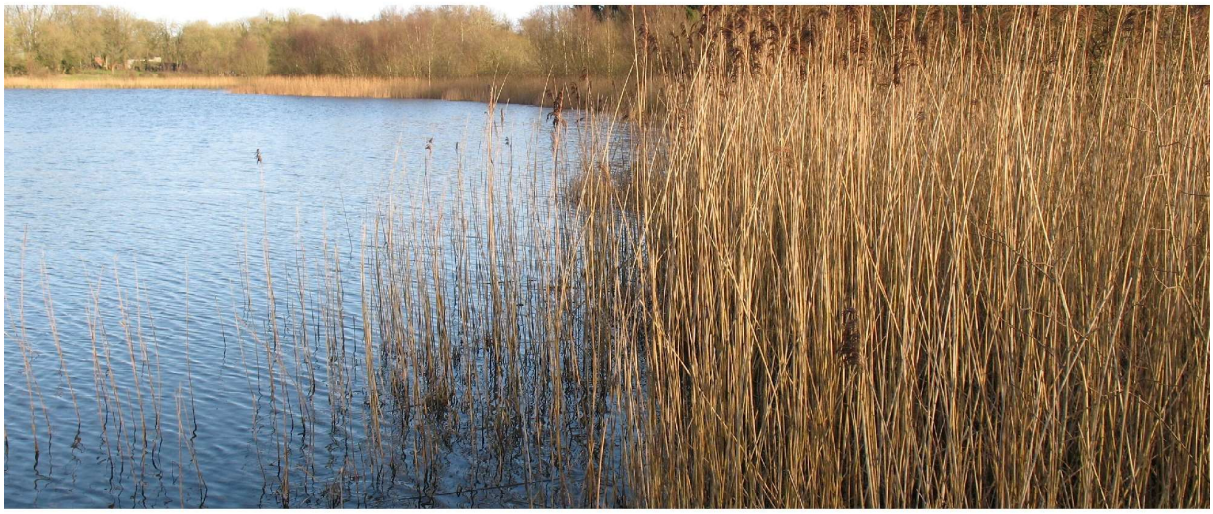

Sub littoral Vegetation of Lough Arrow in 2019

Report to the INTERREG VA CANN project.

Cilian Roden and Paul Murphy

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Introduction

This survey was undertaken at the request of The Institute of Technology Sligo as part of a more extensive examination of habitats in NW Ireland. The lake was to be surveyed using methods recently developed by Roden and others on contract to the NPWS for sub littoral surveys of Irish Marl Lakes in order to assess their conservation status under the Habitats Directive. The lake is classified as hard oligo-mesotrophic waters with benthic vegetation of Chara species, an annex 1 habitat under the EU habitats directive. Chara is a genus of large algae belonging to the Charophyte or Characeae group. These algae are sensitive to water pollution or siltation. Recent data indicates that many Irish Marl Lakes are under threat and the habitat in Ireland was rated poor in the most recent review of Habitats in Ireland (NPWS 2019 a, b).

Methods

The site was visited on 2nd and 3rd of September 2019 by C.R. and P.M. Sub littoral vegetation was examined by snorkeling with boat cover. A total of ten transects, running from the shore to the maximum depth of vegetation were sampled. A list of species present, the depth of the sub littoral vegetation and the exact position of each vegetation sample was determined. Depths were measured using a SCUBAPRO depth gauge accurate to 0.1 m and position determined using a hand held GPS recorder (Garmin GPSMAP 64s). Vegetation relevés or quadrats (2x2 m) were made by snorkeling and the data recorded by boat handler (in general, fewer than 5 taxa occurred per quadrat so recording was a simple exercise). Samples for later examination were stored in plastic bags and identified within 1 day of collection.

The position of each transect was based on transects examined in earlier surveys by IT Sligo. Figure 1 shows the position of each transect. Figure 2 shows locations of transects in previous surveys. The exact location of each relevé is given in appendix 1. Note one transect (relevé 271 on figure 1) was not surveyed by IT Sligo but was examined by Roden and Murphy in 2012.

Underwater photographs were taken with a Sony RX100ii camera in a waterproof casing.

Nutrient data was provided by the EPA.

Charophyte nomenclature after John et al. (2011).

Results

Flora and vegetation

The position of each vegetation relevé is shown in appendix 1, along with cover values of all species recorded, while figure 3 is a two way cluster diagram showing species grouping.

The Flora

Only three charophyte species were recorded, *Chara virgata, C. rudis and C. curta*, the last species is very scarce. Several *Potamogeton* species occur along with two introduced *Elodea* species, *Elodea canadensis* and *E. nuttallii*. The most unusual taxon was a *Cladophora* species (probably *C. aegropila*) forming round colonies, probably formed by wave action (figure 6). The remaining taxa are commonly recorded in mesotrophic and eutrophic lakes in Ireland.

The vegetation

In the 2 way cluster diagram (figure 3), 3 main groups can be distinguished;

1) A *Littorella* cyanophyte crust group occurring in shallow water
2) A *Chara virgata /Chara rudis* group in mid water
3) A *Potamogeton/Elodea* group close to the euphotic depth of about 4 m.

In addition, some local groupings were noted, such as the *Cladophora* community noted above. The *Littorella* Cyanophyte crust community is close to the cyanophyte crust community found in many marl lakes and occurs in the same depth range of 0-2m. It differs however in the far greater abundance of *Littorella* and other angiosperms, the very patchy distribution of the crust and its poor condition, (figures 8, 9, 10).

The *Chara virgata* community is the commonest *Chara* formation in the lake, occurring from 1 m to 3.5 m. A *Chara rudis* zone occurs in a few places at the same depth. This zonation differs from marl lakes in good condition in that the *Chara rudis* zone occurs to 5 m in depth and is then followed by a *Chara virgata* zone. In Lough Arrow the zone is largely dominated by *C. virgata* with a few areas dominated by *C. rudis* and with *Elodea* species frequent (figures 5 and 11).

The deepest zone (to 4.5 m) is dominated by *Potamogeton perfoliatus* and *P. lucens*, along with *Lemna trisulca* and *Elodea* sp. (Figure 7 and 12). Sheltered areas have emergent or floating species such as *Phragmites, Schoenoplectus and Nuphar*. In contrast exposed areas have bare rock, while the *Cladophora* ball community is confined to the NW tip of the lough.

Nutrients

The EPA have measured lake nutrients in 2016, 2017 and 2018. Up to five stations have been sampled but large differences did not occur between stations. Average values for nutrients useful in assessing lake trophic status are shown below in table 1:

Year	Colour (hazen units)	total P mg/l
2016	*22.3*	*0.0117*
2017	*19.75*	*0.0128*
2018	*19.8*	*0.0125*
average	*20.6*	*0.0123*

Table 1: Lough Arrow nutrient data from EPA

Discussion

Roden et al. (in press) have proposed a method for assessing marl lake ecological status, based on field surveys performed in 2011, 2012 and 2018. The method is based on the response of benthic vegetation to differing levels of nutrient enrichment-probably caused by eutrophication due to housing, forestry and agriculture and to increased water colour, probably caused by bog cutting and forestry.

The following metrics are used and explained in more detail in Roden et al. (in press)

Lake Area

If the lake's area decreases this is regarded as a negative impact

Number of Charophyte zones

In marl lakes in good condition, at least four vegetation zones can be seen, a cyanophyte crust zone near the surface with isolated clumps of *Chara* species, A well developed *Chara curta* zone to about 3 m, a *Chara rudis* zone to about 5 m and a *Chara virgata* zone to at least 7 m. A final zone of *Chara denudata* or *Nitella flexilis* may also occur.

Euphotic depth

Lakes in good condition have vegetation growing to at least 7 m.

Cyanophyte crust condition

Doddy (2019) has developed a sensitive method to relate cyanophyte crust condition to lake nutrient status. This method was not applied during this survey, but the results of a 2016 analysis are used. In addition, a visual preliminary assessment of lake crust was done where crust was encountered. Crust disintegrates and becomes over grown with mosses and green algae as nutrient concentration increases.

Charophyte+crust (C+K) score

This is calculated by first summing cover values of all charophytes and cyanophyte crust for each transect, then summing cover values for all taxa recorded. Charophyte and crust is then expressed as a proportion of total plant cover, more eutrophic lakes have a higher proportion of angiosperms.

Lake level

In some lakes excessive drainage has reduced lake level and exposed charophyte beds.

Total P

Total P in excess of .01 mg/l is correlated with declines in euphotic depth, charophyte cover and crust condition.

Colour

This metric is also correlated with deterioration of marl lake vegetation.

Index

The product of TP and Colour yields an index highly correlated with charophyte cover and euphotic depth.

Table 2 shows the values associated with differing ecological quality in Irish marl lakes

Parameter	**Favourable or Good**	**Unfavourable-Inadequate or Poor**	**Unfavourable-Bad or Bad**
Area	Stable or increasing	Decrease <10%	Decrease ≥10%
Number of Charophyte zones	4 or more	2–3	1 or none
Euphotic depth m	>7	4.5–7	<4.5
CRUST METRICS (not applied in this study)			
crust cover %	*>70*	*70–20*	*<20*
Crust chlorophyll a µg/cm^3	*<45*	*>45*	*undefined*
Crust chlorophytes % frequency	*<45*	*>45*	*undefined*
C&K score	>0.6	0.3–0.6	<0.3
Lake level	at or above cyanophyte crust	>50% of cyanophyte crust exposed	*Chara curta* visible above water
Total P mg/l	<0.01	0.01–0.02	>0.02
Colour Hazen units	<15	15–30	>30
Index (TP* Colour)	<0.1	>0.1<0.5	>0.5

In table 3 below, the survey data is used to calculate the above metrics for each transect sampled in Lough Arrow.

Transect	**7**	**8**	**9**	**10**	**17**	**1**	**16**	**x**	**12**	**15**	**Lake average**
Charophyte zones	2	2	2	3	1	3	1	2	1	2	**1.9**
Euphotic depth	4.5		4	4.5	4	4	4.8	3.6	4	4	**4.1556**
Crust metrics (taken from Doddy 2016)											**0**
C&K score	0.35	0.487	0.3	0.59	0.085	0.51	0.24	0.606	0.163	0.384	**0.3715**
Total P											**0.012**
Colour											**21**
Index											**0.25**

Table 3 assessment of transect ecological condition and average for whole lake with lake values for TP and colour. Crust metrics taken from Doddy (2019).

Comparing these values to the standards listed in table 2, Lough Arrow is rated as Unfavorable Poor. No measurement falls within the good range and several fall into the bad category but average values are in the Poor range.

The previous status of Lough Arrow and future prospects.

	1897	1984	2001	2012	2019
krustenstein	?				1
Red cyanophyte					
Chara virgata var.annulata				1	
Chara aspera	1	1	1		
Chara contraria		1			
Chara denudata					
					1
Chara curta	1	1	1		plant
Chara globularis		1	1		
Chara hispida		1	1		
Chara polyacantha		1			
Chara rudis		1		1	1
Chara tomentosa					
Chara virgata	1	1		1	1
Chara vulgaris	1				
Nitella opaca		1			
Tolypella glomerata		1			

Table 4. Historical charophyte records (Nick Stewart, pers com.)

Older records of Charophytes from Lough Arrow are shown in table 4 (data courtesy of Nick Stewart). In 1897 Praeger termed Lough Arrow a beautiful clear lake but recorded few plants in its waters-a typical feature of marl lakes where the shallows are dominated by cyanophyte crust. In 1974 Flanagan and Toner (1975) noted water colour of 10 hazen units which would indicate good status (see table above). In 1984, 10 charophyte species were recorded in a survey by the Central Fisheries Board without snorkeling which might have revealed additional species. In 2001 4 species were noted by the CFB. In 2012 Roden and Murphy recorded 2 species in a limited snorkel survey and a euphotic depth of 4-5m. Their results mirror those of the present survey.

Up to 1984, the large number of charophyte species, comparable to the best marl lakes in Ireland and the low water colour strongly suggest an excellent example of hard water lake habitat. Sometime thereafter, the habitat declined to its present POOR status. The reasons for this disastrous decline in habitat quality are outside the scope of this report. While under the WFD directive Lough Arrow was classified as being of good status up to 2015, the latest assessment rates it as moderate. In terms of benthic habitat, this may underestimate the degree of environmental damage that has occurred.

As the precise drivers of ecological decline have not been identified it is difficult to determine future prospects but in the absence of changes in land use, forestry and sewage treatment, there is no reason to anticipate an improvement in ecological condition.

The following table is taken from Roden and Murphy (2013) and summarises the lakes future prospects.

Increasing sediment P	No data
Decreasing transparency	Possibly comparing anecdotal evidence of euphotic depth
Changes from optimal marl lake vegetation	Yes, decline in species number
Evidence of vegetation change since 1900	Yes, based on missing charophyte species
Large watershed	No, unless groundwater input is large
Introduced macrophyte species	Yes, Elodea species
Prospects	Uncertain, the small watershed may allow effective catchment management

Despite the unfavorable ecological status of Lough Arrow, it retains one striking botanical feature; the magnificent development of Cladophora “balls” seen in figure 6. These have been recorded as an unusual feature in the outflowing River Unshin and presumably originated in the lake (John et al. 2011). Neither Roden nor Murphy have seen a comparable development in other Irish lakes. They constitute another reason for the lake’s future conservation.

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Figure 1; Stations sampled on 2nd and 3rd September 2019. Note the transect with waypoint 271 was first sampled in 2012 by Roden and Murphy. It is labelled transect x in this survey.

Figure 2: stations sampled by IT Sligo. The majority of samples were single or two point transects which did not establish the euphotic depth. In the 2019 survey fewer transects with more relevés were sampled. Transect numbers are the same for both surveys.

Figure 3: 2 X way cluster analysis of 2019 sub littoral vegetation survey, with species names on x axis and relevé numbers on y axis. Five groups can be distinguished at the 30% information remaining level (from top to bottom). Zebra mussel dominated samples, *Chara rudis virgata* samples, *Littorella* cyanophyte crust samples, *Lemna trisulca* samples and *Potamogeton Elodea* samples. The *Lemna trisulca* samples are combined with the *Potamogeton* samples for discussion purposes.

Figure 4: depth distribution of commoner plant species arranged along a gradient of increasing euphotic depth. Orange asterisks = cyanophyte crust, Red circle = *Chara rudis*, green circle = *Chara virgata*, purple circle = *Potamogeton perfoliatus*.

Figure 5 *Chara virgata* growing on submerged peat along transect 7.

Figure 6. Unusual *Cladophora* balls growing on transect 7.

Figure 7: *Potamogeton perfoliatus* and *Lemna trisulca* growing at about 3 m. on transect 8.

Figure 8: *Littorella* sward with occasional stones covered with remnant cyanophyte crust on transect 8. Both the dense *Littorella* sward and fragmentary cyanophyte crust indicate eutrophication.

Figure 9; Signs of eutrophication on transect 8. Abundant Zebra mussels, decaying cyanophyte crust and mixed *Chara virgata /Littorella* community.

Figure 10. Close up of damaged cyanophyte crust or krustenstein, note flaking away of crust exposing rock and overgrowth of green algae, as well as Zebra mussel colonization.

Figure 11. Infrequent bed of *Chara rudis* along transect x.

Figure 12. base of euphotic zone on transect x at 3.6 m, showing *Elodea* stand followed by *Lemna trisulca* and algal film giving way to bare mud. This sequence is not seen in undamaged marl lakes where the euphotic depth is double the depth recorded here.


Giants Grave
Gate
Ballindoon Abbey
Lough Arrow
Lough Annaminvrack
Lough Agh
Loughbrick Bay
Loughankedy
Loughangrania
Gate
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Hut
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L1905
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L58039
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Figure 1

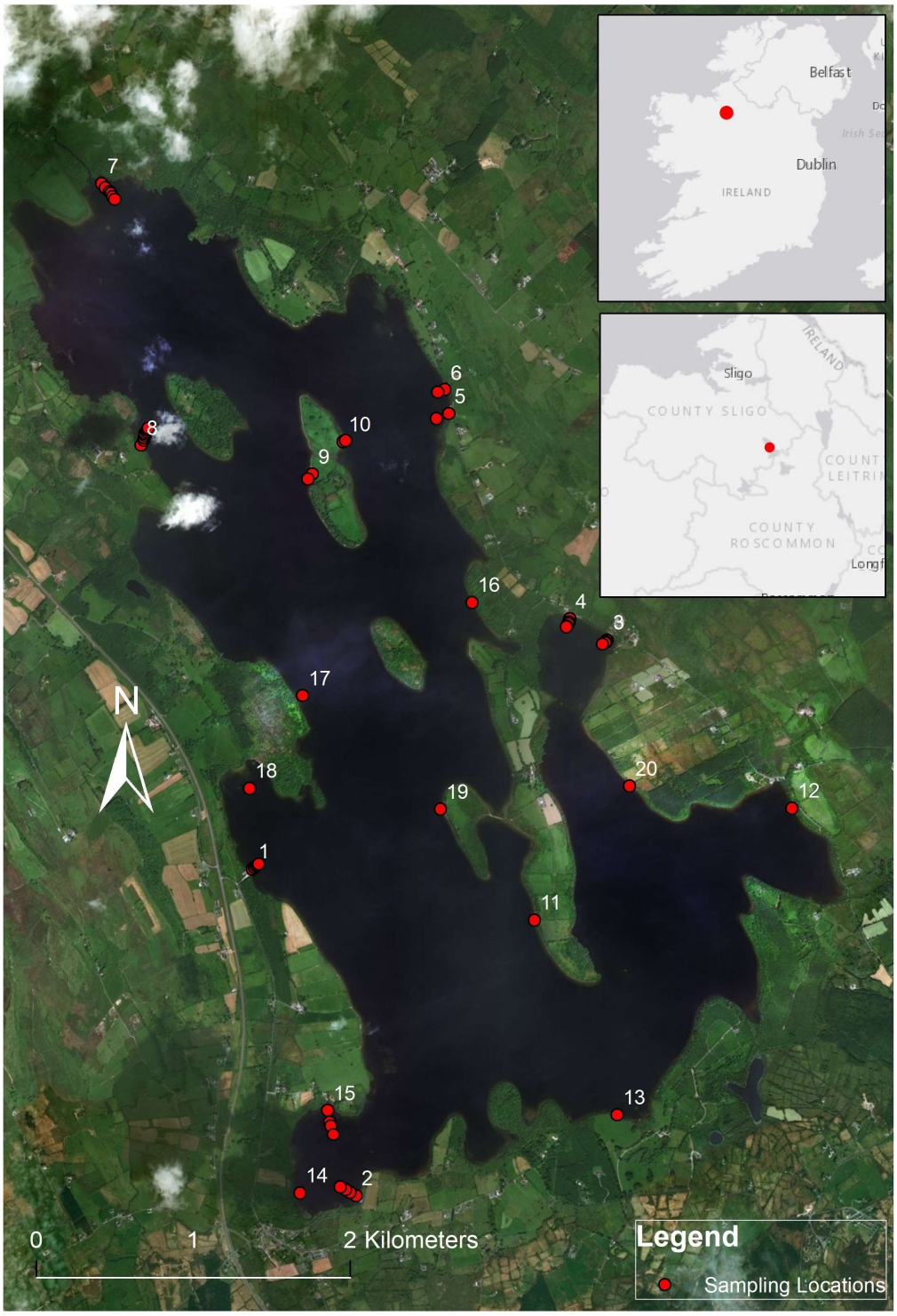
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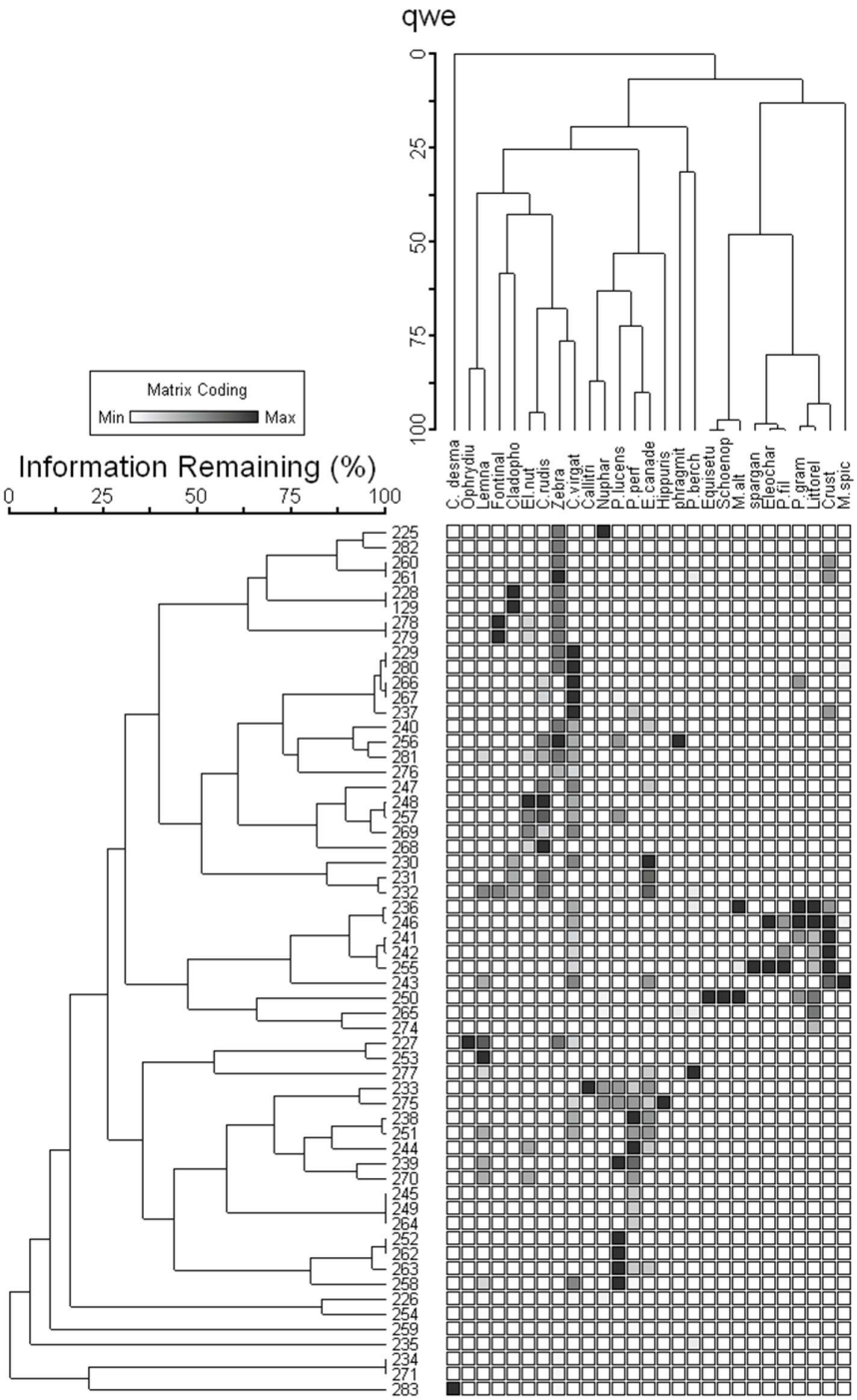
Figure 2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Nuphar
P.lucens
P.perf
E.canade
Hippuris
phragmit
P.berch
Equisetu
Schoenop
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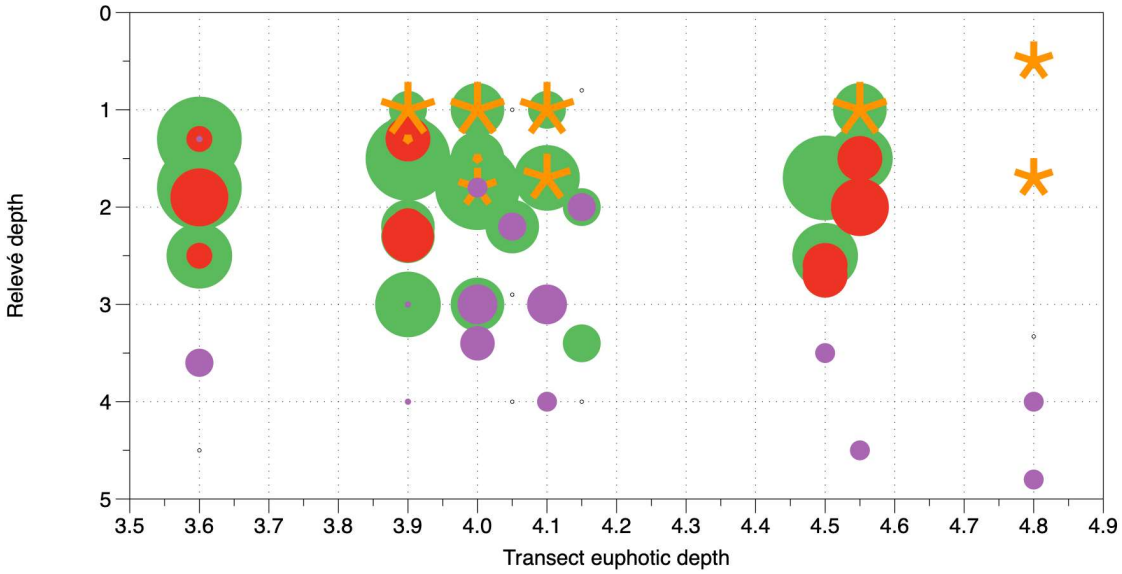
Figure 3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Transect euphotic depth

Figure 4

Figure 5

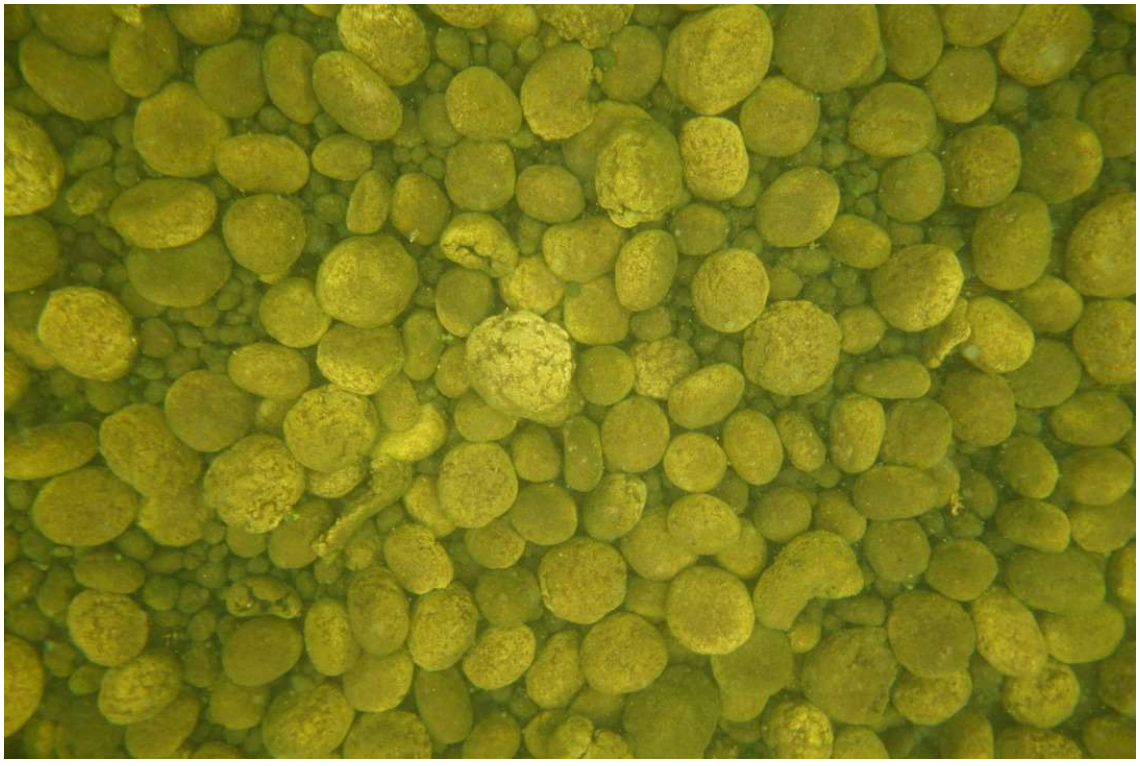

Figure 6

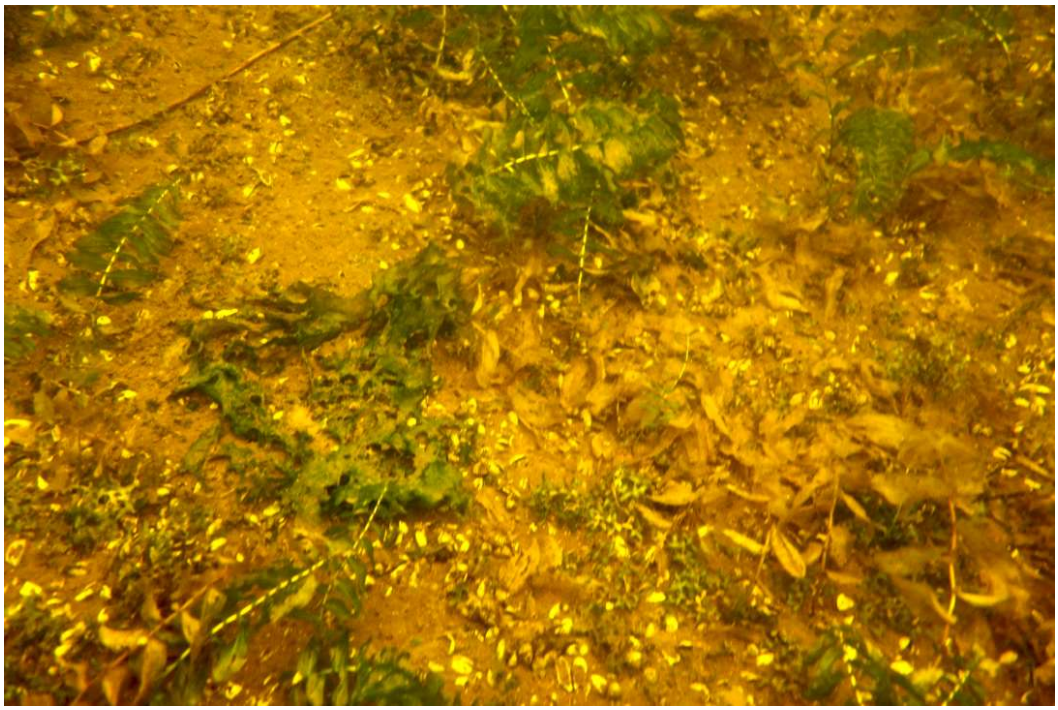

Figure 7

Figure 8

Figure 9

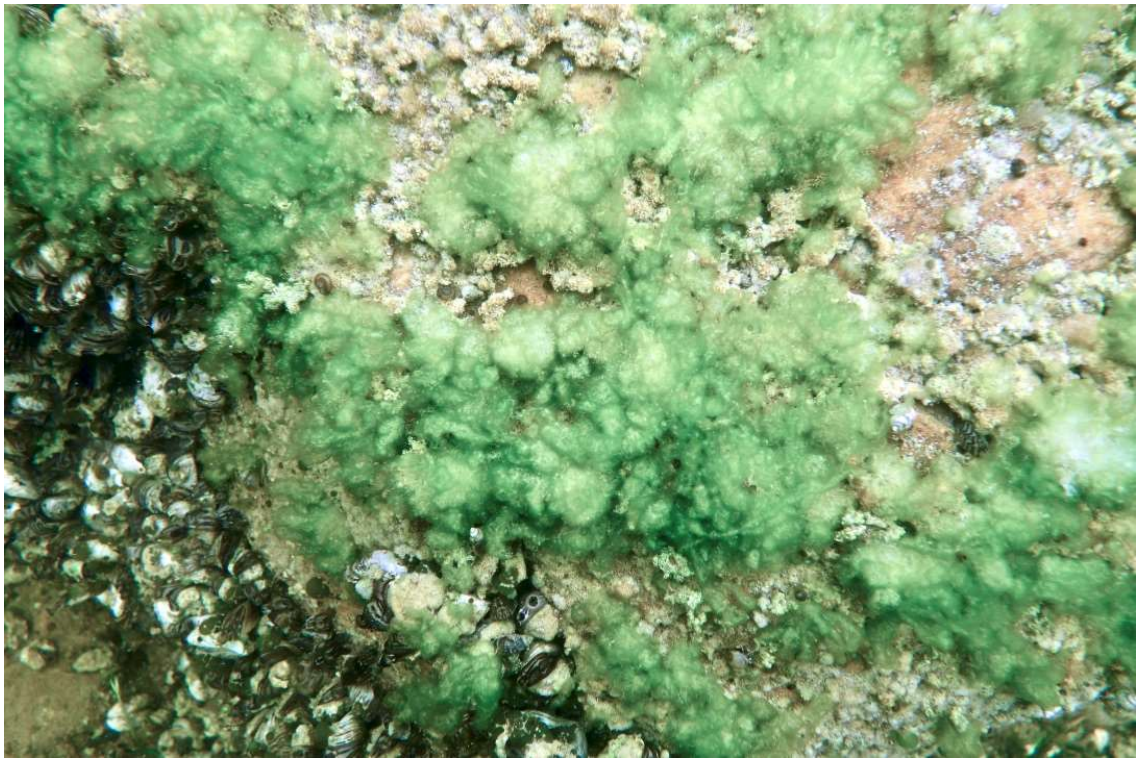

Figure 10

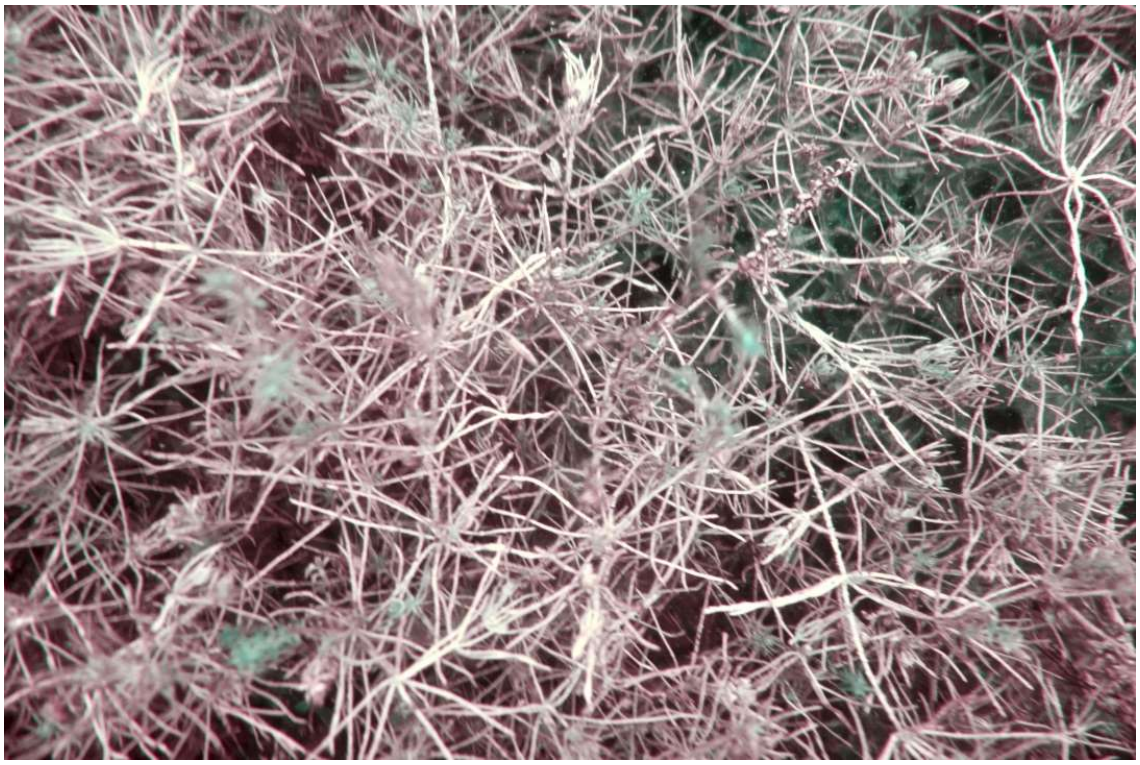

Figure 11

Figure 12