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Preliminary report on plant research by diving in deep water in The Netherlands

Abstract

Water plants in 36 artificial lakes in the Netherlands were investigated by scuba diving. Although the species lists cannot all be considered complete, 67 taxa were recorded, including several that are rare and/or threatened both in the Netherlands and throughout their range. Vascular plants were frequently found to a depth of between 6 and 9 meters and the maximum depth recorded to-date for bryophytes was 17 m.

Some species were recorded some distance from their known range of distribution and for some it was not known they grow in deep water.

The species observed were often not those which would be expected from the character of surrounding habitats. This appears to be partly because the substrate and groundwater in deeper water differ from surface waters and soil types. However all of the lakes are relatively new and it is possible that the species recorded simply represent the first wave of colonisation.

It appears likely that the morphology of some plants, such as leaf dentation in Sphagnum as well as the life cycle of annuals may be different in deep water to typical growth form and behaviour in shallow water or at the surface.

Management plans for these lakes should be modified to take account of the presence of rare, threatened and/or protected species.

Scuba diving by skilled botanists is a more accurate and less damaging investigation method than use of rakes or grapnels and a combination of these methods may be the most efficient research method.

Keywords: macrophytes, maximum macrophyte depth, artificial lakes, deep lakes, scuba diving, water plants, Charophytes, Bryophytes, plant distribution.

1 Introduction

The aim of this report is to present for the first time an overview of plant growth in deeper waters in the Netherlands employing the preliminary results of three years of botanical investigation by scuba diving into 36 lakes. To understand the Dutch situation, it is important to recognise that:

- all still deep waters in the Netherlands are artificial pits created by extraction of sand, gravel or clay and recent in origin; there are no natural deep lakes;

- most botanists and ecologists believe that there is no vegetation in Dutch deep lakes beyond the zone close to the shore (e.g. IAWM 1985), although an overview report was recently published describing deeper waters which includes some information on macrophytes (van Weeren 2010);
- there has been little research into the vegetation of deep waters in the Netherlands, and that which has been done has rarely involved scuba diving (Bruinsma 2011). Exceptions include the vegetation research in the 1980's in lake Maarsseveense Plassen (Best 1981; Best 1987) and the research in de Zevenhuizerplas and the Oostvoornse Meer by Bureau Waardenburg (Bouma & Lengkeek 2009; Bouma et al., 2010). Research was carried out into the control of eutrophication by using "Phoslock" in Rauwbraken, Tilburg (Oosterhout & Lurling 2010), but the vegetation element of this investigation has not been published.
- most of the results may not have international significance but they are interesting within a Dutch context (e.g. finding Red list plants in new locations) or relevant to the distribution of species (e.g. finding species typical of hard water in an area that is naturally very acid and where the surface water is nowadays hyper-eutrophic).

2 Methods

All lakes were investigated by scuba diving, one or several times between 2009 and 2011. In 34 lakes the author did the diving, most times accompanied by a buddy who was not primarily interested in plants. In one waterbody (the Maarsseveense Plassen) a scuba diving excursion was organised for diving members of the Plantensociologische Kring Nederland ('Dutch Phytosociological Society'). In two lakes buddy teams of Lutra, the diving club of which the author is a member, were asked to collect all different plants they saw under water and to estimate the maximum depth at which plants were rooted. Two lakes (Zevenhuizense Plas en Oostvoornse Meer) were investigated by professional divers. Thanks to the courtesy of Rob van de Haterd (Bureau Waardenburg) the results of these investigations have been added to the database.

Plants were identified, under water if possible or by taking them to the surface if necessary. Names of vascular plants follow van der Meijden (2005), those of Charophytes follow van Raam (1998) and those of mosses follow Siebel & During (2006).

Herbarium material of all Charophyte taxa and some other critical species is preserved in the National Herbarium in Leyden (L) and in some regional herbaria, mainly in the herbarium of the Milieu Educatie Centrum in Eindhoven.

For several reasons the results are referred to as 'preliminary'.

- The number of visits to each waterbody varies: from one to several, e.g. in the Put van Heel near Tilburg, the 'house lake' of the author's diving club;
- With increasing diving experience the author had more opportunity to look around, note plants and numbers and collect specimen;
- On a single occasion collected specimen were lost under water, so these species (Charophytes) could not be determined with certainty;
- Most dives into each lake were made from a single entrance point, so the sampling area within the lake is limited.
- The choice of water bodies is – as usual – determined by the author's domicile;
- some dives were made outside the regular growing season, e.g. in February.
- The shallow zone, i.e. 1 m and less, is under-recorded, especially for helophytes.

3 Results

Tab. 1 Plants observed by scuba diving in 36 lakes in the Netherlands: abbreviated lake names x plant names + maximum vegetation depth + an indication of the completeness of each list.

Lake name short	MVP	Zev	Bel	NIO	Aqu	PvD	Bus	Vi8	GvH	GHv	Sch	PvH	Rad	Lan	Dro	Gef	Bos	ENC	Tij	Emp	Rie	PWp	Gal
Plants: scientific name																							
Elodea nuttallii	2	5	7	x	8	x	7		x	8		4	x	8	8	1	x	8	x	5	8		
Potamogeton pectinatus	2	7	x	x	x			3	x	x	2	2	x	3	5	6	x		x	2			
Chara globularis v. *globularis*	7	7	x	1	x	x	1		x	x		2		1			x		x		1	1	
Potamogeton pusillus		6	x	x	x			2	x	x		2	x		5		x		x				
Nitellopsis obtusa	7	2	x		8		8	8	x	8	8	x			8								
Myriophyllum spicatum		2	x		2		1		x		6			8		1		8			8		
Potamogeton crispus	2	1					1			x		1		3			x	3					
Nitella flexilis + N. opaca				1			2			2	3					8					1		
Potamogeton perfoliatus	3	4	x		x		2	3		x							x			2			
Chara contraria v. contraria			x	1	x		3	4		6										2			
Filamentous algae		4		8					x										9				7
Ranunculus circinatus	2	6		x			1		x						2								
Chara globularis v. *virgata*		1	x					3								9							
Juncus bulbosus													x										2
Myriophyllum alterniflorum						x					2		x								6		
Alisma species		1		x					x								x						
Chara contraria v. *hispidula*			x		x		4																
Nuphar lutea	2					x																1	
Potamogeton lucens	4													2	3					2			
Alisma gramineum	1							2							2								
Chara vulgaris v. *vulgaris*			x	3																		1	
Fontinalis antipyretica	1							6															
Nitella opaca	6					x								8									
Phragmites australis		2		x								4											
Tolypella glomerata			x		x					3													
Warnstorfia fluitans											1												8
Ceratophyllum demersum	1										1												

Lake name short	MVP	Zev	Bel	NIO	Aqu	PvD	Bus	Vi8	GvH	GHv	Sch	PvH	Rad	Lan	Dro	Gef	Bos	ENC	Tij	Emp	Rie	PWp	Gal
Chara contraria		6														2							
Chara vulgaris		1												1									
Chara vulgaris v. *longibracteata*												2						1					
Chara vulgaris v. *papillata*				x	x																		
Eleocharis acicularis						x							x										
Hippuris vulgaris	1																					2	
Mentha aquatica													x					1					
Najas marina		1														2							
Nitella hyalina	4						8																
Potamogeton trichoides			x																x				
Sphagnum cuspidatum																							3
Tolypella intricata				1																		1	
Zannichellia palustris		2																					
Zannichellia palustris s. *palustris*					x				x														
Baldellia ranunculoides s. *repens*						x																	
Callitriche brutia var. hamulata																							
Chara connivens																							
Chara major	4																						
Elatine hexandra																							
Leptodictyum riparium													x										
Littorella uniflora						x																	
Luronium natans																							
Myriophyllum verticillatum															6								
Nitella capillaris						x																	
Nitella flexilis													x										
Nitella gracilis						x																	
Nitella translucens						x																	
Nymphaea alba																		3					
Octodiceras fontanum	1																						
Persicaria amphibia																		1					
Pilularia globulifera											2												
Potamogeton berchtoldii																							
Potamogeton mucronatus	3																						

Lake name short	MVP	Zev	Bel	NIO	Aqu	PvD	Bus	Vi8	GvH	GHv	Sch	PvH	Rad	Lan	Dro	Gef	Bos	ENC	Tij	Emp	Rie	PWp	Gal
Schoenoplectus lacustris												2											
Sparganium emersum																							
Sphagnum denticulatum																							5
Tolypella species								3															
Veronica anagallis-aquatica								x															
Warnstorfia exannulata																							
N species	18	17	13	13	12	11	11	10	10	10	9	9	9	8	8	7	7	7	6	5	5	5	5
Species list complete	y	y	y	y	y	y	y	y	y	y	y	y	y	y	r	r	n	y	r	r	y	n	y
Max distribution depth [m]	11	5+		8+	7	6	8.5	7	9	9	6.2	9	5	9	6,5	11+	6				8	7+	17

Lake name short	ViZ	Wei	Vee	RoP	LkU	Rau	Ber	Vor	PWw	GHg	OvM	LiH	N lakes
Plants: scientific name													
Elodea nuttallii			x	1	9	7	2	x		9			27
Potamogeton pectinatus											7		19
Chara globularis v. *globularis*													16
Potamogeton pusillus					1				x				15
Nitellopsis obtusa	8												13
Myriophyllum spicatum									1				12
Potamogeton crispus					1			x					11
Nitella flexilis + N. opaca						7	x	x					10
Potamogeton perfoliatus													10
Chara contraria v. contraria													8
Filamentous algae						7							7
Ranunculus circinatus													7
Chara globularis v. *virgata*							x						6
Juncus bulbosus		x		8									5
Myriophyllum alterniflorum			x										6
Alisma species													5
Chara contraria v. *hispidula*													4
Nuphar lutea	6												5
Potamogeton lucens													5
Alisma gramineum													4
Chara vulgaris v. *vulgaris*													4
Fontinalis antipyretica	8												4
Nitella opaca													4
Phragmites australis													4
Tolypella glomerata													4
Warnstorfia fluitans		x											4
Ceratophyllum demersum													3
Chara contraria													3
Chara vulgaris													3
Chara vulgaris v. *longibracteata*													3
Chara vulgaris v. *papillata*													3
Eleocharis acicularis													3
Hippuris vulgaris													3
Mentha aquatica													3
Najas marina													3
Nitella hyalina													3
Potamogeton trichoides													3
Sphagnum cuspidatum		x											3
Tolypella intricata													3
Zannichellia palustris												1	3
Zannichellia palustris s. *palustris*													3
Baldellia ranunculoides s. *repens*													2
Callitriche brutia var. hamulata				6									2
Chara connivens	8												2
Chara major													2
Elatine hexandra			x										2
Leptodictyum riparium													2
Littorella uniflora													2
Luronium natans				8									1
Myriophyllum verticillatum													2
Nitella capillaris													2
Nitella flexilis													2
Nitella gracilis													2
Nitella translucens													2
Nymphaea alba													2
Octodiceras fontanum													2

Lake name short	ViZ	Wei	Vee	RoP	LkU	Rau	Ber	Vor	PWw	GHg	OvM	LiH	N lakes
Persicaria amphibia													2
Pilularia globulifera													2
Potamogeton berchtoldii			x										2
Potamogeton mucronatus													2
Schoenoplectus lacustris													2
Sparganium emersum													1
Sphagnum denticulatum													2
Tolypella species													2
Veronica anagallis-aquatica													2
Warnstorfia exannulata		x											2
N species	4	4	4	4	3	3	3	3	2	1	1	1	
Species list complete	y	y	n	r	r	y	r	n	r	y	y	r	
Max distribution depth [m]	6	15,4	4+	5,5	5,5+	9(+?)		7	3	10	6	2	

Survey results are presented in Table 1. Each line is a taxon. The order of the taxa is the reverse order of frequency, each column is a lake, indicated by an abbreviated names. The lakes are in reversed order of the number of observed taxa. In each cell is the abundance of a species in a lake. The abundance of plants employs a decimalised Tansley scale where 1: scarce, 2: rare, 3: occasional, 4: locally frequent, 5: frequent, 6: locally abundant, 7: abundant, 8: co-dominant, 9: dominant. An ‘x’ indicates presence only. The maximum depth at which macrophytes were found growing is indicated. Usually below a certain depth the vegetation becomes patchy; this zone was included, taking care to note only rooted plants. Plants that had fallen from upper levels but which were not rooted were excluded. If the dive did not reach the maximum macrophyte depth the figure is followed by a +. So 8+ = indicates that plants grew to at least 8 m. A subjective estimate of the completeness of each species list is given in the line ‘completeness’ on a three-point scale: n = not complete, r = largely complete, y = ‘complete’. Tab. 2 shows the names of the lakes with the abbreviations used in Tab. 1.

Despite the above mentioned shortcomings in the field work, the results contradict the opinion that Dutch deep waters are devoid of vegetation.

A total of 66 taxa was observed, including some unsolved determination problems, such as vegetative *Nitella opaca / flexilis*, the impossibility of naming varieties in poorly developed *Chara vulgaris*-material, a yet unsolved discussion about the determination of *Tolypella intricata* and/or *prolifera* in one of the lakes and apparently both *Alisma gramineum, A. lanceolatum* and *A. plantago-aquatica* can grow submerged at several meters.

The maximum macrophyte distribution depth was recorded in 32 lakes. The 19 middle values are between 6 and 9 m. The deepest point at which vegetation was seen is 17 m. The maximum depth at which vascular plants were observed is 10m, charophytes were seen at 11m+ and mosses at 17 m.

Tab 2. Lake names, abbreviated and full, and location.

Name lake abbreviated	Name lake	Location
Aqu	Aquabest	Best
Bel	Beldert, De	Zoelen
Ber	Berendonck, De	Wijchen
Bos	Bosmolenplas	Panheel
Bus	Bussloo	Apeldoorn
Dro	Drosse Plas	Lienden
Emp	Empelse plas	Empel
ENC	ENCI-groeve, visvijver	Maastricht
Gal	Galderse Meren	Galder (Breda)
Gef	Geffense plas	Oss
GHg	Groote Hegge	Thorn
GHv	Groene Heuvels	Bergharen
GvH	Gat van Hage	Slijk-Ewijk
Lan	Langspier	Boxtel
LiH	Lithse Ham	Oss
LkU	Leemkuilen Udenhout	Udenhout
Mee	Meerse Plas	Den Dungen
MVP	Maarsseveense plas (Grote ..)	Maarsseveen
NIO	NION-plas = Watertorenplas	Raamsdonkveer
OvM	Oostvoornse Meer	Oostvoorne
PvD	Put van Drunen	Drunen
PvH	Put van Heel	Tilburg
PWp	Put van Waspik	Waspik
PWw	Put van Waalwijk	Waalwijk.
Rad	Radioplas	Stevensbeek
Rau	Rauwbraken	Berkel-Enschot
Rie	Rielse zandput =e Katsbogte	Tilburg,
RoP	Rooye plas, De = De Rooye Asch	Handel
Sch	Schaartven	Overloon
Tij	Tijningenplas	Zaltbommel
Vee	Veenmeer	Tynaarlo
Vi8	Vinkeveense plas, eil.8+9	Vinkeveen
ViZ	Vinkeveense plas, o van	Vinkeveen
Vor	Vormerse plas = Vormer, Het	Wijchen
Wei	Weijkermeer	Gilze
Zev	Zevenhuizerplas	Rotterdam

4 Discussion and conclusions

There is a lot of vegetation in deep water, far more than had previously been believed. The depths at which plants were recorded in these lakes is quite new in the Dutch context, however they are insignificant in an international context, e.g. mosses in New-Zealand up to 70 m (De Winton and Beever 2004), Charophytes in Sweden and Kroatia at nearly 40 m (Krause 1997).

Many of these species are (inter-)nationally and/or locally rare. Species which are rare throughout their range include *Luronium natans* and *Baldellia ranunculoides* subsp. *repens*, although both are not uncommon in the region where they were found in deep water. Nationally rare and/or threatened species include *Elatine hexandra*, *Littorella uniflora, Myriophyllum alterniflorum, Najas marina, Chara connivens*, the spined variety of *Chara contraria*: var. *hispidula*, *Nitella capillaris, N. gracilis, N. hyalina, N.opaca, Nitellopsis obtusa, Tolypella glomerata, Tolypella intricata*, and, if the determination proves to be correct, *Tolypella prolifera* (vascular plants: Floron 2011; Charophytes: Landelijk Informatiecentrum voor Kranswieren 2012).

The Dutch distribution maps of some species will change considerably as a result of these surveys. *Nitellopsis obtusa* is the most significant example, it was found in almost one-third of all lakes, far outside it's known range in the western parts of the Netherlands (Landelijk Informatiecentrum voor Kranswieren 2012). In Germany *Nitellopsis obtusa* has been found in deep water so often, that it will be removed from the Red data list or at best included in an early warning list (Klaus van de Weyer pers. comm. 2012), in Belgium the species was found in deep water twice recently after not having been seen for 50 years (Denys et al. 2005).

From the margin it is hard to predict which species one is going to see in deeper water. This seems to be due to possible differences between the deeper soil type and groundwater compared with the surface soil type and surface water. One may also speculate that because all the lakes are quite new, we are only seeing the first arrivals, which have the advantage of being able to colonise virgin waterbodies. Another possibility is that in some lakes – especially those of low alkalinity – pH has changed during recent decades. Due to the reduction of acidifying agents, especially sulphuric acid, in these acid lakes pH may have risen by 1 scale point, thereby becoming suitable for plants that normally grow in moderately low alkaline waters, such as *Elatine hexandra, Pilularia globulifera, Nitella gracilis, N.translucens* and others (personal comment by Ronald Buskens, 2011).

Some plants that were regarded as amphibious in a Dutch context were found to grow much deeper than was previously known, e.g. *Elatine hexandra* (Dijkhuis 2011-1, Dijkhuis 2011-2), *Littorella uniflora, Baldellia ranunculoides* subsp. *repens*, *Pilularia globulifera, Juncus bulbosus* and *Luronium natans* growing at depths up to 3-5 m.

As has been noted by other authors (e.g. De Winton and Beever 2004), deep submersion appears to modify plant characters, e.g. Sphagnum plants develop dentate leaf margins and lack hyaline cells in the upper half of their leaves (Bruinsma and Smulders 2011); Elatine hexandra –usually an annual – is fresh green in February (Dijkhuis 2011-1).

Under water there may be abundant plant growth of species which are rare, threatened and/or protected. Authorities responsible for these lakes should take this into account when plans are made for them, e.g. filling with contaminated soil, or reducing the depth. Such actions should only be undertaken after investigation of the deepwater vegetation.

Compared to raking, either from the shore or from a boat, scuba diving by botanists skilled in water plant identification leads to larger number of species being recorded, a more accurate estimate of their abundance and a more accurate assessment of the maximum macrophyte depth (van de Weyer 2006). Moreover diving will damage the vegetation less than sampling using rakes or grapnels. A

quick sample including using a rake to decide whether it makes sense to send in divers, may be the most efficient way to sample deep waters.

The results of the two occasions on which Lutra members were asked to sample all different species under water, show that diving by a group of non-botanist divers may provide a good impression of the vegetation, but no fine determination can be expected. However they did collect a new species from a lake where the author had looked six times already.

As a matter of fact and as usual, a lot of field work can still be done, some of it by amateurs who know their species, more elaborate ones by professionals. Examples are: expanding the number of sites, vegetation zonation, the maximum depth of each species, vegetation changes over time and the ecology of (the vegetation of) lakes.

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