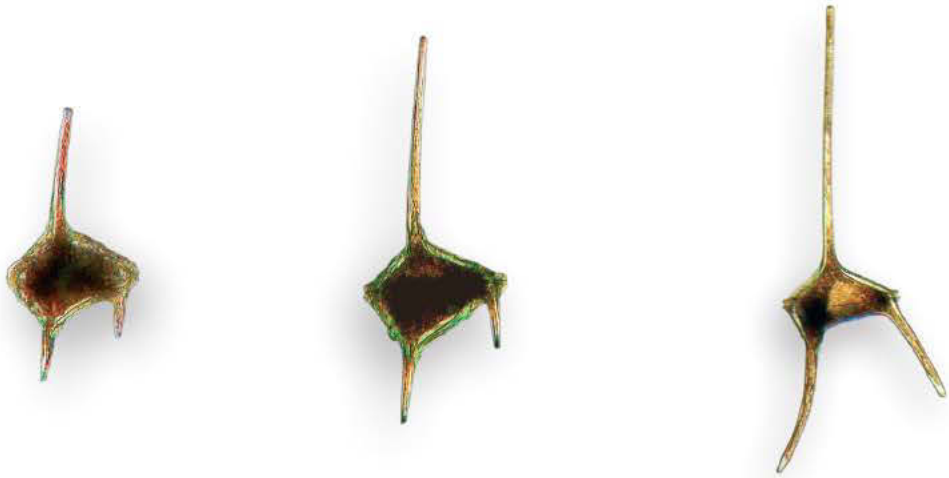

Fig. 1. *Neoceratium candelabrum* and related taxa: from left to right, *N. candelabrum* var. *candelabrum* (type species), intermediate taxa *N. candelabrum "candelabrum-depressum"* and *N. candelabrum* var. *depressum*.

large-sized planktonic dinoflagellates. Moreover, *Neoceratium* species are known to be sensitive to temperature in terms of biogeography (Dodge & Marshall, 1994) seasonality and morphology (Sournia, 1968) and were hence proposed as biological indicators of water masses (Raine *et al.*, 2002), current regimes (Dowidar, 1973) and climate change (John *et al.*, 2003; Tunin-Ley *et al.*, 2009).

Classical morphological concept of species was very well studied in the genus *Neoceratium* and numerous references are available to help identification (Sournia, 1968; Jørgensen, 1911 & 1920; Halim, 1960; Dodge, 1982). Even if the nomenclature changed over time, those modifications are generally traceable, but a lot of original references are needed, the oldest ones being sometimes difficult to find.

Our experience in *Neoceratium* diversity (Tunin-Ley *et al.*, 2007 & 2009; Pizay *et al.*, 2009) confirmed that taxonomic determination within this genus is more arduous than it may first appear. The great morphological plasticity affects particularly the length and the shape of the horns (see day and night variation of *Neoceratium ranipes* in Pizay *et al.*, 2009). However this aspect is only partially described in the numerous published iconographies, which are not always representative of living specimens and/or are not in accordance to each other. As a consequence, the infraspecific variability is often neglected in studies, leading to frequent erroneous identifications.

Moreover, molecular tools to compare morphological and genetic diversities in microplankton have already been used to demonstrate cryptic or pseudocryptic species (Kooistra *et al.*, 2008). Those tools could also bring to light that two distinct species belong in fact to the same taxa. Comparing morphotypes and genotypes in *Neoceratium* genus is under investigation and will probably lead to modify the status of several taxa. A perfect and non-questionable identification of *Neoceratium* taxa, at specific and infraspecific levels, is then needed to follow the evolution of nomenclature that, doubtless, will happen with the general use of genetic tools.

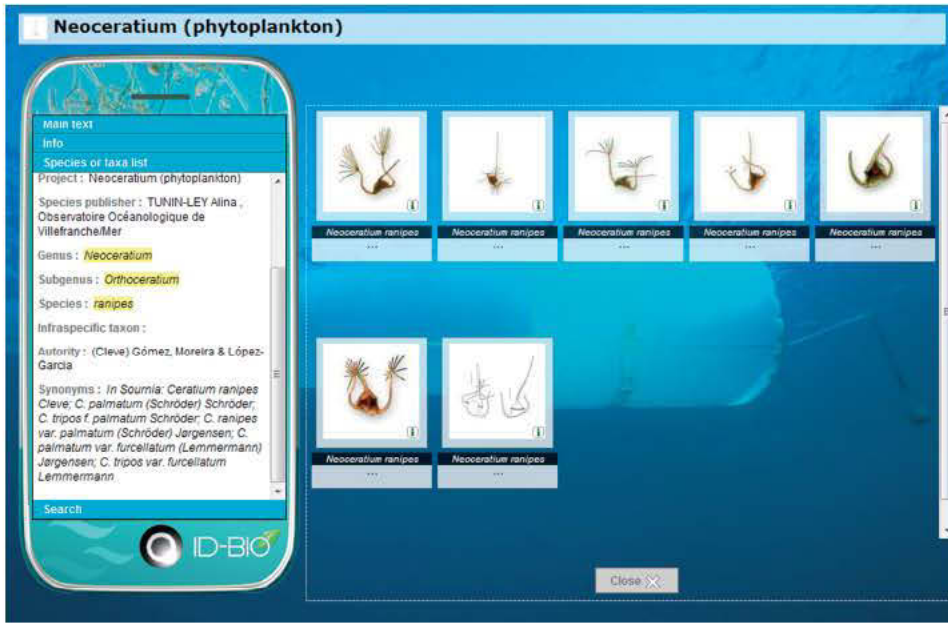

Fig. 2. Example of taxon card of the *Neoceratium* web site (*Neoceratium ranipes*). It displays the current valid name and authority of the taxon, main synonyms found in the literature, card publisher and associates one or several corresponding pictures.

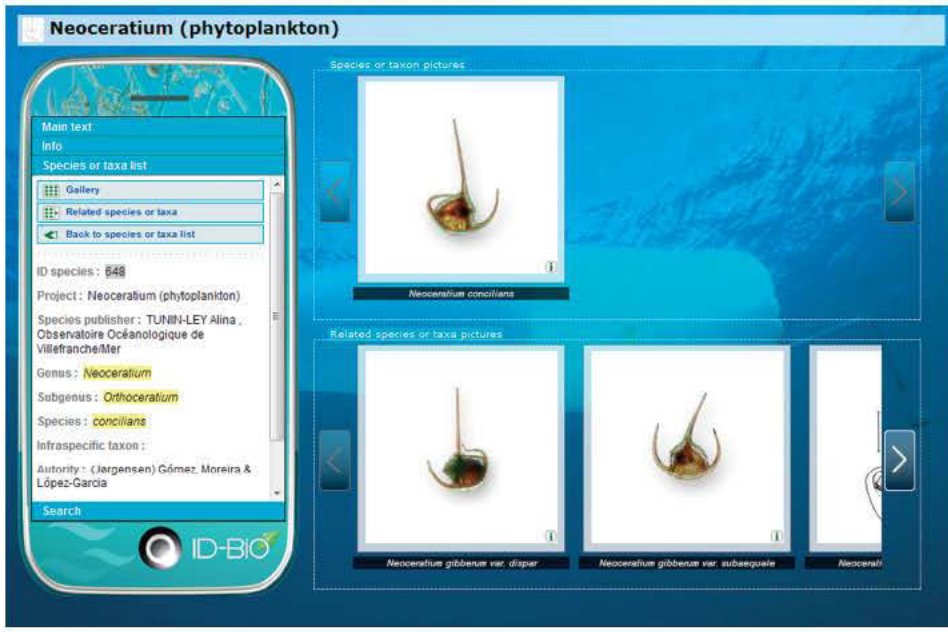

Fig. 3. The "Related species or taxa" option allows to display simultaneously the picture of a chosen taxon (up), and the pictures of infraspecific taxa within the same species, and/or morphologically close taxa of other species (down). Example with *Neoceratium concilians* card.

Our purpose is to provide to scientists an accessible and detailed taxonomic tool allowing identification of *Neoceratium* taxa with accuracy. To avoid future misinterpretation related to *Neoceratium* taxa distribution, biology and ecology, we strongly recommend to planktonologists working on diversity to define as precisely as possible the taxa of the genus *Neoceratium*. Recent molecular and morphological analysis assigned all marine *Ceratium* species to *Neoceratium* gen. nov. (Gómez *et al.*, 2010). While there is still a discussion among specialists on the validity of the new genus name (Calado and Huisman, 2010), Gómez and his collaborators (2010) provided evidence of a clear morphological and phylogenetic separation between marine species and freshwater ones. However, we assume that the non-classical nomenclature, proposed by Sournia in 1968 to allow the determination of all the infraspecific forms, remains the most appropriate. Indeed Sournia's work includes the description of varieties and also transition morphs between these varieties. As an example, the species *Neoceratium candelabrum* (Fig. 1) is divided into two varieties, *N. candelabrum* var. *candelabrum* (type species) and *N. candelabrum* var. *depressum*, and three intermediate taxa, *N. candelabrum "candelabrum-depressum"*, *N. candelabrum "candelabrum>depressum"* (nearer from the variety *candelabrum*) and *N. candelabrum "depressum>candelabrum"* (nearer from the variety *depressum*). As a consequence this website presents the new combinations based on the new genus name *Neoceratium* Gómez, Moreira *et* López-Garcia in accordance with the particular nomenclature established by Sournia (1968).

At the infraspecific level, the genus *Neoceratium* includes 120 reliable taxa, 85 uncertain and nearly the same number of synonyms (Sournia 1986). Among the 80 described species, 77 infraspecific taxa corresponding to 46 species are already present on our web site. Each taxon is described in a taxonomic card specifying the complete taxonomic name, based on Sournia's nomenclature. The new authorities corresponding to the genus name *Neoceratium* are clearly indicated and the current synonyms found in the literature (Fig. 2) are listed, first mentioning the previous name given by Sournia (1968).

All the taxa are illustrated by one or several pictures taken on a light microscope of lugol-fixed cells mainly collected in the NW Mediterranean Sea where the genus is particularly speciose (Jørgensen, 1911, 1920; Tunin *et al.*, 2007; Gomez & Gorsky, 200). To avoid focus problems and display the most of morphological details, several pictures of the same cell were assembled using © Helicon focus software. The resulting "merged" picture is neat and sharp all the way from the center of the body till the ultimate extremity of any horn. For some taxa, the microscope picture is accompanied with the corresponding drawing from Sournia's monography (1968).

Information relative to the picture (picture's author, sampling details, particular comments) is easily available, via the icon located at the bottom-right corner of each picture. The option *"Related species or taxa"* proposes to display the pictures corresponding to the different infraspecific taxa of a same species, and/or the species morphologically close, to facilitate a visual comparison between very similar taxa.

Even if unitary and interoperable projects are needed for future development of taxonomy on the web (see review in Jouenne *et al.*, 2009), our taxonomic data was not integrated to any of the existing web sites dedicated to plankton taxonomy, for two main reasons: first, these sites often do not take into account the infraspecific level and second, it is rarely possible to visualize together morphologically related taxa. This function is particularly interesting for identifying work to avoid confusion between infraspecific taxa of the same species and

between morphologically close taxa belonging to different species. In our *Neoceratium* web site, all morphological related taxa could easily be visualized just near the initial chosen taxa (see Fig. 3).

The *Neoceratium* web site is designed as a collaborative project, aimed to evolve with the contribution of other specialists. A quick update of the web site is expected, as new authorized contributors will add new pictures and text related to the different taxa along. Each contribution is clearly associated to the author of text and pictures. In addition, future bibliographic references on the protologue, including associate figures, will be added in the synonyms section, in order to clearly identify the first description within the numerous synonyms. Finally, phylogenetic information will be integrated when new results will be published. The original structure of this web site is now limited to the genus *Neoceratium* but could easily be adapted to other microplanktonic groups.

Address of the *Neoceratium* web site: http://obs-vlfr.fr/Neoceratium.

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