Selectivity on epilithic diatom consumption for two tropical sympatric gobies: *Sicydium punctatum* Perugia, 1986 and *Sicydium plumieri* (Bloch, 1786)

by

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Abstract. – Rivers of the Caribbean islands harbour a freshwater fauna mainly constituted of migrant diadromous species. In these hyperturbulent ecosystems, the primary producers are mostly represented by a thin epilithic biofilm, mainly composed of diatoms. Comparison of the diatoms available from the environment with the ones consumed and located in the digestive tracts of two gobiid fish, *Sicydium punctatum* Perugia, 1896 and *Sicydium plumieri* (Bloch, 1786) were made at twelve sampling locations, located upstream or downstream of six rivers, in Guadeloupe. One hundred and ninety-one epilithic diatom species were identified. A statistical approach was used to determine diatoms that best characterize the two species digestive tracts content (*i.e.* "diagnostic species") and to evaluate the statistical relationship between species abundances and groups of sites or conditions. Eight taxa belonging to five families were considered as significant diagnostic species of digestive tracts from fish collected upstream (*Achnanthidium subhudsonis*, *Achnanthes rupestoides*, *Diadesmis contenta*, *Diadesmis* sp., *Eolimna* sp., *Navicula (dicta) seminulum*, *Navicula difficillima* and *Nupela* sp.), and five taxa belonging to three families were considered as significant diagnostic species for fish collected downstream (*Gomphonema parvulum*, *Navicula arvensis*, *Navicula cruxmeridionalis*, *Nitzschia frustulum* and *Navicula incarum*). Results indicate selective consumption of epilithic diatoms by the two major fish observed in the mid and upper stream of Caribbean rivers

Résumé. – Consommation sélective de diatomées épilithiques chez deux espèces tropicales sympatriques : *Sicydium punctatum* Perugia, 1986 et *Sicydium plumieri* (Bloch, 1786).

Les rivières des îles des Caraïbes abritent une faune essentiellement composée d'espèces diadromes, migratrices. Dans ces écosystèmes hyperturbulents, le compartiment producteur est principalement constitué par un biofilm épilithique où les diatomées sont majoritaires. Une comparaison des assemblages diatomiques présents dans l'environnement avec ceux situés dans les tubes digestifs de deux Gobiidae, *Sicydium punctatum* Perugia, 1896 et *Sicydium plumieri* (Bloch, 1786) a été réalisée sur douze stations localisées en amont ou en aval de six rivières, en Guadeloupe. Cent quatre-vingt-onze taxons de diatomées épilithiques ont été identifiés. Une approche statistique a été utilisée pour déterminer les diatomées qui caractérisaient le mieux les contenus digestifs des deux poissons (*i.e.* "espèce indicatrice") et évaluer la relation statistique entre les abondances diatomiques, les sites ou encore les conditions amont/aval. Huit taxons appartenant à cinq familles de diatomées se sont révélés indicateurs des contenus digestifs de poissons situés en amont des rivières (*Achnanthidium subhudsonis*, *Achnanthes rupestoides*, *Diadesmis contenta*, *Diadesmis* sp., *Eolimna* sp., *Navicula (dicta) seminulum*, *Navicula difficillima* et *Nupela* sp.), et cinq taxons appartenant à trois familles se sont révélés indicateurs chez les poissons pêchés en aval des rivières (*Gomphonema parvulum*, *Navicula arvensis*, *Navicula cruxmeridionalis*, *Nitzschia frustulum* et *Navicula incarum*). Les résultats ont montré une consommation sélective de certaines espèces de diatomées par les deux espèces de poissons majeurs des cours d'eau moyens et supérieurs aux Antilles.

The rivers of Guadeloupe and Martinique islands (French West Indies) are influenced by steep slopes and have hyperturbulent flows with a bed composed of large andesitic blocks, which only move under exceptionally high discharge. The organization of the foodwebs is distinct compared to most European rivers, with a scarcity of phytoplanktonic, zooplanktonic, and macroalgal components (Coat *et al.,* 2009) as well as a limited aquatic insect fauna

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in the most turbulent reaches of the rivers, from mid to high elevations (Touron-Poncet, 2014). Autochthonous production consists of an epilithic biofilm growing on stones in the river bed. This biofilm, tightly affixed to the stony substrate, is one of the few perennial resources available. Considering the extreme variability of allochthonous inputs in these rivers, epilithic biofilm and diatoms therein could be regarded as pivotal for the sustainability of freshwater biodiversity in these regions (Burns and Keith 2000; Brito *et al.,* 2006; Lefrançois *et al.,* 2010).

Rivers on Guadeloupe and Martinique are inhabited by sympatric Sicydiinae gobies (genus *Sicydium*: *S. punctatum* and *S. plumieri*; Teleostei: Gobioidei). These species are prominent in the Caribbean region, the Greater Antilles and the Bahamas (Lyons, 2005; Monti *et al.*, 2010; Keith *et al.*, 2011; Tabouret *et al.,* 2011, 2015). Sicydiinae gobies are amphidromous, *i.e.* they migrate from freshwater to saltwater (seawater or mangrove) at different moments of their life cycle (Lejeune *et al.,* 2016). The adults live and reproduce in rivers and the larvae hatch in freshwaters (Bell *et al.,* 1995, 1997), then drift downstream in generally less than three days (Ellien *et al.*, 2011). After a dispersal phase, larvae return to freshwater where they undergo a true metamorphosis (Taillebois *et al.*, 2011) and immediately migrate upstream in a schooling behaviour, until they find a territory to settle and reproduce (Bell and Brown, 1995; Blob *et al.*, 2006; Maie *et al.*, 2007; Kawano *et al.,* 2013). These two species are the only fish found in the Caribbean rivers that have a trophic specialization so high, as they only scrape epilithic biofilm and diatoms off the substrate to feed (Erdmann, 1961, 1986; Coat *et al.*, 2009; Barbeyron *et al.,* 2017).

This study aims to analyse, by determining diatoms in the environment and in the gut tubes of *S. punctatum* and *S. plumieri*, whether (1) the two fish exhibit selective feeding within the available diatoms in their environment; (2) if there are any differences in available diatoms species and their consumption between upstream and downstream habitats and (3) whether these two sympatric gobies exploit the same diatom species from the biofilm.

MATERIALS AND METHODS

Samples were collected in February and March 2013, in six rivers of Guadeloupe Island (Fig. 1; Tab. I) known for their pristine or polluted contexts (OEG databases, 2013). In each river, the biofilm and fish were sampled upstream and downstream in riffles. At these twelve sampling locations, epilithic biofilm was scraped from the surface of submerged rocks with a knife and a brush, according to standard NF T 90-354 (20 cm under the surface and 100 cm^2 collected on at least five stones), and each sample was fixed in buffered formaldehyde at a final concentration of 10 percent. The preparation and mounting of diatoms were also made in accordance with standard protocol NF T 90-354. Because identification of diatoms is based on microscopic examination of their siliceous frustules, samples were treated with hot concentrated hydrogen peroxide (H_2O_2 30%) to eliminate protoplasm and, when appropriate, with hydrochloric acid (removal of carbonates). After drying, the diatoms were mounted in refractive resin, Naphrax (Northern Biological Supplies Ltd., England – Refractive index = 1.74) and then identified. The counting protocol and identification of diatom valves is defined by the European Standard EN 14407

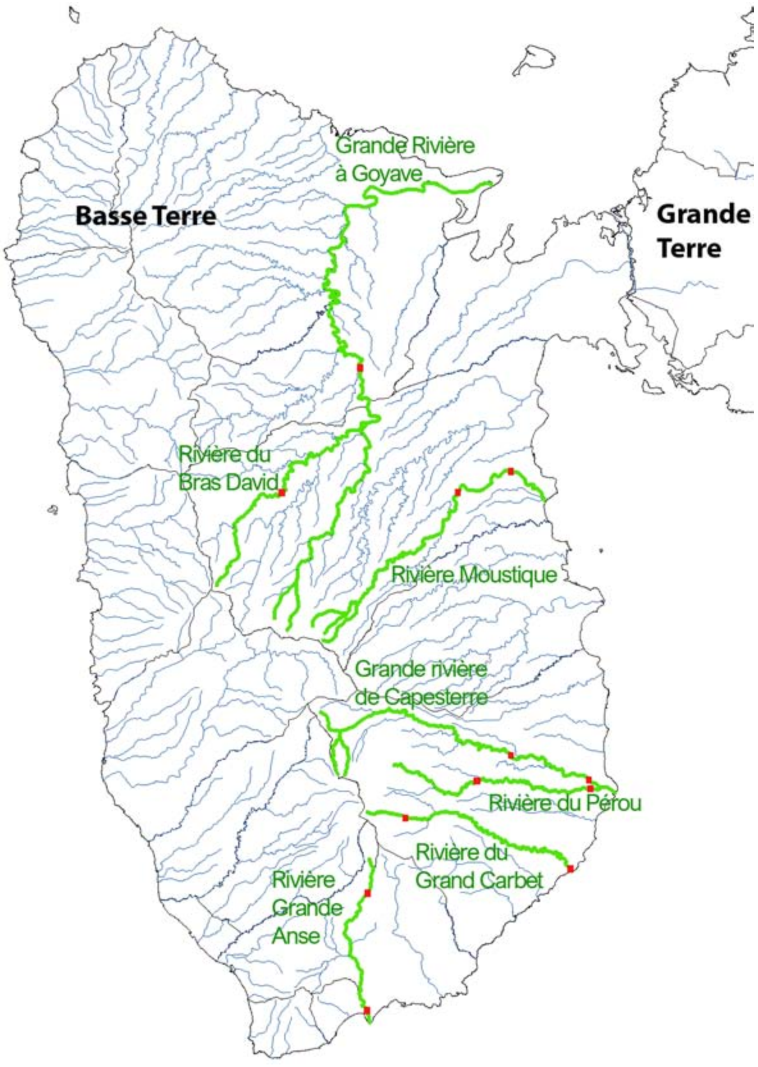

Figure 1. – Locations of the upstream and downstream sampling sites.

Table I. – Rivers, sites and number of fish sampled. Pu: *Sicydium punctatum*, Pl: *Sicydium plumieri*.

River	Site	N	Location WGS84 (UTM-UPS)
Grande Rivière à Goyave	Upstream	5 Pu	648418/1775875
	Downstream	5 Pu	653283/1775472
Rivière Moustique	Upstream	8 Pu, 3 Pl	647422/1788595
	Downstream	8 Pu, 3 Pl	649799/1789578
Grande Rivière de Capesterre	Upstream	5 Pu, 10 Pl	649550/1777258
	Downstream	15 Pu, 5 Pl	653197/1775959
Rivière du Grand Carbet	Upstream	8 Pl	645062/1774248
	Downstream	13 Pu, 3 Pl	652422/1771991
Rivière du Pérou	Upstream	5 Pu, 8 Pl	648418/1775875
	Downstream	13 Pu, 8 Pl	653283/1775472
Rivière Grande Anse	Upstream	0	643411/1770863
	Downstream	5 Pu	643210/1765781

Figure 2. – *Sicydium plumieri* (**A**) and *Sicydium punctatum* (**B**). Pictures and copyright Erick Vigneux.

2004 (see also Stoermer *et al.,* 1996). Four hundred diatom valves were counted and identified to the species level for each sample.

Fish were captured using a backpack electrofishing device (DEKA 3000 Gerätebau, Marsberg, Germany). Individuals were kept alive in ice, then killed and dissected the same day in the laboratory. Fish bodies were preserved in ethanol and digestive parts in formaldehyde solution to determine the diatom communities in diets. Because of a strong morphological convergence between the two-targeted Sicydiinae species at a juvenile stage, species identifications for the smallest individuals (under 50 mm in total length) were genetically determined by amplifying and sequencing part of the mitochondrial Cytochrome Oxydase I (COI) according to the method described in Lord *et al.* (2012). The diatom assemblages of the entire digestive tract of the fish (*i.e.* oesophagus to anus) were analyzed, as described above for epilithic diatom communities. No methodological difficulties have been encountered with regard to the identification of diatoms ingested by fish. Sixty-two quantitative lists of diatoms were thus obtained, both for diatoms on stones and for diatoms located in the digestive tracts of the fish.

The statistical approach used to determine diatoms that best characterize the two species digestive tracts content (*i.e.* "diagnostic species"), and evaluate the statistical relationship between species abundances and groups of sites or conditions, is described in De Cáceres *et al.* (2012). The method uses two data elements: (1) a community data matrix (here, the abundances of diatoms); and (2) a vector that describes the classification of samples into groups. This latter vector was made by their distribution in six predetermined groups obtained independently of species data: upstream stones, downstream stones, and digestive tracts of *Sicydium punctatum* located upstream, of *S. punctatum* located downstream, of *Sicydium plumieri* located upstream, and of *S. plumieri* located downstream. The package *indicspecies* (De Cáceres and Jansen, 2014) and its function *multipatt* developed for the R environment (R Development Core Team, 2008) were used to measure the association between each diatom species and each group. This function calculates an *IndVal* index, which is the product of two components: 'A', the probability that the sample belongs to the target group, given the fact that the species has been found, and named *positive predictive value*; and 'B', the probability of finding the species in elements belonging to the group, and named *sensitivity*. Finally, the statistical significance of this relationship was tested using a permutation test (De Cáceres, 2013).

RESULTS

The results of these analyses are presented in Table II and coupled with indications on, first, diatom species biovolumes (µm^3, Lecointe *et al.*, 1993; Rimet and Bouchez, 2012). For undetermined species, biovolumes have been calculated according to their shape and mathematical equations (Hillebrand *et al.,* 1999). The second information is on the diatom status (abundance of species in Diatom Index of water quality database for French West Indies (Gueguen *et al.,* 2013) with ≥ 10%: dominant taxon, [5%-10%[: main taxon, [2.5%-5%[: secondary taxon, < 2.5%: rare taxon. The

Table II. – **A**: Diatom species found in *Sicydium* species guts in the upstream locations. a) biovolumes (µm3), b) diatom status (abundance of species in Diatom Index of water quality database for French West Indies (Guegen *et al.*, 2013) with ≥ 10% : dominant taxon, [5%-10%[: main taxon, [2.5%-5%[: secondary, < 2.5%: rare, c) type of association, and d) shape. **B**: Diatom species found in *Sicydium* species guts, in the downstream locations. a) biovolumes (µm3), b) diatom status (abundance of species in Diatom Index of water quality database for French West Indies (Guegen *et al.*, 2013) with ≥ 10% : dominant taxon, [5%-10%[: main taxon, [2.5%-5%[: secondary, < 2.5%: rare, c) type of association, and d) shape.

Code	Fish species	Biovolume	Diatom species	Family	Status	Association	Shape	A	B	p-value
				Upstream						
ADSH	*S. punctatum*	66	*Achnanthidium subhudsonis*	Achnanthidiaceae	dominant	solitary	pedunculate	0.358909	1.0000	0.0332
ARPU	*S. punctatum*	191	*Achnanthes rupestoides*	Achnanthaceae	dominant	solitary	pedunculate	0.480083	0.7273	0.0295
DCOT	*S. plumieri*	129	*Diadesmis contenta*	Diadesmidaceae	dominant	colonial	ribbon-shaped	0.452786	0.8889	0.0307
DI05	*S. plumieri*	30	*Diadesmis* sp. 5	Diadesmidaceae	main	colonial	ribbon-shaped	0.794521	0.3333	0.0228
EO06	*S. plumieri*	88	*Eolimna* sp. 6	Sellaphoraceae	dominant	solitary	motile	0.337014	1.0000	0.0489
ND02	*S. plumieri*	69	*Navicula (dicta) seminulum*	Sellaphoraceae	dominant	solitary	motile	0.390477	0.8889	0.0194
NDIF	*S. plumieri*	55	*Navicula difficillima*	Naviculaceae	secondary	solitary	motile	0.954344	0.4445	0.0166
NUP1	*S. plumieri*	89	*Nupela sp1*	Diadesmidaceae	dominant	solitary	motile	0.433017	1.0000	0.0125
				Downstream						
GPAR	*S. punctatum*	331	*Gomphonema parvulum*	Gomphonemataceae	dominant	solitary	pedunculate	0.479289	0.7895	0.0461
NAR1	*S. plumieri*	51	*Navicula arvensis*	Naviculaceae	secondary	solitary	motile	0.743709	0.3636	0.024
NCXM	*S. plumieri*	113	*Navicula cruxmeridionalis*	Naviculaceae	dominant	solitary	motile	0.455251	0.7273	0.0234
NIFR	*S. plumieri*	258	*Nitzschia frustulum*	Bacillariaceae	dominant	solitary	motile	0.39144	0.9091	0.0173
NINK	*S. plumieri*	325	*Navicula incarum*	Naviculaceae	dominant	solitary	motile	0.533299	0.6364	0.0313

third information is the type of association, and the fourth the shape of the diatoms. The two latest criteria are presented in Table III.

In total, one hundred and ninety-one epilithic diatom species were identified (App. I) and numbered according to the classification and criteria used in the Caribbean area (Asconit consultants, 2014). Within these 191 species, only eight belonging to five families were considered as significant diagnostic species of digestive tracts from fish collected upstream (*Achnanthidium subhudsonis*, *Achnanthes rupestoides*, *Diadesmis contenta*, *Diadesmis* sp5, *Eolimna* sp6, *Navicula (dicta) seminulum*, *Navicula difficillima* and *Nupela* sp1). Five species belonging to three families were considered as significant diagnostic species of digestive tracts from fish collected downstream (*Gomphonema parvulum*, *Navicula arvensis*, *Navicula cruxmeridionalis*, *Nitzschia frustulum* and *Navicula incarum*). The significant results ($p < 0.05$) mean that these diatom species can be interpreted as taxonomic signatures of the fish digestive tract contents.

Additional information is given by the examination of the A and B components of the diatom species indicative value. Some of these species indicate a feeding choice general to a group because they appear in all digestive tracts of a defined group of fish (*i.e.* $B = 1$). This is the case, upstream, of *Achnanthidium subhudsonis* for *S. punctatum* and also *Eolimna* sp. 6 and *Nupela* sp1 for *S. plumieri*, but are not restricted to it ($A = 0.358909$, 0.337014 and 0.433017, respectively). These species could be defined as a common ($A \neq 1$) and very appreciated ($B = 1$) food source upstream.

DISCUSSION

When looking at the biovolumes, the results show smaller species consumed upstream, which is consistent with the results obtained by Passy (2007), who showed that species of short stature are highly correlated to high current velocity. From our analyses we found that whether upstream or downstream, *S. punctatum* appear more specialized than *S. plumieri*, which feed significantly on more taxonomically variable and less dominant species.

The diatom morphotypes show neat differences between the two fish species, with an apparent preference (either upstream or downstream) for pedunculate species by *S. punctatum*. *Sicydium plumieri*, on the contrary, fed significantly on ribbon-shaped diatoms upstream. These results can be compared with previous research done on the teeth of these tropical gobies, which have been qualified as having "the most remarkable dentitions in the animal kingdom" (Berkovitz, 2013) because of the huge replacement processes occurring on teeth worn on the rocks during scraping. *Sicydium plumieri* was defined as a "stone biting goby", scraping algae from rock surfaces with his strong unicuspid teeth and *S. punctatum* as an "algae eating goby", feeding on filamentous algae and other soft vegeta-

Table III. – Type of association and shape of diatom taxa.

Life form			Commentary
Type of association		Shape	
Solitary	Free	Planktonic Moving cell	
	Fixed	Prostrated	Patched on the substratum by the whole cell
		Adnate	Mucilage pad and patched on the substratum
		Tuft forming	Mucilage pad
		Stalk forming	Mucilage stalk
Colonial		Chain colony Ribbon colony Zig-zag colony Rosette colony Star colony Arbuscular colony Mucous tubule colony	

tion because of its more fragile tricuspid teeth extremities (Watson, 2000). Our results partially corroborate this latter hypothesis, with *S. punctatum* selecting pedunculate cells, less firmly attached to the substrate.

The ecological profiles of common (A ≠ 1) and very appreciated (B = 1) diatom species in upstream locations (*Achnanthidium subhudsonis* for *S. punctatum* and *Eolimna* sp6 and *Nupela* sp1 for *S. plumieri*), when compared with the analysis of 458 pairs of diatom inventory/physico-chemical data (Gueguen *et al.,* 2013), reveal that they are more commonly found in high quality sites. On the contrary, no diatom was consumed exclusively by a group (*i.e.* occurs in sites or species belonging to this group only, with A = 1), which means that trophic niche of these two fish is, at least partially, overlapping. These elements are consistent with the general ecological conclusion that grazers are typically generalist feeders (Cummins, 1973). When looking at the proportion of samples of a given group where one or another indicative species is found (*coverage*), the values indicate full coverage for *S. punctatum* upstream and downstream (with values of 1 and 1) and partial fulfilment of the mission for the indicative species regarding *S. plumieri* (with 0.789473 and 0.909091, respectively). These elements could be linked with the greater number of indicative species in the digestive tract of this latter species, suggesting more extensive feeding territories or more efficient scraping strategy.

The notion of relative availability of food resources actively searched by species in the upper parts of the rivers has been evoked to play a key role in the migration of amphidromous species (Gross *et al*., 1988). Amphidromy represents a successful adaptation to the colonisation of tropical island systems (McDowall, 2007; Keith and Lord, 2011). Sicydiinae gobies, as well as other taxonomic groups (molluscs, crustaceans) living in swiftwater, show the ability to adapt to varying environments by selecting their food based on the abundance and composition of stream algae (Kido, 1996; this study). Moreover, the climbing aptitude of these Sicydiinae is closely linked to the oral movements made when grazing biofilm. This hypothesis of possible coopting of similar movements, named *exaptation,* has been evidenced on a relative, *Sicyopterus stimpsoni* in Hawai'i, and generalized to Sicydiinae (Cullen *et al.,* 2013). The relative order in the emergence of the evolutionary forces that led to the actual mechanisms of climbing and grazing is currently unknown, but may relate to the origin of these abilities in species found at high altitudes in the French Caribbean. Our results identify several species of diatoms particularly consumed by these fish upstream, and their spatial repartition and nutritive characteristics would be interesting to assess, specially the species-specific capacity of diatoms to survive fish ingestion (Grubach, 2010). Diet gaps or shifts have been demonstrated to have ecological and evolutionary consequences for gobies because a failure of food availability and changes in diets could cause a decrease in reproductive fitness (Jackson *et al.,* 2002; review in Jackson and Rundle, 2008).

Bioindication based on epilithic diatomic counts is the most powerful tool used for ecological management in this region where the complexity of freshwater ecosystem function leads to a scarcity of other bioindication candidates. Taking into account its good integration capabilities and a pivotal role in the input of energy in aquatic ecosystems, the biofilm (and its diatomic component) is found to be highly consumed and therefore *biologically redesigned* (redesigned by the selective trophic exploitation of some of its components). Our work shows selective consumption of diatom taxa by the two major fish observed in the mid and upper stream of Caribbean rivers. In addition, some research done on tropical crustaceans showed that these species could be also selective in their diatom consumption (Abreu *et al.,* 2007) with an unknown impact on biofilm structure and components. These are crucial elements that need to be further studied in order to refine bioindicative conclusions based on diatom assemblages in these regions.

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Appendix I. – List of diatoms species found.

ACHD	ACHNANTHIDIUM F.T. Kützing
AD05	*Achnanthidium* sp5
AD07	*Achnanthidium* sp7
AD11	*Achnanthidium* sp11
AD13	*Achnanthidium* sp13
AD14	*Achnanthidium* sp14
AD15	*Achnanthidium* sp15
AD18	*Achnanthidium* sp18
AD19	*Achnanthidium* sp19
ADCT	*Achnanthidium catenatum* (Bily & Marvan) Lange-Bertalot
ADEG	*Achnanthidium exiguum* (Grunow) Czarnecki
ADMI	*Achnanthidium minutissimum* (Kützing) Czarnecki
ADSH	*Achnanthidium subhudsonis* (Hustedt) H. Kobayasi
AFON	*Amphora fontinalis* Hustedt
AM10	*Amphora* sp10
AMMO	*Amphora montana*
AMUS	*Adlafia muscora* (Kociolek & Reviers) Moser Lange-Bertalot & Metzeltin
APED	*Amphora pediculus* (Kützing) Grunow
ARPU	*Achnanthes rupestoides* Hohn var. *uniseriata* Lange-Bertalot & Monnier
ASTG	*Amphora subturgida* Hustedt
BNE1	*Brachysira neoexilis* forme 1
BNE2	*Brachysira neoexilis* forme 2
BR01	*Brachysira* sp1
CA01	*Caloneis* sp1
CAGR	*Cyclotella atomus* var. *gracilis* Genkal & Kiss
CEUG	*Cocconeis euglypta* Ehrenberg
CLCT	*Caloneis lancettula* (Schulz) Lange-Bertalot & Witkowski
CMLF	*Craticula molestiformis* (Hustedt) Lange-Bertalot
CPL1	*Cocconeis placentula* var. *placentula sensu* Jahn *et al.* (2009)
CPLA	*Cocconeis placentula* Ehrenberg var. *placentula*
CPLI	*Cocconeis placentula* Ehrenberg var. *lineata* (Ehr.) Van Heurck
CRA4	*Craticula* sp4
CTRO	*Cymbella tropica* Krammer var. *tropica* Krammer
CYC1	*Cyclostephanos* sp1
CYM1	*Cymbella* sp1
DCOF	*Diadesmis confervacea* Kützing var. *confervacea*
DCOT	*Diadesmis contenta* (Grunow ex V. Heurck) Mann
DCRS	*Diadesmis confervacea* Kützing *f. rostrata* (Krasske) Metzeltin & Lange-Bertalot
DEN1	*Denticula* sp1
DI05	*Diadesmis* sp5
EADN	*Epithemia adnata* (Kützing) Brebisson
EEX1	*Eunotia exigua* forme 1

ELEP	*Eolimna lepidula* (Manguin) Metzeltin & Lange-Bertalot
ENMI	*Encyonema minutum* (Hilse *in* Rabh.) D.G. Mann
EO01	*Eolimna* sp1
EO02	*Eolimna* sp2
EO03	*Eolimna* sp3
EO05	*Eolimna* sp5
EO06	*Eolimna* sp6
EOMI	*Eolimna minima* (Grunow) Lange-Bertalot
EORH	*Eolimna rhombelliptica* Moser Lange-Bertalot & Metzeltin
EORU	*Eolimna ruttneri* (Hustedt) Lange-Bertalot & Monnier
ESBM	*Eolimna subminuscula* (Manguin) Moser Lange-Bertalot & Metzeltin
ESLE	*Encyonema silesiacum* (Bleisch *in* Rabh.) D.G. Mann
ESUB	*Eunotia subarcuatoides* Alles Nörpel & Lange-Bertalot
EUNO	EUNOTIA C.G. Ehrenberg
FCRS	*Frustulia crassinervia* (Breb.) Lange-Bertalot & Krammer
FFON	*Fragilaria fonticola* Hustedt
FGOU	*Fragilaria goulardii* (Brébisson) Lange-Bertalot
FGRA	*Fragilaria gracilis* Østrup
FMUD	*Fallacia muraloides* (Hustedt) D. Mann
FR01	*Fragilaria* sp1
FSAP	*Fistulifera saprophila* (Lange-Bertalot & Bonik) Lange-Bertalot
FSBH	*Fallacia subhamulata* (Grunow *in* V. Heurck) D.G. Mann
FTNR	*Fallacia tenera* (Hustedt) Mann *in* Round
GAFF	*Gomphonema affine* Kützing
GBOB	*Gomphonema bourbonense* E. Reichardt & Lange-Bertalot
GBPA	*Gomphonema brasiliense* ssp. *pacificum* Moser Lange-Bertalot & Metzeltin
GDEC	*Geissleria decussis* (Ostrup) Lange-Bertalot & Metzeltin
GDES	*Gomphonema designatum* E. Reichardt
GE01	*Geissleria* sp1
GEXL	*Gomphonema exilissimum* (Grun.) Lange-Bertalot & Reichardt
GLGN	*Gomphonema lagenula* Kützing
GO48	*Gomphonema* sp48
GO49	*Gomphonema* sp49
GO51	*Gomphonema* sp51
GO53	*Gomphonema* sp53
GO54	*Gomphonema* sp54
GO58	*Gomphonema* sp58
GO59	*Gomphonema* sp59
GO61	*Gomphonema* sp61
GO62	*Gomphonema* sp62
GO64	*Gomphonema* sp64
GO67	*Gomphonema* sp67
GO68	*Gomphonema* sp68
GO71	*Gomphonema* sp71
GO76	*Gomphonema* sp76
GO77	*Gomphonema* sp77
GO79	*Gomphonema* sp79
GO80	*Gomphonema* sp80
GO81	*Gomphonema* sp81
GO82	*Gomphonema* sp82
GO85	*Gomphonema* sp85
GO89	*Gomphonema* sp89
GO91	*Gomphonema* sp91
GO92	*Gomphonema* sp92
GO96	*Gomphonema* sp96
GOMP	GOMPHONEMA C.G. Ehrenberg
GPAR	*Gomphonema parvulum* (Kützing) Kützing var. *parvulum f. parvulum*
GPP1	*Gomphosphenia* sp1
GPUM	*Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot
GYRE	*Gyrosigma reimeri* Sterrenburg
LAEQ	*Luticola aequatorialis* (Heiden) Lange-Bertalot & Ohtsuka
LU01	*Luticola* sp1
LUTI	LUTICOLA D.G. Mann
MAPE	*Mayamaea atomus* var. *permitis* (Hustedt) Lange-Bertalot
MRCD	*Mayamaea recondita* (Hustedt) Lange-Bertalot
NA46	*Navicula* sp46
NA58	*Navicula* sp58
NA62	*Navicula* sp62
NACD	*Nitzschia acidoclinata* Lange-Bertalot
NACI	*Nitzschia acicularis* (Kützing) W.M.Smith
NAMP	*Nitzschia amphibia* Grunow *f. amphibia*
NANT	*Navicula antonii* Lange-Bertalot
NAR1	*Navicula arvensis* forme 1
NARV	*Navicula arvensis* Hustedt
NCLA	*Nitzschia clausii* Hantzsch
NCTE	*Navicula cryptotenella* Lange-Bertalot
NCXM	*Navicula cruxmeridionalis* Metzeltin, Lange-Bertalot & Garcia-Rodriguez
ND02	*Navicula (dicta) seminulum* forme 2
ND03	*Navicula (dicta) seminulum* forme 3
NDEN	*Nitzschia denticula* Grunow
NDIF	*Navicula difficillima* Hustedt
NDMA	*Nitzschia dissipata* (Kützing) Grunow *fo. maewensis* Foged
NER2	*Navicula erifuga* forme 2
NER3	*Navicula erifuga* forme 3
NERI	*Navicula erifuga* Lange-Bertalot
NESC	*Navicula escambia* (Patrick) Metzeltin & Lange-Bertalot

NFIC	*Nitzschia filiformis* var. *conferta* (Richter) Lange-Bertalot
NFIL	*Nitzschia filiformis* (W.M. Smith) Van Heurck var. *filiformis*
NGRE	*Navicula gregaria* Donkin
NHUB	*Navicula humboldtiana* Lange-Bertalot & Rumrich
NI41	*Nitzschia* sp41
NI43	*Nitzschia* sp43
NI47	*Nitzschia* sp47
NI73	*Nitzschia* sp73
NI76	*Nitzschia* sp76
NIFR	*Nitzschia frustulum* (Kützing) Grunow var. *frustulum*
NIGE	*Nitzschia ingenua* Hustedt
NIGR	*Nitzschia gracilis* Hantzsch
NINC	*Nitzschia inconspicua* Grunow
NINK	*Navicula incarum* Lange-Bertalot & Rumrich
NINT	*Nitzschia intermedia* Hantzsch ex Cleve & Grunow
NITZ	NITZSCHIA A.H. Hassall
NLGC	*Navicula longicephala* Hustedt var. *longicephala*
NLIN	*Nitzschia linearis*(Agardh) W.M. Smith var. *linearis*
NLOR	*Nitzschia lorenziana* Grunow *in* Cleve et Möller
NMIC	*Nitzschia microcephala* Grunow *in* Cleve & Moller
NNGO	*Naviculadicta nanogomphonema* Lange-Bertalot & Rumrich
NPA2	*Nitzschia palea* forme 2
NPA3	*Nitzschia palea* forme 3
NPA5	*Nitzschia palea* forme 5
NPA6	*Nitzschia palea* forme 6
NPAE	*Nitzschia paleacea* (Grunow) Grunow *in* van Heurck
NPAL	*Nitzschia palea* (Kützing) W. Smith
NQDJ	*Navicula quasidisjuncta* Lange-Bertalot & Rumrich
NROS	*Navicula rostellata* Kützing
NRVL	*Navicula rivulorum* Lange-Bertalot & Rumrich
NSIA	*Navicula simulata* Manguin
NSLC	*Navicula salinicola* Hustedt
NSRH	*Navicula subrhynchocephala* Hustedt
NSUA	*Nitzschia subacicularis* Hustedt *in* A. Schmidt *et al*.
NTEN	*Navicula tenelloides* Hustedt
NTER	*Nitzschia terrestris* (Petersen) Hustedt
NTPT	*Navicula tripunctata* (O.F. Müller) Bory
NUP1	*Nupela* sp1
NUP2	*Nupela* sp2
NURU	*Nupela rumrichorum* Lange-Bertalot
PACR	*Pinnularia acrospheria* W. Smith var. *acrospheria*
PI40	*Pinnularia* sp50
PLBI	*Planothidium biporomum* (Hohn & Hellerman) Lange-Bertalot
PLEV	*Pleurosira laevis* (Ehrenberg) Compere *f. laevis* Ehrenberg
PLFR	*Planothidium frequentissimum* (Lange-Bertalot) Lange-Bertalot
PRBU	*Planothidium robustius* (Hustedt) Lange-Bertalot
PTS1	*Platessa* sp1
RGIB	*Rhopalodia gibba* (Ehr.) O. Muller var. *gibba*
RH01	*Rhopalodia* sp1
RH04	*Rhopalodia* sp4
RHOP	RHOPALODIA O Müller
ROPE	*Rhopalodia operculata* (Agardh) Hakansson
SDRO	*Simonsenia delognei* Lange-Bertalot ssp. *rossii*
SE02	*Sellaphora* sp2
SMST	*Seminavis strigosa* (Hustedt) Danieledis & Economou-Amilli
SPUP	*Sellaphora pupula* (Kützing) Mereschkowksy
SSEM	*Sellaphora seminulum* (Grunow) D.G. Mann
STAU	STAURONEIS C.G. Ehrenberg
STHE	*Stauroneis thermicola* (Petersen) Lund
TDEB	*Tryblionella debilis* Arnott ex O'Meara
ULAN	*Ulnaria lanceolata* (Kütz.) Compère
UPSG	*Ulnaria pseudogaillonii* (Kobayasi & Idei) Idei