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RESEARCH ARTICLE

Phytoplankton composition in six Northern Scotland lagoons (Orkney Islands)

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Abstract

1 - Transitional waters are ecotones between freshwater, marine and terrestrial ecosystems and include a number of different ecosystem types, one of which is constituted by lagoons.

2 - Lagoons are important patches in the coastal landscapes, which constitute for their ecological relevance a priority habitat (1150) in the EC Nature 2000 Directive.

3 - In the Northern part of Scotland and in the Scottish islands, lagoons are typical coastal ecosystems, while estuaries dominate the Southern Scottish coast.

4 - In this study, we investigate the phytoplankton communities in six Scottish lagoons in Orkney Islands (Kirwall, Ouse, Oyce of Isbister, Point of Backaquoy, Skaith and Loch of Stenness), describing their taxonomic composition and abundance.

5 - The taxonomic list consists of 9 phyla and 16 classes, including 160 taxa, which are evenly distributed among classes. Generally, the higher taxonomical abundance in the studied lagoons is reached by Bacillariophyceae, Chlorophyceae, Coscinodiscophyceae and Dinophyceae. The dominant groups among all the systems in terms of number of cells are: small undetermined phytoplankton and phytoflagellates, which are numerically abundant in all the six Scottish lagoons, Bacillariophyceae, Chlorophyceae, Coscinodiscophyceae, Cyanophyceae and Fragilariophyceae.

Keywords: phytoplankton, taxonomic composition, coastal lagoons, Orkney Islands, North Sea.

Introduction

The Water Framework Directive (2000/60/EC) defines transitional waters as "*bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows*" (EU-WFD 60/2000); they include a number of different habitat types, such as estuaries, deltas, lagoons, coastal lakes and ponds, brackish wetlands and saltmarshes (Basset *et al.*, 2008a) and are functional ecotones between terrestrial, freshwater and marine ecosystems (Zaldívar *et al.*, 2008; Basset *et al.*, 2013). The plant and animal communities of lagoons vary according to physical characteristics and salinity regime, from brackish to hyperhaline waters, with consequently significant differences between sites (Joint Nature Conservation Committee, 2007). Because of their geomorphology, catchment area geology, geographic location, differences in freshwater runoff and tidal salt water exchanges, lagoons are characterized by a great habitat heterogeneity and have peculiar abiotic and biotic conditions that require investigation to understand their complex ecological functions (Basset, 2010; Lucena-Moya *et al.*, 2010). According to geomorphology, tidal range and water salinity, lagoon ecosystems in the Mediterranean Eco-region are classified into different types (Basset *et al.*, 2006).

Scotland is rich in freshwater and wetland habitats due to its high rainfall and rugged, glaciated landscape. Wetland vegetation helps to maintain a high water quality and contributes to the high quality of some Scottish rivers and lochs. The condition of the water plays an important role for Scotland biodiversity, supporting many important habitats and species, health, enjoyment of countryside and economy (Mackey and Mudge, 2010). In particular, British, Irish and Scottish lagoons may be clustered together on particular stretches of coasts, based on the dependence from local physical processes, such as sediment transport systems; every shaped cluster has been considered particularly important for the conservation of lagoon structure and functions and due to the typology of these lagoons, rare elsewhere in Europe, they represent a priority habitat type. Furthermore, lagoons show a wide range of geographical and ecological variations; therefore, five main sub-types have been identified in the UK, based on their physiography (Table 1).

Phytoplankton is one of the quality elements for determining the ecological status of transitional water ecosystems as stated in the Water Framework Directive, because of its high species richness and sensitivity to environmental, physical and chemical factors (Murphy *et al.*, 2002). Size and shape, morphological descriptors of phytoplankton, are related to environmental variables of various kinds (Naselli-Flores *et al.*, 2007, Stanca *et al.*, 2013a). Recently size spectra and size class sensitivity to natural (Sabetta *et al.*, 2005, 2008a) as well as anthropogenic (Sabetta *et al.*, 2008b; Lugoli *et al.*, 2012; Vadrucci *et al.*, 2013) gradients of variation have

Table 1- UK Lagoon physiographic typologies summarized from Annex I habitat type (Jackson and McLeod, 2000).

LAGOON PHYSIOGRAPHIC TYPOLOGY	
Isolated lagoons	completely separated from sea or estuary by a rocky or sand barrier; variable and low salinity; limited lifespan because of infilling and coastal erosion
Percolation lagoons	formed by natural process of sediment transport; separation from the sea through shingle banks; percolation of seawater; variation in water level due to tidal changes; variability in salinity
Silled lagoons	retention of water through a rocky barrier, the sill; regular input of seawater; generally high and seasonally variable salinity; present as sedimentary basins or bedrocks in the North and West of Scotland
Sluiced lagoons	formed because of changes in the natural movement of water between lagoon and sea due to artificial structures; variability in substrate type and salinity
Lagoonal inlets	input of seawater at each tide; high salinity; presence of salinity gradient responsible of the habitat and species diversity in the site in which in occurs

been emphasised. The use of size-mediated parameters to assess ecological status of phytoplankton is taking advantage from the recent development of confocal techniques improving the accuracy in the cell biovolume assessment (e.g., Roselli *et al.*, 2013a). Phytoplankton organisms are the primary producers in all the aquatic ecosystems and they can rapidly adapt to changes in environmental conditions (Basset *et al.*, 2008b). The aim of this study was to investigate the phytoplankton communities of 6 Scottish lagoons in Orkney Islands, describing their taxonomic composition and abundance and providing a systematic list, in order to improve the knowledge about biological features of phytoplankton communities in these Scottish lagoons.

Materials and methods

Study area

The study area is located in the archipelago of Orkney Islands in the Northen Scotland. Orkney comprises approximately 70 islands (20 of which are inhabited); the largest island is "Mainland" (area of 523.25 square kilometers), with coastal cliffs to the north and west and two sizeable lochs: the Loch of Harray and the Loch of Stenness; here are located the 6 coastal lagoons sampled: Kirwall lagoon, The Ouse, Oyce of Isbister, Point of Backaquoy, Skaith, Loch of Stenness (Fig. 1); each lagoon presents peculiar physical and physiographic features (Table 2).

Kirkwall lagoon is connected to Kirkwall harbour in the north-east Mainland. The western side of the lagoon is isolated from the rest of the lagoon by a concrete walkway which forms the boundary of boating pond, which connects to the lagoon via a series of pipes and is connected to the harbor by a sluice gate, which is at high water level, allowing seawater input in the lagoon. Freshwater input is from direct run-off from surrounding land, from drainage water and cooling water from the power station (Thorpe, 1998).

The Ouse is located in north-east Mainland; the lagoon is connected to the Bay of Firth via a subtidal channel under a road bridge. There is substantial freshwater input from a stream which enters at the north-western corner and in this point the upper shore was muddy gravel with pebbles. The upper to mid-shore zone at the western end of the lagoon is stony gravel with a slight covering of muddy sand. Cobbles, pebbles and gravel with some mud and fine sand in between characterize the upper shore in the remainder of the main basin and of the mid-shore zone. The sublittoral zone of the main basin consists of fine muddy sand. The tidal rapids are predominated by cobbles and pebbles (Thorpe, 1998).

Oyce of Isbister is located on the north-east coast of Mainland Orkney; it is connected to the Bay of Isbister via a narrow channel through a shingle spit. Freshwater input derives from a stream which enters at the north-western corner. The lagoon is surrounded by saltmarsh and backed by pasture land. The main body of the lagoon consists of sandy gravel overlain by a layer of fine sand (Thorpe,1998).

Point of Backaquoy is located on north-east Mainland. The lagoon connects to Wide Firth through a shingle bar at mid-tide level, via a narrow channel about 3 m wide and 10 m long. The lagoon is surrounded by grassland. The main basin of the lagoon consists of soft anoxic mud. Most of the basin drains at low tide level. The entrance of channel consists of pebbles and cobbles (Thorpe,1998).

Skaith is a large lagoon located at the head of Waulkmill Bay on the south coast of Mainland. The lagoon is connected to the sea with a sill at high tide level and seawater enters the lagoon on most high tides. The freshwater input from a stream at western end is high enough to keep the salinity as low 2 at low tide. Between 0 and 0.3 m depth the lagoon is a mixture of sand and gravel, covered by a thin layer of fine sand

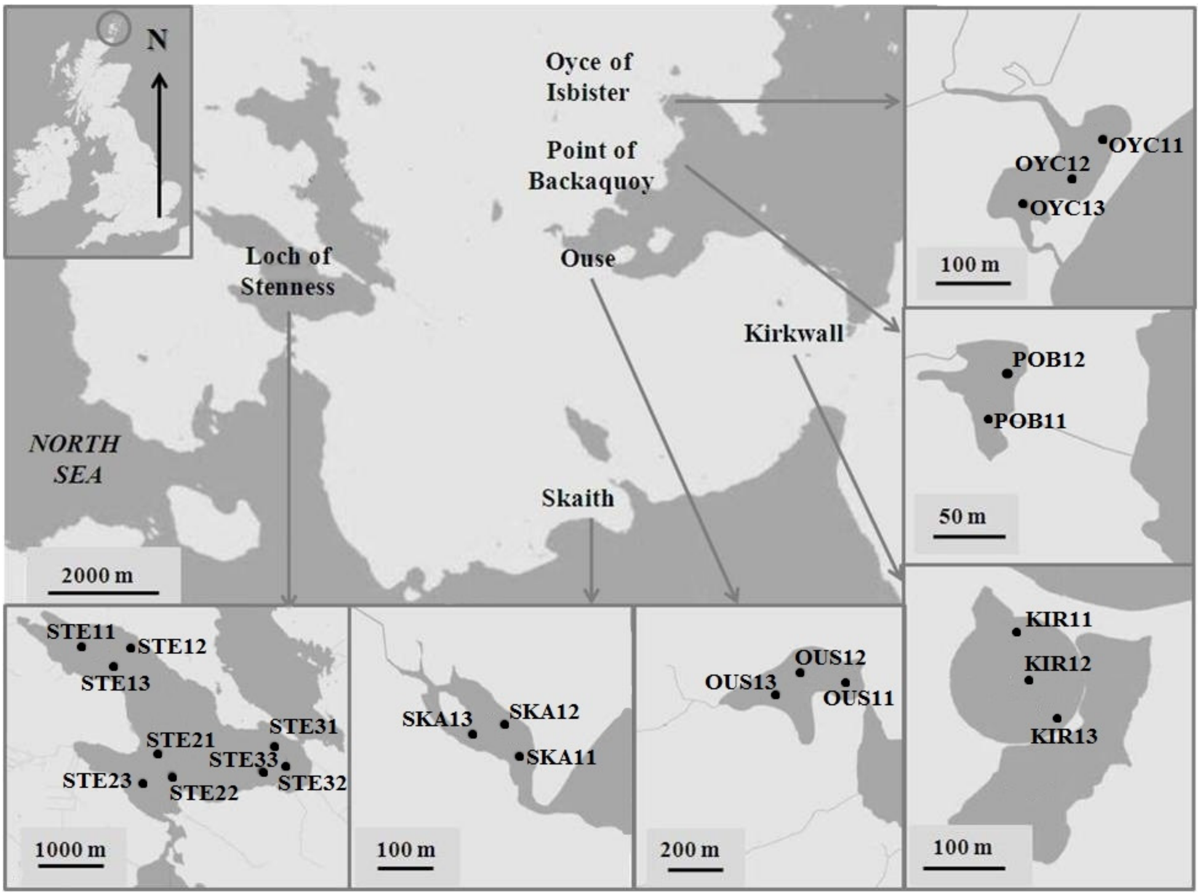

Figure 1. Map of the Orkney Islands lagoons; the location of sampling sites for each lagoon is reported using labels and black spots.

Table 2 - Physical features of studied Scottish lagoons.

	KIRKWALL	OUSE	OYCE OF ISBISTER	POINT OF BACKAQUOY	SKAITH	STENNESS
Latitude	58° 59.0’ N	59° 02.8’ N	59° 02.8’ N	59° 01.7’ N	58° 56.4’ N	58° 59.9’ N
Longitude	02° 57.9’ W	03° 03.5’ W	03° 03.5’ W	03° 03.7’ W	03° 05.3’ N	03° 12.5’ W
Physiographic type	Sluiced saline lagoon	Saline lagoon inlet	Silled saline lagoon	Silled saline lagoon	Silled saline lagoon	Saline lagoon inlet
Area	10 ha	11 ha	8 ha	1.5 ha	5 ha	860 ha
Maximum Lenght	0.3 km	0.7 km	0.4 km	0.3 km	0.3 km	6.2 km
Bathymetry (Maximum depth)	0.5 m	1.5 m	0.4 m	0.4 m	0.3 m	5.0 m
Wave exposure	Ultra sheltered	Extremely sheltered	Ultra sheltered	Ultra sheltered	Ultra sheltered	Very sheltered
Tidal stream	Very weak	Very weak	Very weak	Weak	Very weak	Very weak
Tidal range	Negligible	1.5 m	0.5 m	< 0.3 m	0.2 m	0.3 m
Salinity	22-35	5-35	5-18	28	5-18	5-22

(Thorpe,1998).

Stenness is located north-east of Stromness and is connected to the sea through a channel with subtidal still, The Bush. At the eastern corner, sluices connect the lagoon to the southern end of the Loch of Harray, a freshwater loch. The majority of the bottom of Loch of Stenness consists of soft, flocculent mud between 3 and 4 m depth; this habitat makes up the majority of the southern end of the loch and extends about two-thirds of the way up the north-western arm where the sediment is deeper than 3 m; here, the sublittoral zone between 0 and 0.5 m depth is muddy and dominated by large plants. At the western extremity of the north-western basin and extending along the northern edge of the lagoon, the sublittoral fringe zone consists of pebbles and cobbles on mud. In the south-western corner two streams enter the loch, and, between 0.1 and 0.3 m depth, the bottom comprised cobbles and pebbles. Along the southern margins of the loch there is a mixture of small boulders, cobbles, pebbles and fine sand. Close to the sluice gates, at the eastern and of the Loch of Stenness and at the southern end of Loch of Harray, the substratum between 0.1 m height and 0.1 m depth is composed by cobbles, pebbles and gravel (Thorpe,1998).

(For further information on these lagoons, visit the website: http://phytobioimaging.unisalento.it/StudySites/SitesandSpecieslist/Scotland.aspx?img_folder=scotland_varie_1andnum_images=4).

Sampling design and phytoplankton identification

A hierarchical sampling design was followed, according to the criteria adopted for a large scale survey, which is currently in progress in various worldwide eco-regions (POR Strategic Project) (see, Stanca *et al.*, 2013b; Souza *et al.*, 2013; Roselli *et al.*, 2013a; Stanca *et al.*, 2013c for other world eco-regions).

The sampling was carried out during the first week of July 2011. Inside each lagoon, on the basis of their typology (Table 3), based on the granulometry of the sediments and the presence and type of vegetation (Roof and Taylor, 2000), three stations were selected (excepted for Point of Backaquoy in which only 2 stations were selected), and, for each station, 3 replicates of water samples were collected for phytoplankton using a net mesh (6 μm) and fixed with Lugol's solution (15 ml per litre of sample).

Phytoplankton analysis was carried out using an inverted microscope (Nikon Eclipse Ti-

Table 3 - Lagoon typology for studied Scottish lagoons according to Roff and Taylor (2000).

Ecosystem	Stations	Tipology
Kirkwall	KIR11;KIR12;KIR13	Gravel with *Enteromorpha* and *Chaetomorpha*
Ouse	OUS11; OUS12; OUS13	Fine muddy sand with *Arenicola* and *Zostera*
Oyce of Ibister	OYC11;OYC12;OYC13	Gravel and sand with *Ruppia* and *Fucus ceranoides*
Point of Backaquoy	POB11;POB12	Mud with *Enteromorpha*
Skaith	SKA11;SKA12:SKA13	Sand and gravel with *Enteromorpha* and *Fucus ceranoides*
Stenness	STE11;STE12; STE13	Mud with *Potagemon*, *Cladophora*, *Hydrobia* and *Mya*
	STE21;STE22; STE23	Mud with patchwork of *Cladophora*,*Arenicola* and *Mya*
	STE31;STE32; STE33	Cobbles , pebbles and gravel with *Fucus ceranoides*, *Ruppia*, filamentous green algae and brown algae

S) and taxonomic composition of nano- and microphytoplankton was assessed using Utermöhl's method at 400x magnification (Utermöhl, 1958). Phytoplankton counts were performed semi-automatically using a video-interactive image analysis system (L.U.C.I.A Version 4.71, Laboratory Imaging) connected to the microscope, after sedimentation of 5 to 10 ml subsamples. For each subsample, 400 organisms were identified, counted and measured. For more detailed identification, an inverted microscope Nikon Eclipse T*i*-E coupled with an image analysis system (NIS–Elements AR Nikon Instruments software, version 3.06) was used. Moreover, morphometric measurements were taken for each organisms and a geometric shape was associated to each taxon according to Hillebrand *et al.*, 1999; Sun and Liu, 2003; Vadrucci *et al.*, 2007. However, investigations and speculations about these topics are not matter of the present work.

Taxonomic identification was carried out using several literature references: West *et al.*, 1912; Cupp, 1943; Rampi and Bernhard, 1980; Dodge, 1982; Sournia, 1986; Chrétiennot-Dinet, 1990; Streble and Krauter, 1997; Tomas, 1997; Wehr and Sheath, 2003; Fernández and Parodi, 2005; Morales and Vis, 2007.

The "cf." qualifier was used to indicate specimens that were similar to (or many actually be) the nominated species. Taxa which contain the "undet." (undetermined) identifier were likely to be algal entities, but could not be identified as any identifies genus. In some cases, species were broken up into separate taxa based on size (e.g., Dinophyceae undet > 20 µm).

During phytoplankton identification, sometimes was not possible to identify the organism to the species level, though recognizing common characteristics within a group of cells belonging to the same genus. In this case, to identify that organism in the phytoplankton list was reported the name of the genus followed by numbered "sp." (e.g. *Scenedesmus* sp. 1, *Scenedesmus* sp. 3, *Scenedesmus* sp. 4, etc). The complete list, including all numbered species, is available on the website www.phytobioimaging.unisalento.it.

Results and discussions

The taxonomic list is shown in Appendix 1; 160 taxa were identified, 28.75% of which at the species level, 48.75% of which at genus level, 14.37% at higher taxonomic levels, belonging to 9 phyla and 16 classes. The 8.13% of counted taxa is represented by small phytoflagellates and other undetermined phytoplankton. Taxa are evenly distributed among classes: Bacillariophyceae, which clusters the highest number of taxa, represented only the 17.50% of the overall phytoplankton taxonomic richness in the studied lagoons (Table 4). Even the distribution of taxa among the six Scottish lagoons is more or less unvarying; as a matter of fact, the total taxonomic richness per lagoon is 34.38% of the overall number of taxa identified in this study in Kirwall, 32.50% in Ouse, 39.38% in Oyce of Isbister, 41.25% in Point of Backaquoy, 39.38% in Skaith and 45.00% in Stenness.

In table 5 the taxonomic abundance of each phylum, and of each class inside it, is shown for the six Scottish lagoons. In Kirwall, Chlorophyceae and Dinophyceae show the highest species richness (i.e., 16.36% of the overall taxonomic richness for both classes), with a numerical dominance of a freshwater species, *Monoraphidium contortum*, previously described in British waters (John and Tsarenko, 2002; Whitton *et al.*, 2003), which accounted for the 22.47% of the Chlorophyceae cells counted and of *Oblea* spp., which accounted for the 20.08% of the Dinophyceae cells counted from the Kirwall samples. The highest species richness in Ouse

Table 4 - Cumulative number of cells, total cellular abundance (% number of cells), cumulative number of taxa and total taxonomic abundance (% number of taxa) per classes among all the studied lagoons.

	N° CELLS	CELLULAR ABUNDANCE	N° TAXA	TAXONOMIC ABUNDANCE
Bacillariophyceae	2453	8.89	28	17.50
Chlorodendrophyceae	45	0.16	1	0.63
Chlorophyceae	2600	9.42	25	15.63
Chrysophyceae	72	0.26	3	1.88
Coccolitophyceae	3	0.01	1	0.63
Conjugatophyceae	96	0.34	5	3.13
Coscinodiscophyceae	8236	29.84	16	10.00
Cryptophyceae	521	1.89	5	3.13
Cyanophyceae	2455	8.90	14	8.75
Dinophyceae	1243	4.50	22	13.75
Euglenophyceae	5	0.02	1	0.63
Fragilariophyceae	3148	11.41	12	7.50
Prasinophyceae	257	0.93	5	3.13
Prymnesiophyceae	499	1.81	2	1.25
Synurophyceae	12	0.04	1	0.63
Trebouxiophyceae	193	0.70	6	3.75
Other	5762	20.88	13	8.13

is reached by Bacillariophyceae and Dinophyceae (respectively, 28.85% and 25.00% of the overall taxonomic richness). In Oyce of Isbister, Bacillariophyceae and Chlorophyceae reach the higher taxonomical abundances (i.e, 20.63% in both classes). In Point of Backaquoy, Bacillariophyceae show the higher species richness (i.e., 22.73% of the overall taxonomic richness); with a numerical dominance of *Navicula* spp., the largest of all diatom genera characterized mainly by bottom living forms (Tomas, 1997), accounted for the 15.38% of the Bacillariophyceae cells counted from the Point of Backaquoy samples. In Skaith, Chlorophyceae reach the 23.81% of taxonomical abundance, among this group, *Gloecystis* spp., which accounted for the 19.86% of the Chlorophyceae, is the numerical dominant taxon. In Stenness, two classes belonging to the same phylum of Bacillariophyta, have the higher species richness; both Bacillariophyceae and Coscinodiscophyceae show the 18.06% of the overall taxonomic richness. In Stenness samples the numerical dominance is reached by *Chaetoceros* spp. (13.21% of Coscinodiscophyceae cells number), *Chaetoceros wighamii* (18.43% of Coscinodiscophyceae cells number), a marine species, and *Skeletonema costatum* (18.09% of Coscinodiscophyceae cells number), a cosmopolitan species, absent from the high Artic and Antarctic (Tomas, 1997) and generally found in North Europe waters (Weckstrom and Juggins, 2006; Scholz and Liebezeit, 2012; Naustvoll, 2001; Marin-Navarro *et al.*, 2010). Phytoplankton taxonomic structure in the 6 Scottish lagoons is characterized by a large number of undetermined species of small dimensions, which are numerical abundant. Typically, they characterize environments with high instability in the structural characteristics of the water mass

Table 5 - Species richness (% taxonomic abundance) of the identified phyla and classes in each lagoon; the higher percentages of species richness per lagoon are highlighted in gray.

LAGOON	Kirkwall	Ouse	Oyce of Isbister	Point of Backaquoy	Skaith	Stenness
Bacillariophyta	**27.27**	**50.00**	**33.33**	**37.88**	**33.33**	**43.06**
Bacillariophyceae	12.73	28.85	20.63	22.73	15.87	18.06
Coscinodiscophyceae	9.09	7.69	4.76	3.03	9.52	18.06
Fragilariophyceae	5.45	13.46	7.94	12.12	7.94	6.94
Charophyta	**-**	**-**	**3.17**	**-**	**1.59**	**4.17**
Conjugatophyceae	-	-	3.17	-	1.59	4.17
Chlorophyta	**25.45**	**3.85**	**23.81**	**18.18**	**34.92**	**15.28**
Chlorodendrophyceae	-	-	-	1.52	1.59	1.39
Chlorophyceae	16.36	1.92	20.63	9.09	23.81	6.94
Prasinophyceae	7.27	1.92	3.17	7.58	1.59	6.94
Trebouxiophyceae	1.82	-	-	-	7.94	-
Cryptophyta	**3.64**	**5.77**	**4.76**	**6.06**	**3.17**	**5.56**
Cryptophyceae	3.64	5.77	4.76	6.06	3.17	5.56
Cyanobacteria	**5.45**	**3.85**	**14.29**	**6.06**	**15.87**	**6.94**
Cyanophyceae	5.45	3.85	14.29	6.06	15.87	6.94
Dinophyta	**16.36**	**25.00**	**11.11**	**16.67**	**7.94**	**15.28**
Dinophyceae	16.36	25.00	11.11	16.67	7.94	15.28
Euglenophyta	**1.82**	**1.92**	**-**	**1.52**	**-**	**-**
Euglenophyceae	1.82	1.92	-	1.52	-	-
Haptophyta	**1.82**	**1.92**	**-**	**3.03**	**-**	**1.39**
Coccolitophyceae	-	-	-	1.52	-	
Prymnesiophyceae	1.82	1.92	-	1.52	-	1.39
Ochrophyta	**1.82**	**1.92**	**3.17**	**1.52**	**-**	**4.17**
Chrysophyceae	-	1.92	3.17	1.52	-	2.78
Synurophyceae	1.82	-	-	-	-	1.39
Other	**16.36**	**5.77**	**6.35**	**9.09**	**3.17**	**4.17**

and in resource availability (Margalef, 1978). Generally, species with small dimensions are opportunistic, they have high replication rates and high surface/volume ratios and they are able to rapidly respond and adapt to environmental change (Reynolds, 2006).

Moreover, not all the classes which show the higher species richness, are also the most numerically abundant. As a matter of fact, Dinophyceae, which account for 22 taxa, represented only the 4.50% of the overall phytoplankton numerical abundance (Table 4). The most abundant groups in terms of number of cells among all the six Scottish lagoons are not only Bacillariophyceae, Chlorophyceae, Coscinodiscophyceae, which show high taxonomic richness (respectively 17.50%, 15.63% and 10.00% of the overall taxonomic abundance in all the studied lagoons), but also Cyanophyceae, and Fragilariophyceae, which are characterized by fewer taxa, which are, nevertheless, numerically abundant (Table 4).

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Appendix 1 - List of phytoplankton taxa identified in 6 Scottish lagoons (Orkney Islands).

LAGOON	Kirkwall	Ouse	Oyce of Isbister	Point of Backaquoy	Skaith	Stenness
Bacillariophyta						
Bacillariophyceae						
Achnanthes spp.			●		●	
Amphora spp.		●	●	●	●	●
Cocconeis scutellum Ehrenberg 1838		●		●		●
Cocconeis spp.	●	●	●	●	●	●
Diploneis crabro (Ehrenberg) Ehrenberg 1854	●	●	●	●		●
Diploneis spp.			●		●	●
Entomoneis alata (Ehrenberg) Ehrenberg 1845	●	●		●	●	
Gyrosigma balticum (Ehrenberg) Rabenhorst 1853		●				
Gyrosigma spp.						●
Membraneis cf. *challengeri*			●			
cf. *Membraneis challengeri*		●				
Navicula transitans Cleve 1883	●	●	●	●	●	
Navicula sp. 2		●				
Navicula spp.	●	●	●	●	●	●
Nitzschia incerta (Grunow) M. Peragallo 1903				●		
Nitzschia sp.						●
Pinnularia lata (Brébisson) W.Smith 1853				●		
Pinnularia spp.				●		
Pleurosigma angulatum W. Smith 1852				●		
Pleurosigma sp. 1						●
Pleurosigma spp.						●
cf. *Psammothidium* sp.			●			
Pseudo-nitzschia spp.		●	●	●		
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot 1980	●	●	●	●	●	
Surirella spp.		●	●	●	●	●
Thalassiophysa hyalina (Greville) Paddock & P.A. Sims 1981		●				
Bacillariophyceae centrales undet.						●
Bacillariophyceae pennales undet.	●	●	●	●	●	●
Coscinodiscophyceae						
Chaetoceros decipiens Cleve 1873						●
Chaetoceros tenuissimus Meunier 1913	●					●
Chaetoceros wighamii Brightwell 1856		●				●
Chaetoceros spp.	●	●			●	●
Cyclotella spp.		●			●	●
Guinardia delicatula (Cleve) Hasle in Hasle & Syvertsen 1997		●				

Appendix 1 - Continued.

LAGOON	Kirkwall	Ouse	Oyce of Isbister	Point of Backaquoy	Skaith	Stenness
Coscinodiscophyceae						
Melosira arctica Dickie 1852			●			●
Melosira varians C.Agardh 1827	●		●	●		●
Melosira sp. 1	●					
Melosira spp.					●	
Paralia sulcata (Ehrenberg) Cleve 1873					●	●
Paralia spp.						●
Podosira stelligera (J.W.Bailey) A.Mann 1907						●
Skeletonema costatum (Greville) Cleve 1873						●
Thalassiosira spp.	●		●	●	●	●
Thalassiosiraceae undet.					●	●
Fragilariophyceae						
Asterionella formosa Hassall 1849					●	
Asterionella cf. *formosa*		●				
Ceratoneis closterium Ehrenberg 1839	●	●	●	●	●	●
cf. *Diatoma*			●			
Fragilaria spp.			●	●	●	
Grammatophora marina (Lyngbye) Kützing 1844		●				●
Licmophora flabellata (Grev.) C.Agardh 1831		●		●	●	●
Licmophora spp.	●		●	●		●
Synedra spp.				●		
Striatella unipunctata (Lyngbye) C.Agardh 1832		●		●	●	
Tabellaria cf. *fenestrata*	●	●		●		●
Tabellaria spp.		●	●	●		
Charophyta						
Conjugatophyceae						
Cosmarium spp.			●		●	
cf. *Cosmarium* sp.						●
Genicularia cf. *elegans*						●
Staurastrum spp.						●
Zygnema spp.			●			
Chlorophyta						
Chlorodendrophyceae						
Tetraselmis spp.				●	●	●
Chlorophyceae						
Ankistrodesmus spp.			●	●	●	
cf.*Carteria* sp.	●			●		
Chlamydomonas spp.				●		
Coelastrum spp.	●		●		●	
Desmodesmus armatus (R.Chodat) E.Hegewald 2000					●	

Appendix 1 - Continued.

LAGOON	Kirkwall	Ouse	Oyce of Isbister	Point of Backaquoy	Skaith	Stenness
Chlorophyceae						
Desmodesmus communis (E.Hegewald) E.Hegewald 2000	●		●		●	
Desmodesmus flavescens (Chodat) E.Hegewald 2000			●		●	
Gloeocystis spp.			●		●	
Kirchneriella spp.		●	●	●	●	●
Monoraphidium contortum (Thuret) Komárková-Legnerová in Fott 1969	●					●
Monoraphidium griffithii (Berkeley) Komárková-Legnerová1969			●	●		
Monoraphidium cf.*curvatum*	●					
Monoraphidium spp.	●					
Pediastrum spp.			●		●	
Scenedesmus sp. 1	●				●	
Scenedesmus sp. 3	●		●		●	
Scenedesmus sp. 4			●		●	
Scenedesmus sp. 5	●			●	●	
Scenedesmus sp. 8			●			
Scenedesmus spp.					●	
Tetraedron caudatum (Corda) Hansgirg 1888			●			
Tetraedron minimum (A.Braun) Hansgirg 1888			●			
Tetrastrum spp.						●
Chlorophyceae undet. 2					●	●
Chlorophyceae undet. 3					●	●
Prasinophyceae						
Pyramimonas spp.	●			●		●
Prasinophyceae undet. 1	●	●	●	●	●	●
Prasinophyceae undet. 2				●		●
Prasinophyceae undet. 3	●			●		●
Prasinophyceae undet. 4	●		●	●		●
Trebouxiophyceae						
Crucigenia spp.					●	
Dictyosphaerium spp.					●	
Lagerheimia minor Fott	●					
Nephrocytium agardhianum Nägeli 1849					●	
Oocystis sp. 1					●	
Oocystis spp.					●	
Cryptophyta						
Cryptophyceae						
Plagioselmis spp.		●				●
Rhodomonas spp.				●		
Cryptophyceae undet.	●	●	●	●	●	●
Cryptophyceae undet. 1			●	●		●
Cryptophyceae undet. 2	●	●	●	●	●	●

Appendix 1 - Continued.

LAGOON	**Kirkwall**	**Ouse**	**Oyce of Isbister**	**Point of Backaquoy**	**Skaith**	**Stenness**
Cyanobacteria						
Cyanophyceae						
Anabaena spp.	●			●	●	●
Chroococcus turgidus (Kützing) Nägeli 1849		●			●	●
Chroococcus spp.			●			●
Coelosphaerium spp.				●	●	
Merismopedia spp.	●	●	●	●	●	
Oscillatoria spp.	●		●			●
Snowella lacustris (Chodat) Komárek & Hindák 1988						●
Spirulina spp.			●			
Spirulina spp. 1					●	
Woronichinia spp.			●		●	
Cyanophyceae undet. 1			●		●	
Cyanophyceae undet. 2			●		●	
Cyanophyceae undet. 3			●	●	●	
Cyanophyceae undet. 4			●		●	
Dinophyta						
Dinophyceae						
Akashiwo sanguinea (K.Hirasaka) G.Hansen & Ø.Moestrup 2000	●		●			
Amphidinium carterae Hulburt 1957		●	●		●	
Amphidinium cf. *carterae*						●
Amphidinium spp.		●		●		●
Cochlodinium spp.		●				
Dinophysis acuminata Claparède & Lachmann 1859						●
Gymnodinium spp.	●			●		●
Oblea spp.	●					
Peridinium cf. *umbonatum var. lubieniense*		●				
Prorocentrum cordatum (Ostenfeld) Dodge 1975				●		●
Prorocentrum lima (Ehrenberg) F.Stein 1878		●				
Prorocentrum micans Ehrenberg 1834	●	●				
Prorocentrum scutellum Schröder 1900		●		●		
Prorocentrum sp.2	●					
Prorocentrum spp.	●			●		●
Protoperidinium bipes (Paulsen) Balech 1974				●		
Protoperidinium spp.	●	●	●	●	●	●
Scrippsiella trochoidea (Stein) Balech ex Loeblich III 1965		●	●			●
Dinophyceae athecate undet. 1 (>20µm)		●	●	●		
Dinophyceae athecate undet. 2 (<20µm)	●	●		●	●	●
Dinophyceae thecate undet. 1 (>20µm)		●	●	●	●	●
Dinophyceae thecate undet. 2 (<20µm)	●	●	●	●	●	●

Appendix 1 - Continued.

LAGOON	Kirkwall	Ouse	Oyce of Isbister	Point of Backaquoy	Skaith	Stenness
Euglenophyta						
Euglenophyceae						
Euglena spp.	●	●		●		
Haptophyta						
Coccolitophyceae						
Phaeocystis pouchetii (Hariot) Lagerheim1896				●		
Prymnesiophyceae						
Prymnesiophyceae undet. 6		●				
Prymnesiophyceae undet. 7	●			●		●
Ochrophyta						
Chrysophyceae						
Ollicola vangoorii (W.Conrad) Vørs 1992			●			●
Ollicola spp.		●	●			●
Chrysophyceae undet.				●		
Synurophyceae						
cf. Boekelovia sp.	●					●
Other						
Phytoflagellates undet.	●	●	●	●	●	●
Phytoplankton undet. 3	●					
Phytoplankton undet. 4	●			●		
Phytoplankton undet. 5	●					
Phytoplankton undet. 12	●	●	●	●	●	●
Phytoplankton undet. 23	●					
Phytoplankton undet. 28	●		●			
Phytoplankton undet. 29	●					
Phytoplankton undet. 32			●			
Phytoplankton undet. 34		●				
Phytoplankton undet. 39	●			●		
Phytoplankton undet. 40				●		
Phytoplankton undet. 41				●		●