Summer 2010 collapse of the Lake Nipissing zooplankton community subsequent to the introduction of the invasive zooplankter *Bythotrephes longimanus*

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A Lake Nipissing Partners in Conservation case study

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Abstract

This study presents what we believe to be the first documented case of *Bythotrephes* nearly eliminating all the zooplankton in a lake come the end of June (2010), followed by the near-immediate collapse of its own population due to a lack of food resources. Come July, in the bulk of Lake Nipissing, a large 87,330 ha lake, remnant populations of *Bythotrephes* form the bulk of the remaining zooplankton food source available to planktivores. This creates an energy flow bottleneck for the predators occupying trophic levels higher up the food web. Larval and small-sized fish may experience a feeding problem due to the early elimination of the small zooplankton in early June. Summer populations of *Bythotrephes longimanus* in Lake Nipissing have exploded since it was first collected in 1998. *Bythotrephes* is severely reducing or even extirpating small zooplankton species/taxons like *Bosmina, Chydorus, Diaphanasoma birgei, Ceriodaphnia* and the like. *Daphnia retrocurva,* ubiquitous in 2001, has just about been extirpated from Lake Nipissing.

In Lake Nipissing we are witnessing nothing less than a complete reorganization of the food web. We document yellow walleye (*Stizostedion vitreum)* and yellow perch (*Perca flavescens*) switching to a diet of *Bythotrephes* come summer. We document the negative correlation of *Bythotrephes* abundance with depth and detail the existence of a cold-water refuge near the outlet of Lake Nipissing, where lake herring (*Coregonus artedi),* rainbow smelt (*Osmerus mordax)* and zooplankton species like *Bosmina, Daphnia pulicaria, Daphnia longiremis, Diacyclops bicuspidatus thomasi, Latona setifera, Eurycercus, Eucyclops elegans, Cyclops scutifer* and possibly *Leptodora* kindtii have sought refuge. *Bythotrephes* abundances in the 1m to 10m strata in the cold-water refuge are comparable to the abundances found elsewhere in the lake and suggest that the large population of lake herring and smelt that summer here do not foray into these strata to take advantage of the *Bythotrephes* food source. The final impact on the multi-million dollar walleye fishery is a concern at this time. To survive, many species may have to adapt and tap into less utilized food sources such as the abundant invertebrate populations that live near, on and in the lake sediments. Increased walleye migrations to the cold-water refuge to feed on lake herring and smelt may also occur. Lake Nipissing may be in a state of transition towards a new, as yet unknown state of equilibrium.

Résumé

Cette étude présente ce que nous croyons est le premier cas documenté où *Bythotrephes* réussi à quasi-éliminer tout le zooplancton d'un grand lac par la fin juin (2010) suivi de l'effondrement de sa propre population occasionnée par un manque alimentaire de zooplancton. L'on retrouve au mois de juillet le lac Nipissing quasi-dépourvu de tout zooplancton sauf pour une population vestige de *Bythotrephes.* Ceci crée un problème alimentaire pour les planctivores ainsi qu'un embouteillage dans l'acheminent d'énergie envers les niveaux trophiques supérieurs. Depuis 1998, l'année de première collection de *Bythotrephes longimanus* dans le lac Nipissing, les populations de *Bythotrephes longimanus* ont subi un accroissement foudroyant. *Bythotrephes* est en train de sévèrement réduire voir éliminer les espèces / taxons de petit zooplancton tels que *Bosmina, Chydorus, Diaphanasoma birgei* et *Ceriodaphnia*. *Daphnia retrocurva,* omniprésente en 2001, a presque disparue du lac Nipissing. Il se peut que les poissons de petite taille éprouvent de la difficulté à s'alimenter suite à la disparition du petit zooplancton.

Nous assistons présentement à une réorganisation complète de la chaîne alimentaire dans le lac Nipissing. Nous documentons un changement dans l'alimentation du doré jaune (*Stizostedion vitreum)* ainsi que de la perchaude (*Perca flavescens*) qui tous deux, en été, consomment maintenant le *Bythotrephes* de façon courante. Nous documentons la corrélation négative entre l'abondance de *Bythotrephes* et la profondeur. Nous mettons en évidence l'existence d'un refuge d'eau froide dans la région de la sortie du lac Nipissing près du début de la rivière des Français. Ici le cisco (*Corégones arteil),* éperlan arc-en-ciel (*Somers Morax)* ainsi que diverses espèce/taxons de zooplancton tel que *Bosmina, Daphnia pulicaria, Daphnia longiremis, Diacyclops bicuspidatus thomasi, Latona setifera, Eurycercus, Eucyclops elegans, Cyclops scutifer* et possiblement *Leptodora* kindtii cherchent refuge. L'abondance de *Bythotrephes* dans les couches d'eau de 1m à 10m est comparable aux abondances retrouvées dans les autres régions étudiées du lac Nipissing. Ceci suggère que, bien que nombreux en profondeur dans ce refuge, le cisco et l'éperlan arc-en-ciel ne migrent pas vers la surface en été pour prendre avantage de la présence de *Bythotrephes*. L'impact final sur la pêcherie du doré jaune, d'une valeur de plusieurs millions de dollars, est inquiétant. Pour survivre, plusieurs espèces de poisson devront s'adapter à utiliser les sources alimentaires qui demeurent disponibles en été. Par exemple, les êtres vivant tout près de, en surface ou dans le benthos pourraient être utilisés d'avantage. Aussi, une migration accrue du doré jaune en destination du refuge d'eau froide pourrait avoir lieu. Il se peut fort bien que le lac Nipissing soit dans un état de transition envers un nouveau point d'équilibre inconnu.

Introduction

Lake Nipissing has a surface area of 873.3 km^2 (87,330 ha or 337.2 sq mi), a mean elevation of 196 m (643 ft) above sea level and is located in the Precambrian shield at lat. 46 N. long. 79 W. between the Ottawa River and Georgian Bay. Excluding the Great Lakes, Lake Nipissing is the fifth-largest lake in Ontario. It was known to the Ojibway people as Gichn-bee or `Big-water'. It is relatively shallow for a large lake with an average depth of only 4.5 m and a few areas near its outlet to the French River which exceed 50 m in depth. Mean summer temperatures of the water in July and August are in the low 20's (Celsius), though surface waters (<2m) in non-windy periods can exceed this considerably for short periods of time. It supports a multi-million dollar walleye fishery and 5% of all angling that takes place in Ontario, takes place on lake Nipissing.

The spiny water flea *Bythotrephes longimanus* was first collected in Lake Nipissing in 1998. This invasive zooplankter has the potential to modify a lake's zooplankton community (Yan 1997, Dumitru 2001). In 1999, a decision was made to quantify the zooplankton communities of Lake Nipissing (for 6 major basins) prior to potential modifications by this unwanted invader. This was a two year endeavour (2000/2001) undertaken by École secondaire catholique Algonquin and Lake Nipissing Partners in Conservation using nets specifically designed for this study and an appropriate vessel loaned to the project by the North Bay Ministry of Natural Resources. The 2000/2001 study showed that *Bythotrephes* populations were just getting started in Lake Nipissing and summer abundances were low, while *Leptodora kindtii* abundances were high in comparison (Filion 2002).

Introduction (page 2)

By the summer of 2009, it was clear that *Bythotrephes longimanus* was carving a niche for itself in the Lake Nipissing food web. Yellow perch (*perca flavescens*) stomachs were now filled with *Bythotrephes longimanus* come summer. Fall Walleye Index Netting surveys were pointing to changes in the habits of yellow walleye (*Stizostedion vitreum*) and stomach-content investigations showed that some angled yellow walleye were feeding exclusively on *Bythotrephes .* Rainbow smelt (*Osmerus mordax*) populations were expanding and it appeared that lake herring or cisco (*Coregonus artedi*) populations were contracting (Nipissing First Nation Biologist – personal communication). All this pointed to important changes occurring in the Lake Nipissing food web.

It was therefore decided to undertake a 2010 zooplankton study to determine whether or not *Bythotrephes longimanus* was having an impact on the Lake Nipissing food web. Lake Nipissing Partners in Conservation graciously agreed to fund the project.

Introduction (page 3)

This report targets Lake Nipissing fisheries biologists and managers, biologists in general, students, the general public and of course those intrepid individuals that intend to pursue the sampling of zooplankton on Lake Nipissing.

Understanding the dynamics of an aquatic food web is of great importance. Presently the food-web dynamics in Lake Nipissing are being re-arranged by *Bythotrephes longimanus* an invasive species that entered Lake Nipissing in the early 1990's. This report is a case study. It contains enough specific information to allow it to be used as a comparison in subsequent studies. It also details sampling methodology appropriate to sampling in Lake Nipissing. In particular, due to the shallow nature of Lake Nipissing, various niches are defined more by depth than by geographical location. Consequently, horizontal hauls tend to be more appropriate (though more work), in Lake Nipissing zooplankton studies.

Introduction (page 4)

This report is to be considered a snapshot in time of a large-lake ecosystem (Lake Nipissing) in a state of flux (perhaps crisis) that is tending to some yet undetermined state of equilibrium.

It is hoped that other parties wanting to sample Lake Nipissing in the future will find this study useful both as a guide and comparison.

Jean-Marc Filion
Project leader
February 2011

Special thanks to our volunteer crew


Lois Filion
DAKINE


Kevin O’Grady
115


Miga

2010 – Sampling Stations – Lake Nipissing

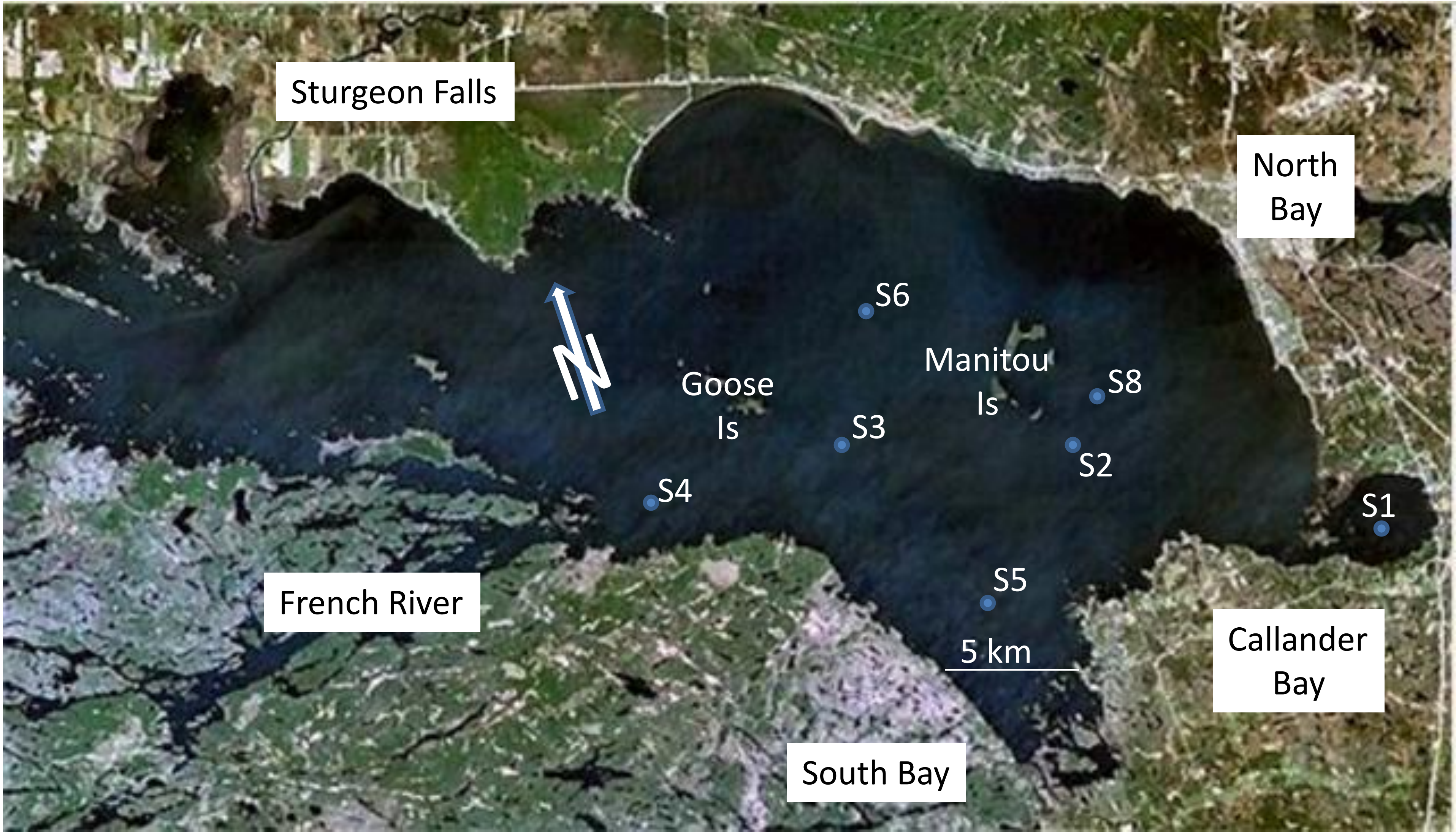


Table 1 - Lake Nipissing pelagic zooplankton sampling locations – 2010 study

Sampling site	Depth(m)	Latitude (N)	Longitude (W)	Geographical area
S1	10	46.20667	79.3975	Callander Bay
S2	16,5	46.24167	79.55001	East Basin (Manitou Islands)
S3	16,5	46.23834	79.65967	Southwest Basin (Manitou / Goose Is.)
S4	54	46.21001	79.78718	French River Basin
S5	13	46.19067	79.60417	South Bay
S6	10	46.28717	79.65167	Northwest Basin
S8	13	46.2581	79.5308	SE of Manitou Is

Sampling sites S1 to S6 were the same as in 2000/2001. S8 was added in 2010.
S7 was the 1932 sampling site and not used in 2010 due to its sheltered location.

Methods

We opted for a series of horizontal hauls in order to quantify abundances of *Bythotrephes longimanus* in various depth strata. To this end a 300 micron bonded-Nitex-mesh-net was constructed with a 30cm x 30 cm mouth opening. The net-proper consisted of a 90 cm x 30 cm x 30 cm first section followed by a 90 cm section that tapered to a 10 cm cod end to which was fixed a short piece of ABS pipe with a screw cap. The efficiency of this net was very near 100%. In order to determine the depth at which the net was operating, a special depth data logger was built using a temperature-compensated pressure sensor and a dedicated microprocessor. This data logger was inserted in the net and secured to the net-mouth via a thin-diameter cord just prior to net immersion. The depth data was read via LED's once the net was back in the boat.

The small angle of attack of the 300 micron mesh to the direction of travel (very near zero degrees), meant that small-diameter zooplankton would tend to tumble towards the cod-end of the net where they would be trapped by the small ABS pipe. This net gave good service and gave good indications of the presence of smaller-sized populations of zooplankton such as *Bosmina.* We quantified these smaller taxa using a ranking system rather than trying to determine absolute abundances. The net was towed a horizontal distance of 150 m at varying depths. It was lowered and retrieved vertically, slicing through the water without sampling. Samples were concentrated using a 80 micron filter to preserve the smaller zooplankton. Samples were preserved in methyl alcohol using a 1:1 ratio approximately.

Methods . . .

We decided to sample a 13m mid-lake station (S8) weekly throughout the summer. In order to see whether or not this was representative of what was going on in other areas of the lake, a second station a three kilometers away (S2 – 15 m) was sampled five times. Finally, all stations were sampled within a three day period (July 7 to July 10). This period was chosen as the food web impacts of *Bythotrephes* seemed to peak at this time.

Except for exceptional circumstances, all *Bythotrephes* were counted without splitting the sample. In addition, note was taken of the number of barbs seen on the spine of each individual in each sample. *Mysis relicta* and *Chaoborus* were also all counted without splitting the samples.

Other zooplankton taxa were quantified using a ranking scale. First total sample volume was determined by placing the sample in a 100 mL graduated cylinder and allowing it to settle. Zooplankton volumes of 0 to 50 mL (excluding *Bythotrephes)* were assigned numbers of 0 to 5, with decimal fractions allowed. For instance a 5 mL volume would be assigned a number of 0.5. For samples having a volume of zooplankton greater than 50 mL, a ranking number of 6 was assigned. All samples that occupied less than 50 mL were then diluted to 50 mL and five 10 mL mixed aliquots extracted. A taxon-based ranking score was then assigned according to the following: 0 – not seen in sample; 1 - trace, most of sample must be scanned to find an individual of this species; 2 – only a few individuals seen in 10 mL; 3 – Individuals of this species require only modest search in 10 mL sample; 4 – Individuals of this species common in 10 mL; 5 - Individuals dominate sample in percentage abundance . A final ranking score for the taxon was obtained by multiplying these two scores together (maximum number possible of 30).

Methods . . .

Each sample was scanned for zooplankton species composition. A low-powered dissecting microscope and a higher-powered (to 400x) microscope were used. For copepods, number of setae on the caudal rami separated *Epischura lacustrus* and *Senecella calanoides* from the other calanoid copepods (Diaptomids). Diaptomid species identification required CVI male copepodids, spotted in the sample by the geniculate right antenna. This caused a problem in samples containing few Diaptomids and in samples where most of the Diaptomids were present in immature forms. Consequently, in the species charts, absence does not necessarily mean that the Diaptomid species is not present. It means that positive identification was not made in that sample. Finally, 5th leg dissections were used to separate *Skistodiaptomus oregonensis* from *Leptodiaptomus minutus* the only two Dipatomids identified in Lake Nipissing in this study.

Cyclopoids were identified using mature females (enlarged first section of urosome). Dissections were used to separate antennae, caudal rami and 5th legs. Size and shape of the egg mass was also used. For instance *Eucyclops elegans,* is fairly large and has an egg mass that is oblong and pointed at the terminal end. *Mesocyclops edax,* has splayed setae at the end of its caudal ramus. *Diacyclops bicuspidatus thomasi,* has small 'wings' just anterior of its caudal ramus and has an unorganized near-spherical egg mass. *Cyclops scutifer* looks a lot like *Diacyclops bicuspidatus thomasi,* but has a more posterior-located lateral seta on its caudal ramus. These macro-criteria helped isolate specimen-candidates for species identification (dissection). Otherwise this task would have proven daunting.

Methods . . .

Daphnia were identified using macro-features followed by dissection. Typically antennae and post-abdomen were dissected out prior to examination. *Daphnia longiremis* is smallish and has a uniformly rounded head, *Daphnia pulicaria* is large but has a tiny head, *Daphnia galeata mendotae* is mid-size and has a typical 'ondulated' shape to its head terminating in a near central point, *Daphnia retrocurva* is smallish and has a large head-shield typically that extends dorsally. Subsequent to sample extraction using these macro-features, positive identification was made by looking at the antennae and pecten on the abdominal claw.

Other species and taxa were quite unique and readily identified. Examples: *Leptodora kindtii, Latona setifera, Sida cristallina, Eurycercus (sp), Bosmina (sp), Diaphanasoma birgei* to name a few.


300 micron net specially
constructed for this project


Line to surface float attaches here
120 m line
10 lb weight

Lowering the net via the float line. Note that on descent the net slices through the water without sampling for organisms.


Net being hauled horizontally
150 m at a depth of 1 m
in this instance.

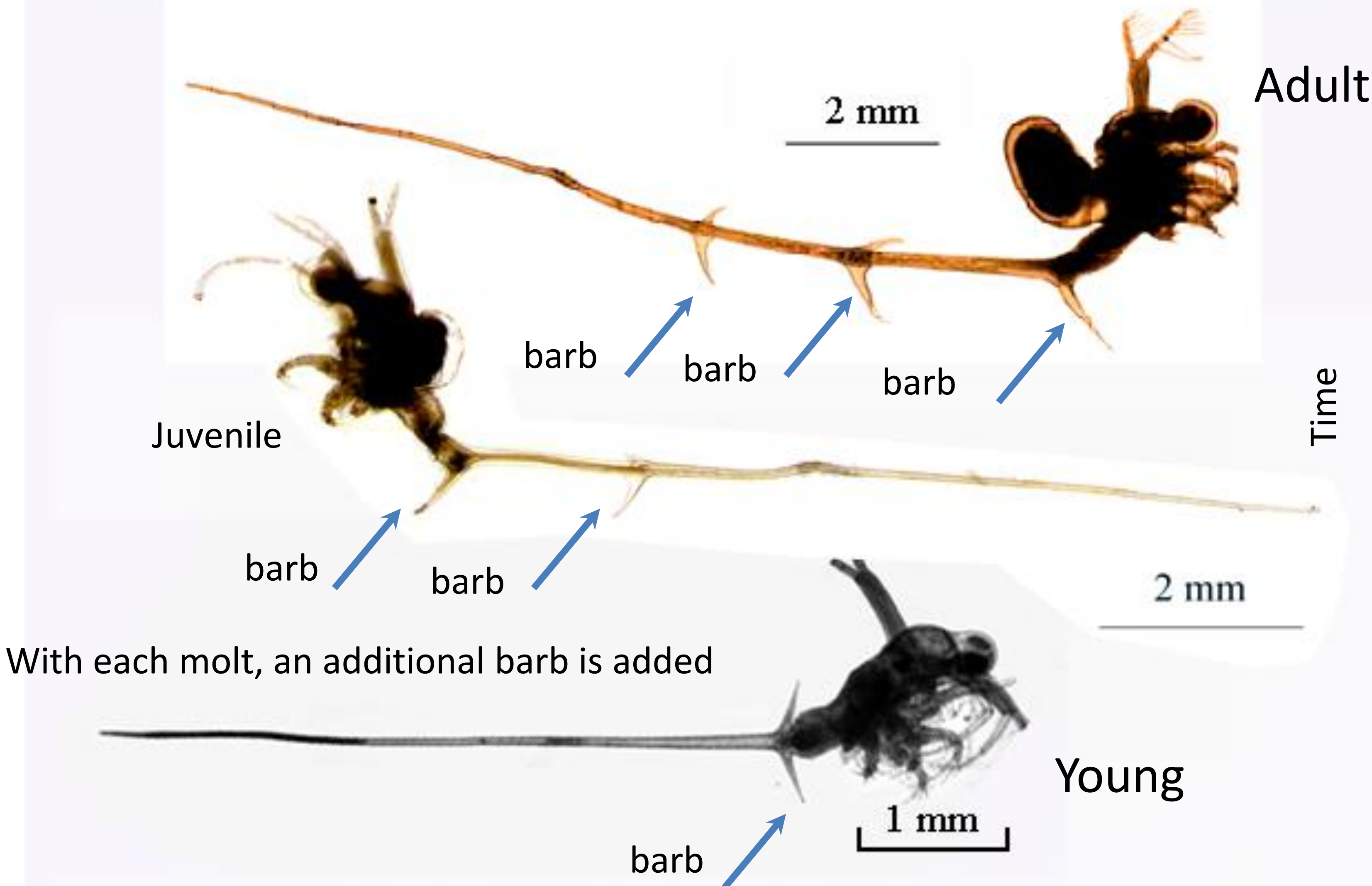

Depth data logger
inserted in net to
monitor depth of haul

Taking the animals
out of the net, and washing them into a large, white, plastic tub

Samples, once concentrated with 80 micron filter

The Players

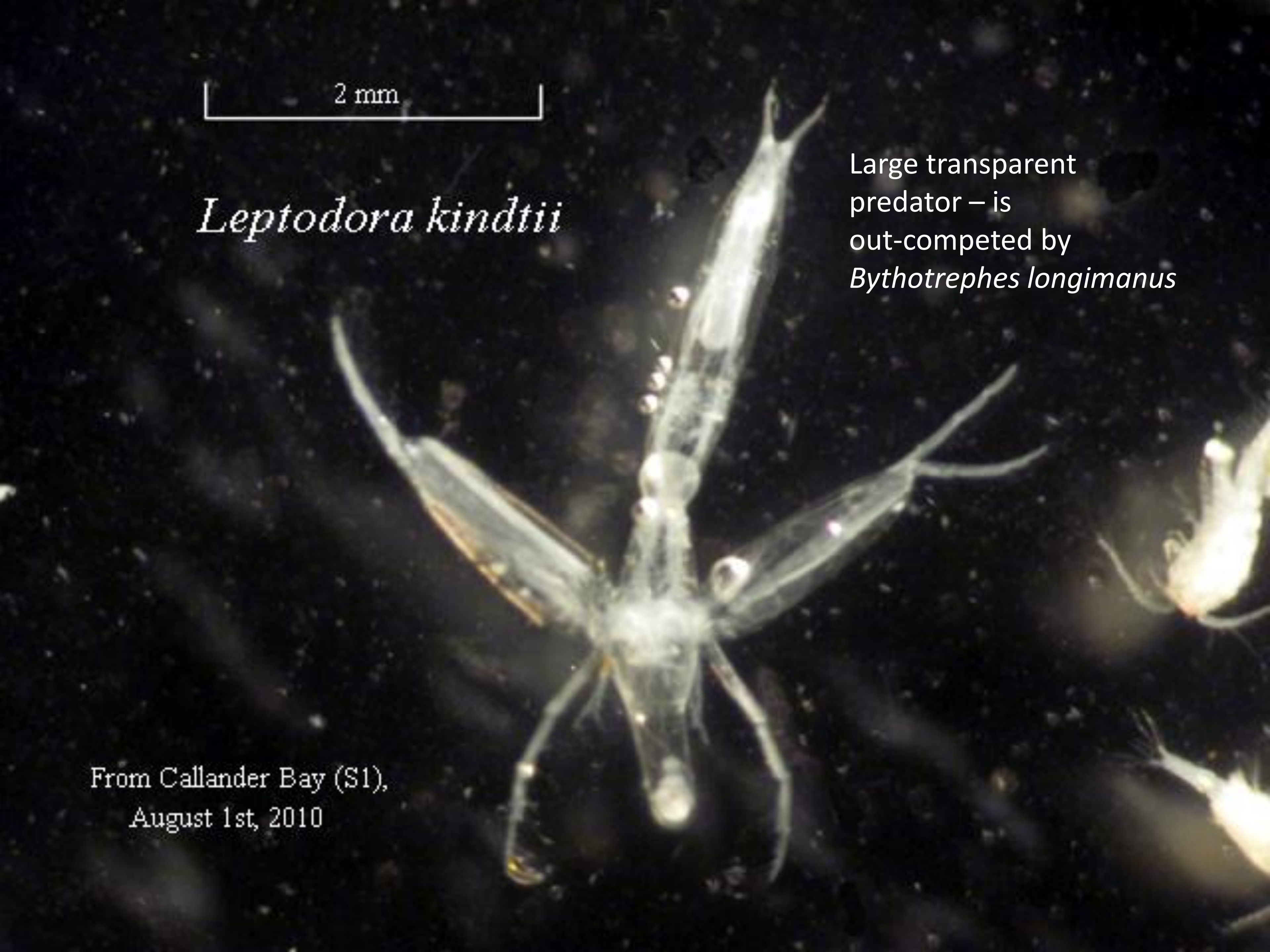
Bythotrephes longimanus



Bythotrephes longimanus - morphology

Bythotrephes can reproduce both by parthenogenesis (cloning) and sexual reproduction. Morphological differences are characteristic for each type. In the summer cloning dominates, with mothers begetting identical daughters. The ability of *Bythotrephes* to reproduce by cloning implies that a single female, if transported to another lake, could potentially start a new infestation.

Once born, *Bythotrephes* develop through consecutive molts but retain their characteristic tail (kinked or not). During molting individuals gain “barbs” on their tail spine. Fully developed parthenogenic individuals have three barbs gained through 2 molts (Yurista 1992).


2 mm
Leptodora kindtii
Large transparent predator – is out-competed by *Bythotrephes longimanus*
From Callander Bay (S1), August 1st, 2010

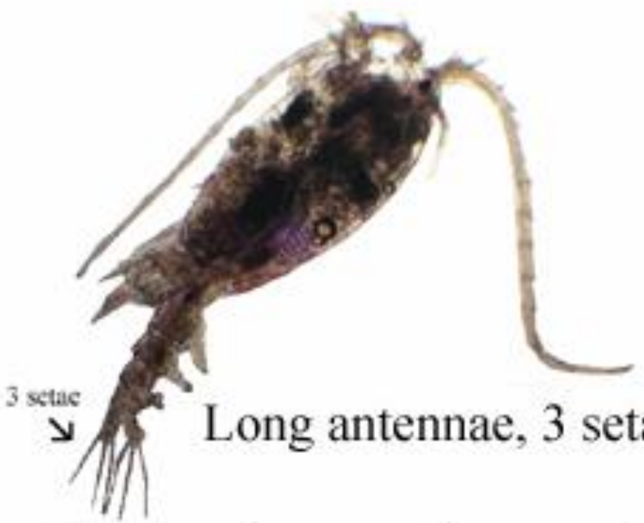
Copepods

Diaptomids

Long antennae,
5 setae

Cyclops

Short antennae

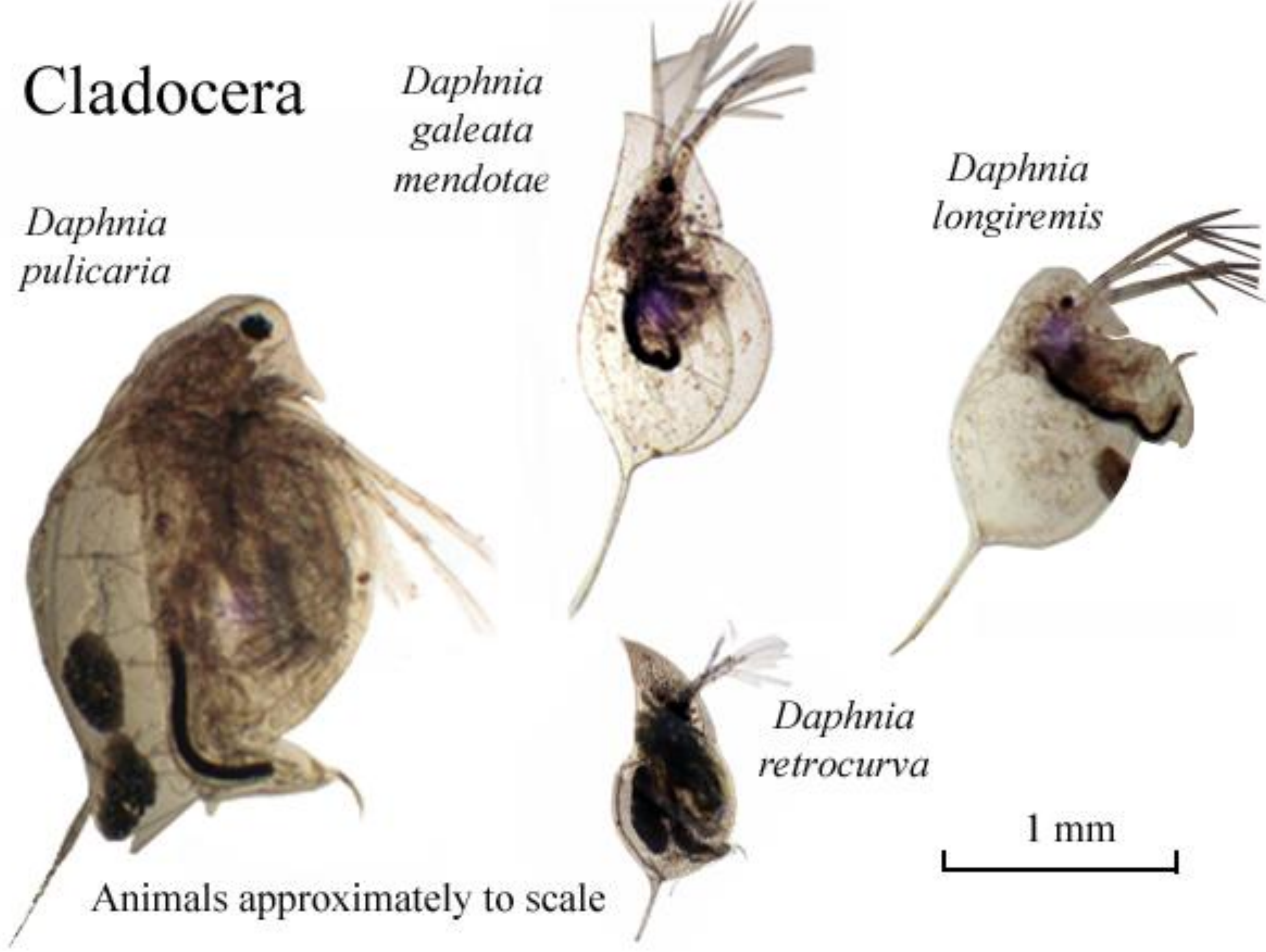


Long antennae, 3 setae

Epischura lacustris

Senecella calanoides

(long antennae, 4 setae)


Cladocera
Daphnia galeata mendotae
Daphnia longiremis
Daphnia pulicaria
Daphnia retrocurva
1 mm
Animals approximately to scale

Cladocera

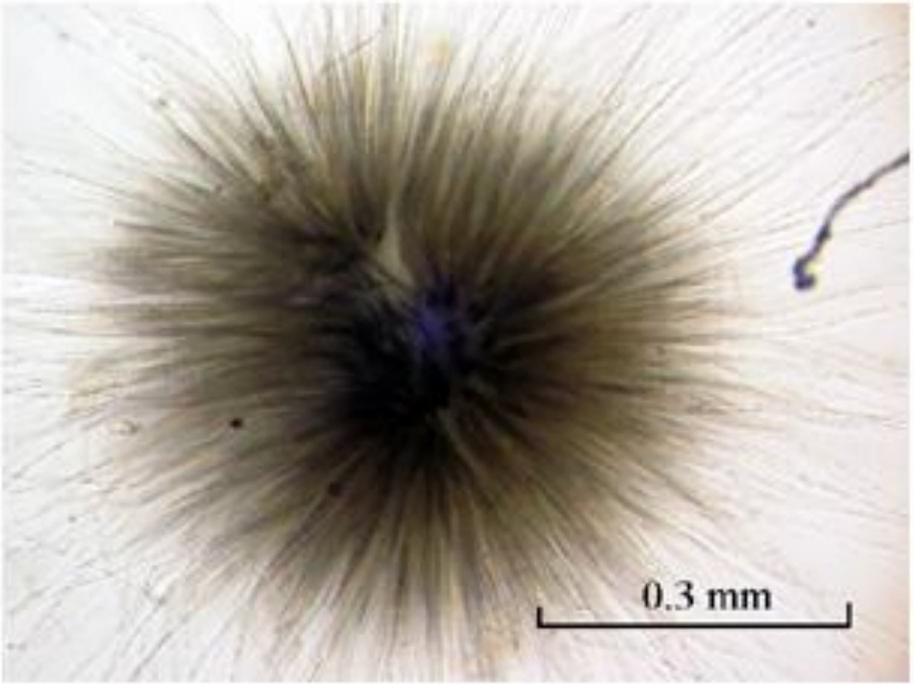
Holopedium gibberum

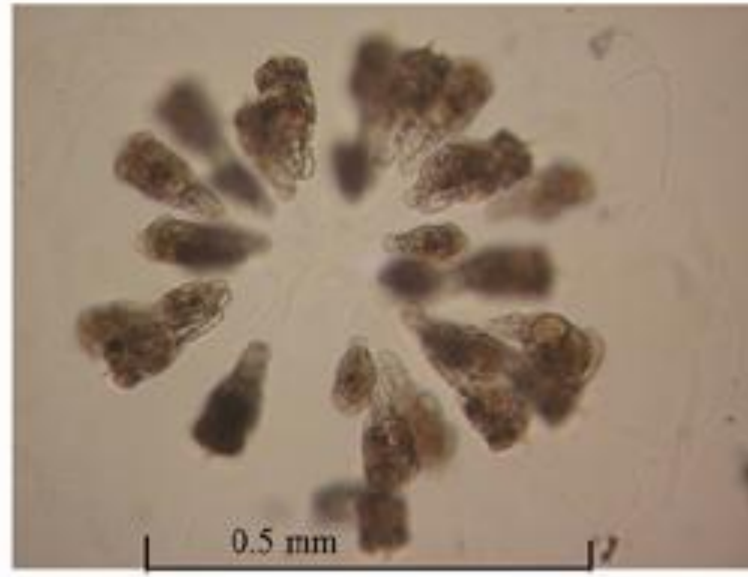
Diaphanasoma birgei

Bosmina

Animals not to scale

Geotrichia *Conochilus unicornis*





Blue green algae Colonial rotifer

Lake herring (Cisco) (*Coregonus artedi)* - to 18 inches approximately

Yellow perch (*Perca flavescens)* – to 12 inches approximately

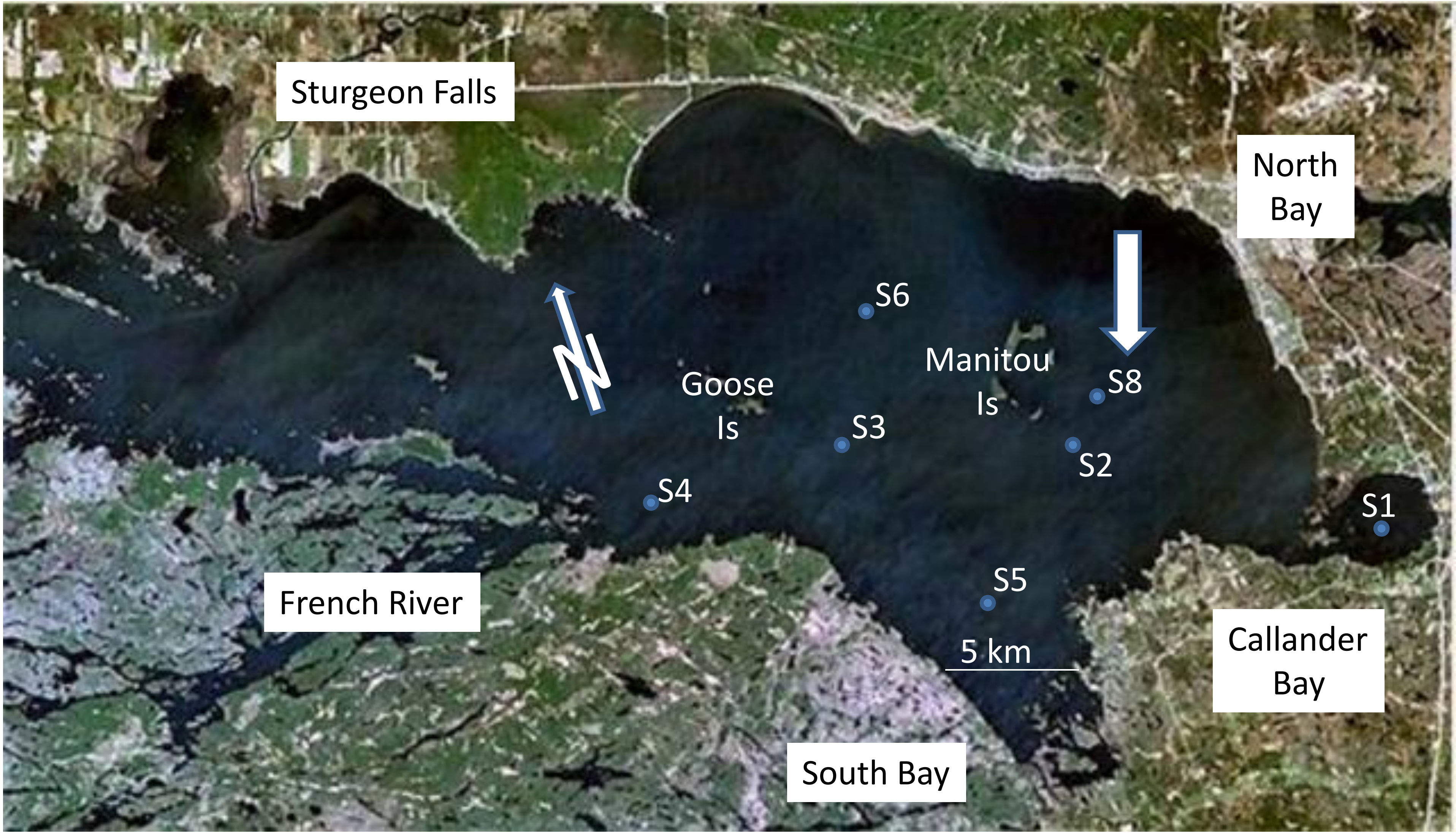
Rainbow smelt (*Osmerus mordax) – to 8 inches approximately*


Yellow walleye
Stizostedion vitreum
This fish was live-released

Results

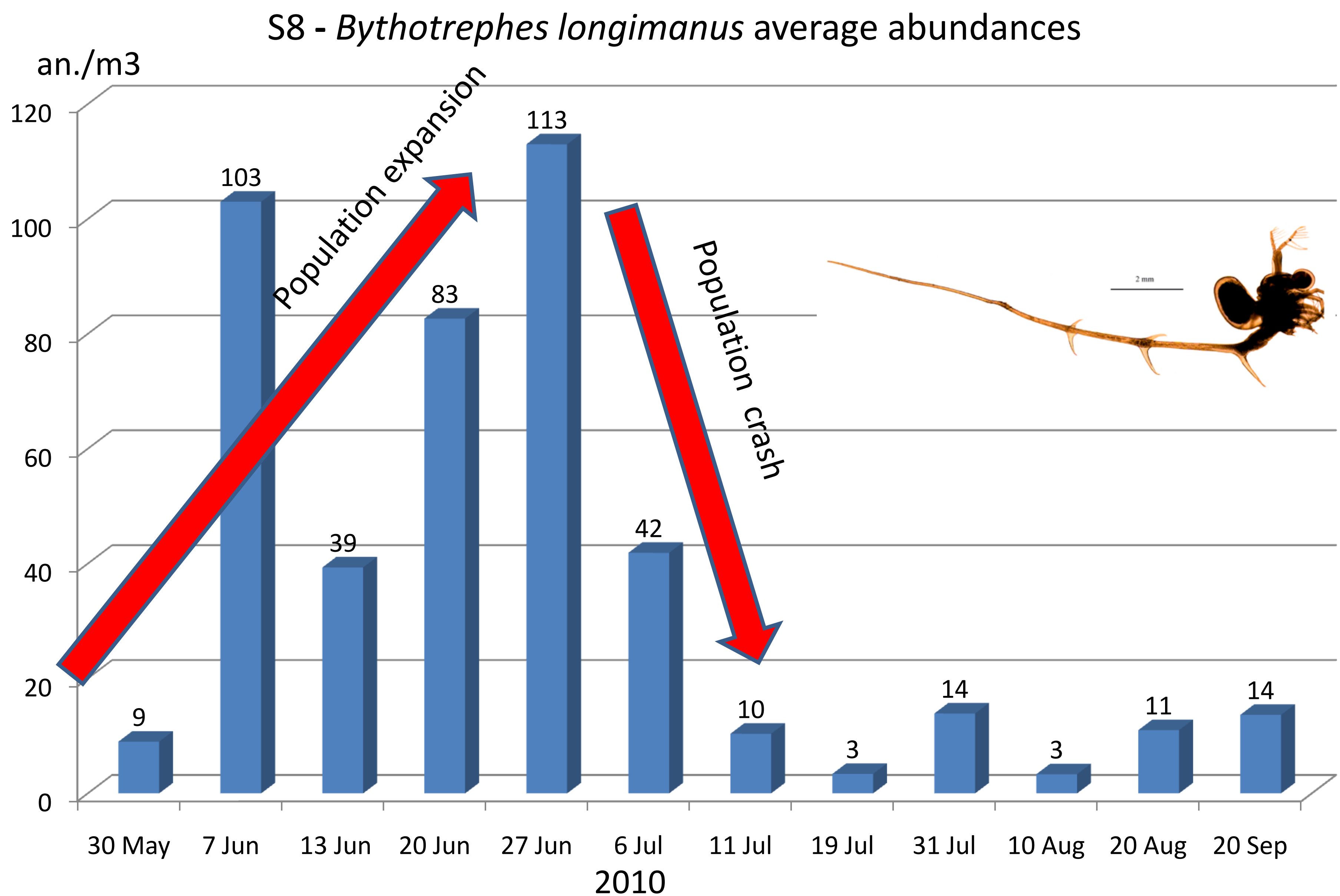
S8 - Summer 2010 abundances of *Bythotrephes longimanus* and its impact on zooplankton abundance

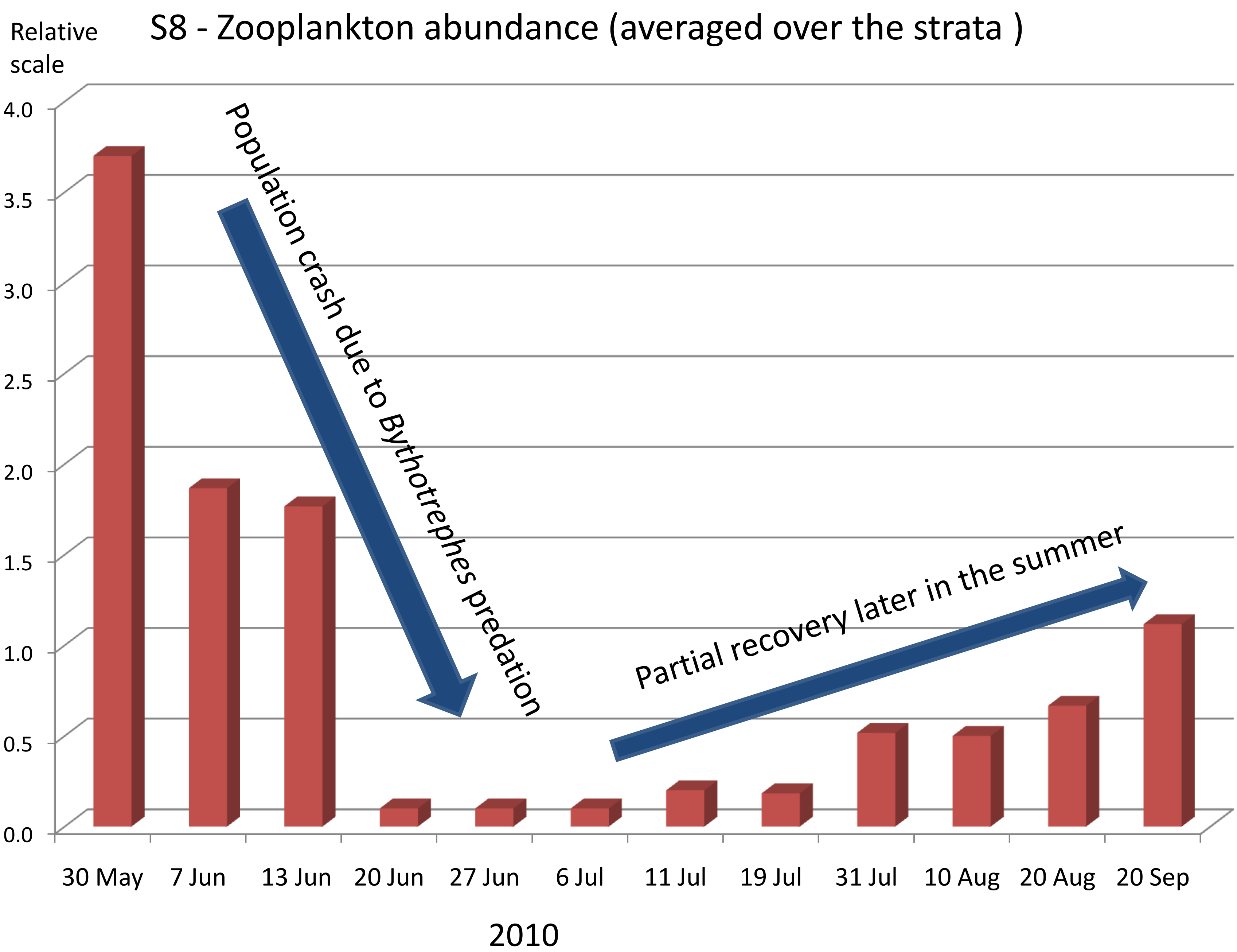
2010 – Sampling Stations – Lake Nipissing



Large *Daphnia galeata mendotae* population

S8, May 30^{th}, 2010 in the 5m stratum

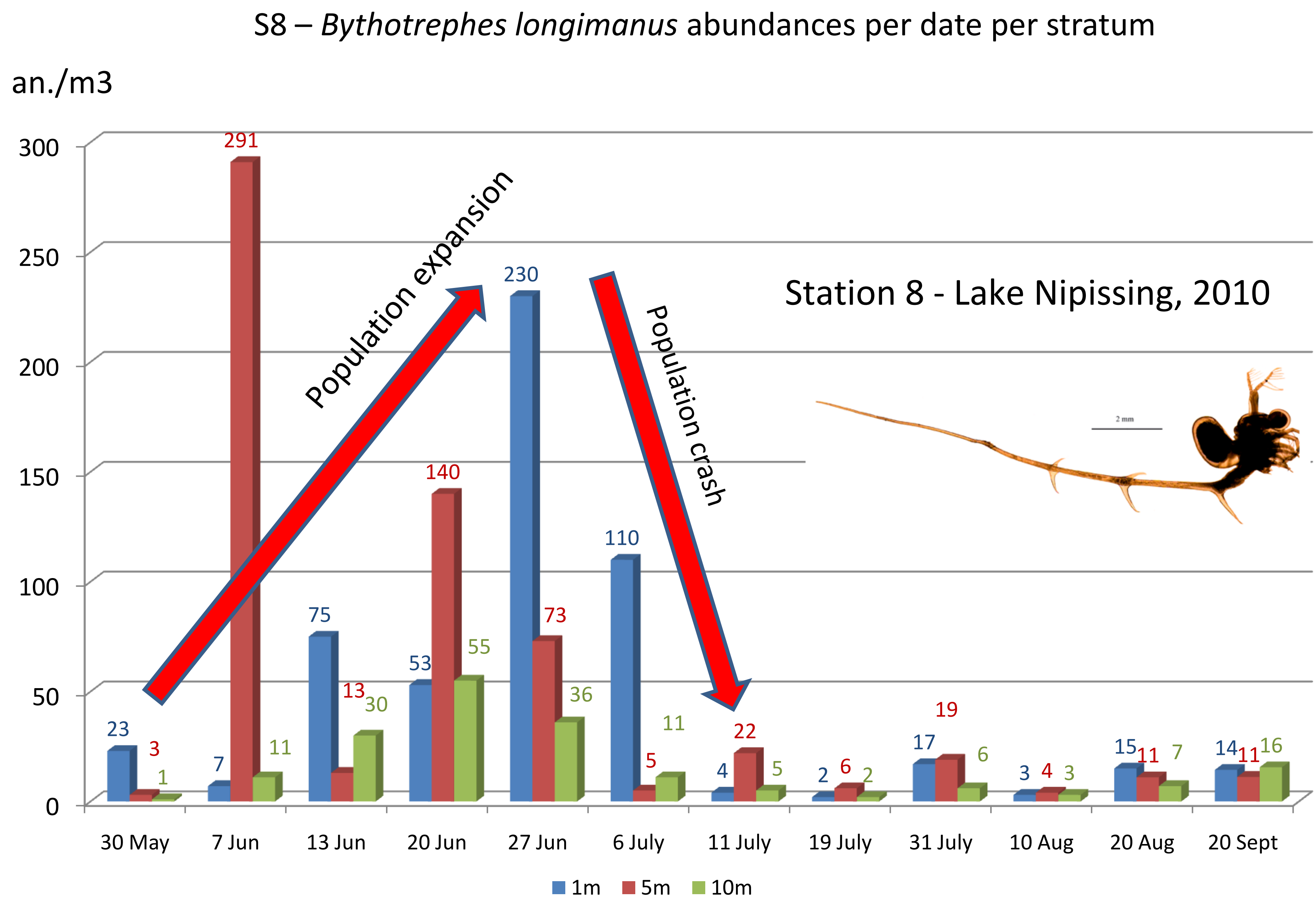

S8 - *Bythotrephes longimanus* average abundances
an./m3
120
100
80
60
40
20
0
Population expansion
Population crash
2 mm
9
103
39
83
113
42
10
3
14
3
11
14
30 May
7 Jun
13 Jun
20 Jun
27 Jun
6 Jul
11 Jul
19 Jul
31 Jul
10 Aug
20 Aug
20 Sep
2010



Relative scale
S8 - Zooplankton abundance (averaged over the strata)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Population crash due to Bythotrephes predation
Partial recovery later in the summer
30 May
7 Jun
13 Jun
20 Jun
27 Jun
6 Jul
11 Jul
19 Jul
31 Jul
10 Aug
20 Aug
20 Sep
2010

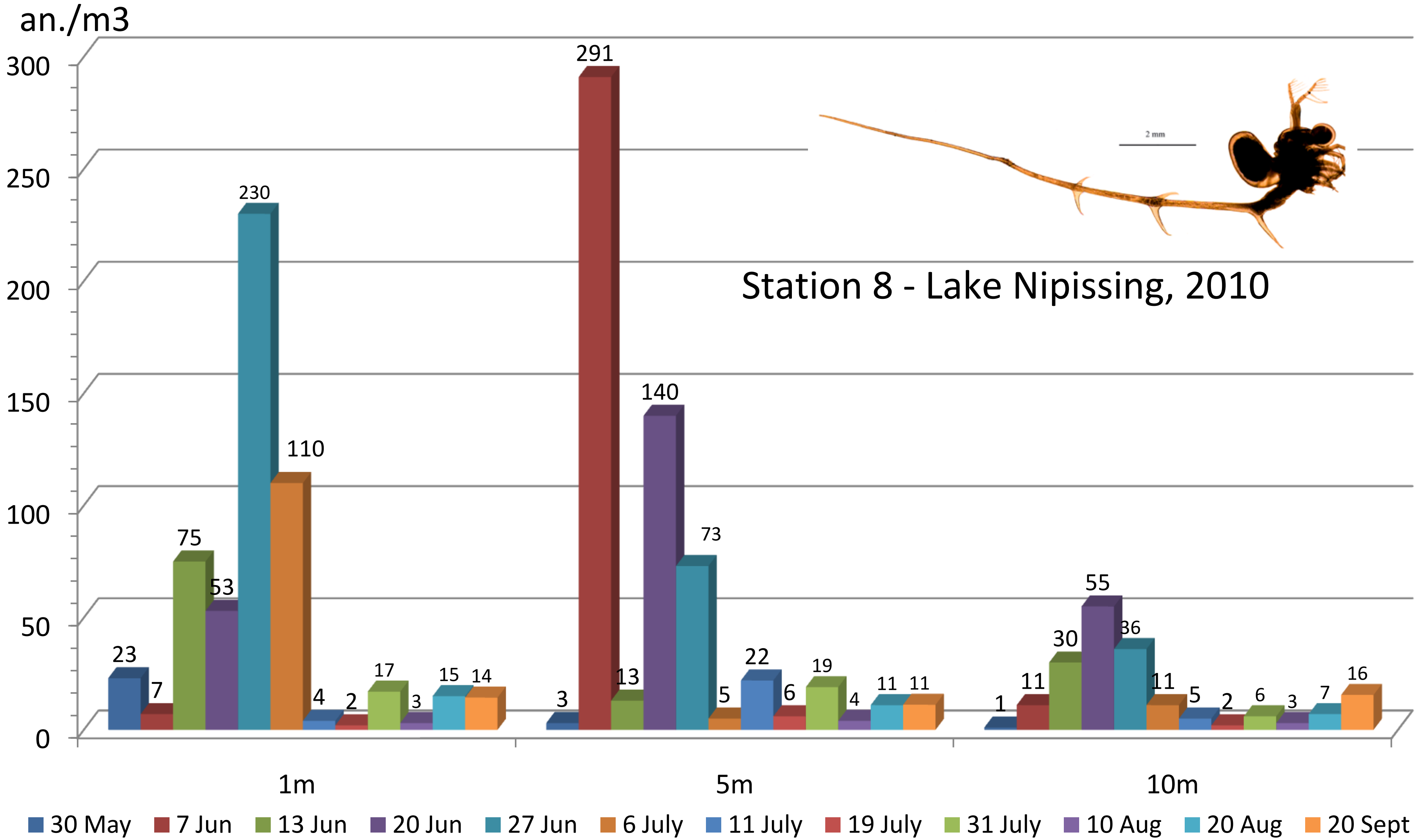
S8 - Summer abundances of *Bythotrephes longimanus* and its impact on the zooplankton community

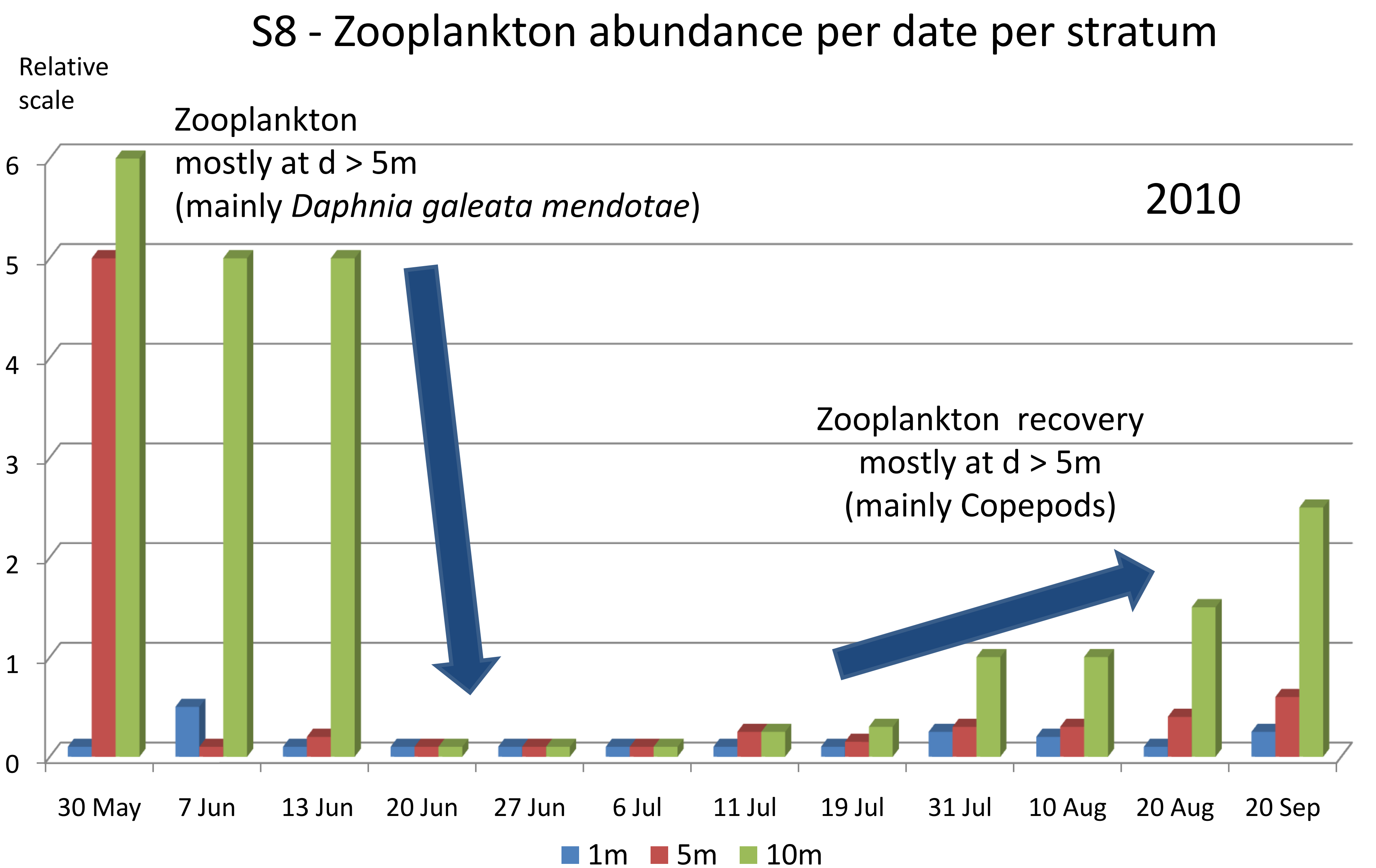
The expansion of the *Bythotrephes longimanus* population is quick off the mark, come spring at Station 8. In fact, the reproductive potential of *Bythotrephes* is one of the most important aspects of it biology (Sikes 2002). By the end of June 2010, *Bythotrephes* had reached an impressive average abundance (averaged over the 1m, 5m and 10m strata) of 113 animals per cubic metre. This high abundance was unsustainable and led to a near complete consumption of the available zooplankton in the water column. Two weeks later (July 11th), the *Bythotrephes* average abundance had collapsed to 10 an./m3. From July 11th to September 20th, the average abundance varied from 3 to 14 an./m3.



S8 – *Bythotrephes longimanus* abundances per date per stratum
an./m3
300
250
200
150
100
50
0
291
230
140
110
75
73
53
55
13
30
36
23
3
1
7
11
11
22
5
4
5
2
6
2
17
19
6
3
4
3
15
11
7
14
11
16
Population expansion
Population crash
Station 8 - Lake Nipissing, 2010
30 May
7 Jun
13 Jun
20 Jun
27 Jun
6 July
11 July
19 July
31 July
10 Aug
20 Aug
20 Sept
1m
5m
10m

Bythotrephes longimanus abundances per stratum per date

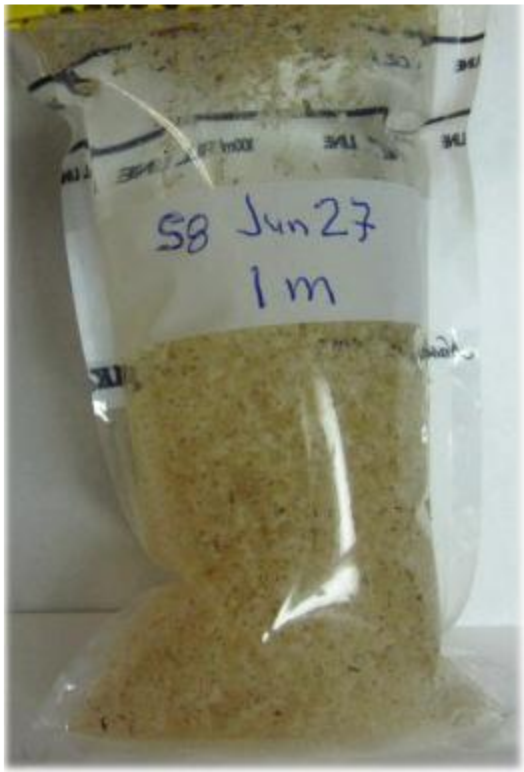



S8 - Zooplankton abundance per date per stratum
Relative scale
Zooplankton
mostly at d > 5m
(mainly *Daphnia galeata mendotae*)
2010
Zooplankton recovery
mostly at d > 5m
(mainly Copepods)
0
1
2
3
4
5
6
30 May
7 Jun
13 Jun
20 Jun
27 Jun
6 Jul
11 Jul
19 Jul
31 Jul
10 Aug
20 Aug
20 Sep
1m
5m
10m


S8 May 30
1 m
300 Bythotrephes
S8 May 30
5m
Mostly
40 Bythotrephes
S8 May 30
10 m
daphnia
10 Bythotrephes
S8 June 7
1 m
100 Bythotrephes
June 7 5m S8
>3900 Bytho
3900 Bythotrephes
June 7 S8
10 m
Nasco WHIRL-PAK
Mostly
daphnia
150 Bythotrephes


1000 Bythotrephes
170 Bythotrephes
400 Bythotrephes
Fewer daphnia
720 Bythotrephes
1900 Bythotrephes
750 Bythotrephes
Zooplankton depleted in all strata

By the end of June, the spiny water flea had pretty well eliminated most of the zooplankton in the water column



3100 Bythotrephes

990 Bythotrephes

480 Bythotrephes

By July 11, 2010, *Bythotrephes* itself had crashed to much lower abundances.

S8 - Summer abundances of *Bythotrephes longimanus* and its impact on the zooplankton community (page 1)

Bythotrephes abundance was highly variable depending on which stratum was analyzed. A maximum abundance of 291 an./m3 was found in the 5m stratum on June 7th, 2010. In comparison, on that same date, the 1 m stratum only had a *Bythotrephes* abundance of 7 an./m3 and the 10 m stratum an abundance of 11 an./m3. Zooplankton abundances on that same date showed that the zooplankton had been nearly completely depleted at the 1 m level, and was pretty well depleted at the 5 m level.

At this moment in time there still existed a large population of *Daphnia galeata mendotae* at the 10 m level. Pangle and Peacor (2009) report that *Bythotrephes* has trouble hunting prey in low light conditions. Consequently in a low light environment as exists at the 10m level in Lake Nipissing, *Bythotrephes* may have trouble catching *Daphnia galeata mendotae* except during periods of high illumination. This explains why the deeper strata are the last to be depleted by *Bythotrephes* and why there exists a zooplankton refuge at depth in Lake Nipissing.

S8 - Summer abundances of *Bythotrephes longimanus* and its impact on the zooplankton community (page 1)

With little left to eat at the 1m and 5m level, it was inevitable that the large *Bythotrephes* population would descend to crop the *Daphnia* at the10 m level. This is exactly what happened. By June 20th the entire zooplankton population at S8 had been reduced to trace levels. With little left to eat, one week later the population of *Bythotrephes* itself crashed and by July 11th, the abundances had fallen to 4, 22 and 5 an./m3 in the 1m, 5m and 10m respectively. One week after that abundances had fallen even further in all strata.

S8 - Summer abundances of *Bythotrephes longimanus* and its impact on the zooplankton community (page 2)

By the 20th of June the zooplankton at Station 8 had pretty well been all consumed. However, the *Bythotrephes* population did not start to crash until after the 27th of June. In its European native range *Bythotrephes* is able to feed on phytoplankton as well as zooplankton (Sikes 2002). It is unknown at this time whether or not the delay in the collapse of the *Bythotrephes* population was due to a partial switch to eating phytoplankton, cannibalism or simply living off fat reserves. Beyond the 27th of June the *Bythotrephes* population collapsed quickly, leaving a zooplankton desert behind.

S8 - Summer abundances of *Bythotrephes longimanus* and its impact on the zooplankton community (page 3)

"Bioenergetic calculations suggest that consumptive demands of *Bythotrephes* populations in Lake Michigan equal or exceed replacement production of *Daphnia* populations in midsummer. Moreover, it appears that at times alternative prey might be necessary to satisfy the physiological requirements of the predator population" – Lehman 1993.

Zooplankton declines have been documented before, and in fact the extirpation of certain species of zooplankton due to *Bythotrephes* predation has previously been documented (Yan 1992, Lehman 1993). However, the present Lake Nipissing study we think is the first documented case of a near-complete *Bythotrephes*-induced elimination of the near-entire zooplankton standing crop in all parts of the water column to 10m followed by the collapse of the *Bythotrephes* population. Given that the average depth of Lake Nipissing is 4.5m, this translates to the very near elimination of all the zooplankton in the entire lake, except for those few areas of the lake deeper than 10m.

S8 - Summer abundances of *Bythotrephes longimanus* and its impact on the zooplankton community (page 4)

In most instances the lowest abundances of *Bythotrephes* were found in the 10m stratum, particularly during the first half of the summer, prior to the collapse of the *Bythotrephes* population. Of interest, the highest zooplankton abundances also occur in the 10m stratum, both early on during the expansion of the *Bythotrephes* population (mainly *Daphnia galeata mendotae*) and later on during the summer during the partial recovery of the zooplankton population (mainly copepods). We think that this is due to *Bythotrephes* having trouble hunting in the low light intensity (Pangle and Peacor 2009) that exists in the 10m stratum. The average depth of Lake Nipissing is 4.5 m.

S8 Results

Come August some harvestable walleye started consuming *Bythotrephes*

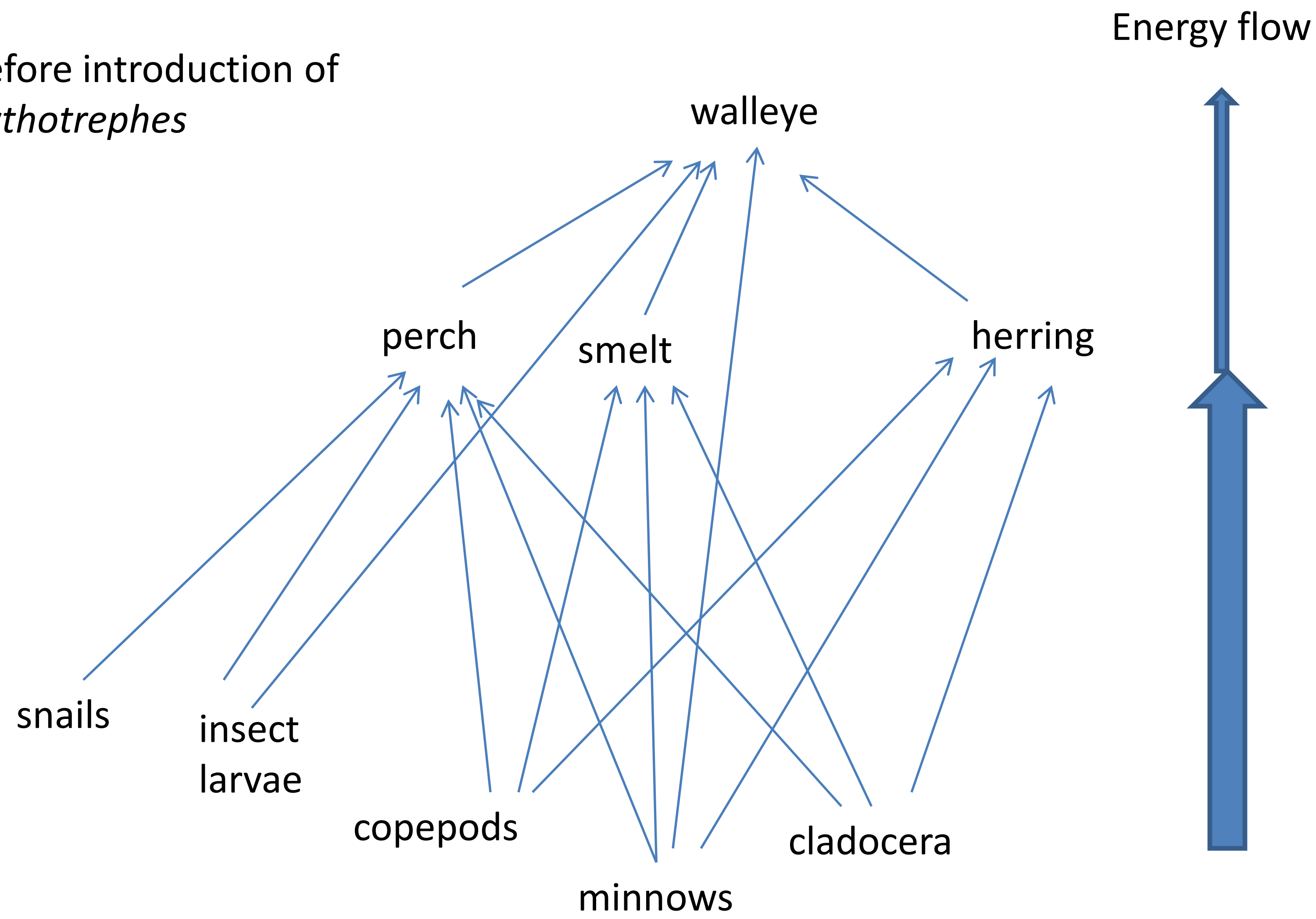
Aug. 7, 2010 Kevin O'Grady captures a 35 cm walleye with only *Bythotrephes* in its stomach.

Aug. 13, 2010 Stéfane Filion captures a 30 cm walleye with only *Bythotrephes* in its stomach.


30 cm walleye stomach contents
Caught near S2, Aug. 13, 2010
0.5 cm

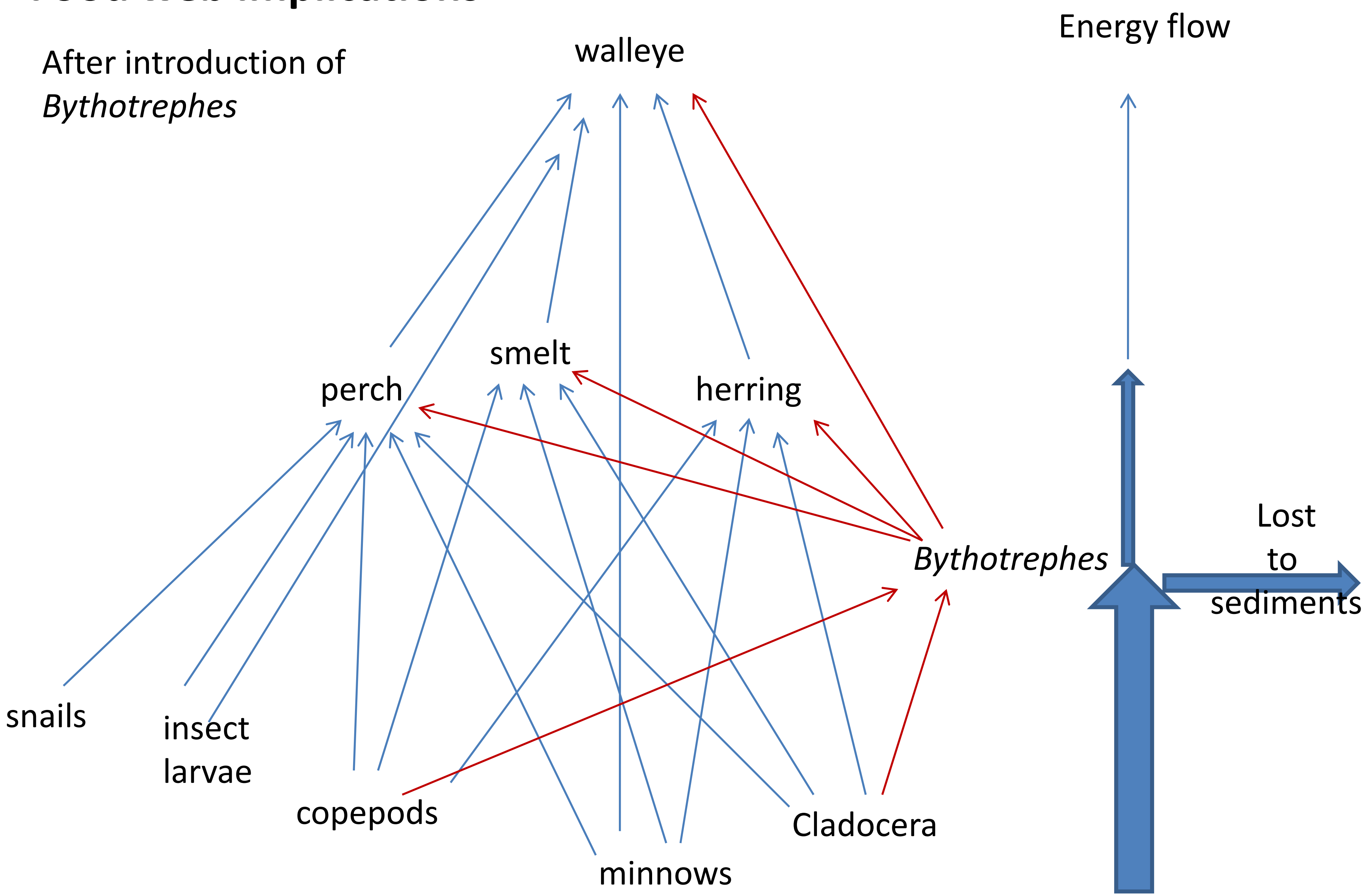
Food web implications

Before introduction of
Bythotrephes



Food web implications

After introduction of *Bythotrephes*



Food web implications

In the very simplified food web that we present, a number of problems arise from the introduction of *Bythotrephes.*

1. A new mid-trophic level has been introduced. One would think that this could lead to increased bioaccumulation of mercury in top predators such as walleye. A recent study looking into this phenomenon has found that in fact this does not occur (Rennie, Sprules 2010)

   "*The introduction of Bythotrephes had no influence on [Hg] or condition of coregonid fish . . . One explanation for these patterns is that mid-trophic invaders like Bythotrephes share existing niches with other functionally similar species when they invade, and as such have no significant effect on trophic positions of consumer species.*"

   The authors go on to explain that climate change poses a far greater risk to coregonid fish condition than the introduction of *Bythotrephes.* In their study they worked with lake herring (*Coregonus artedi)* and lake whitefish (*Coregonus clupeaformis).*

Food web implications

2. Energy flow to the higher trophic levels is being curtailed by two different mechanisms. The addition of an intermediate trophic level (*Bythotrephes*) immediately cuts energy flow by a certain percentage to the perch, smelt, herring trophic level. To make matters worse, a large percentage of the energy that was accumulated in the expansion of the *Bythotrephes* population is lost to the sediments when the *Bythotrephes* population collapses. The question then becomes, is there enough energy left to supply the needs of those predators that lie higher up on the food chain.

   Stomach analyses of yellow perch (*Perca flavescens)* in the winter (a time of little zooplankton availability) shows that they switch to eating snails and *ephemeroptera* (shadfly) naiads (this study). The loss of much of the zooplankton come early summer could affect the survival and growth rates of larval fish and minnows. If minnows were to become scarce, perch could switch to snails and shadfly naiads during the summer as they are used to consuming these in the winter. This would buffer the food web effects of losing the zooplankton biomass in early summer in Lake Nipissing.

Food web implications

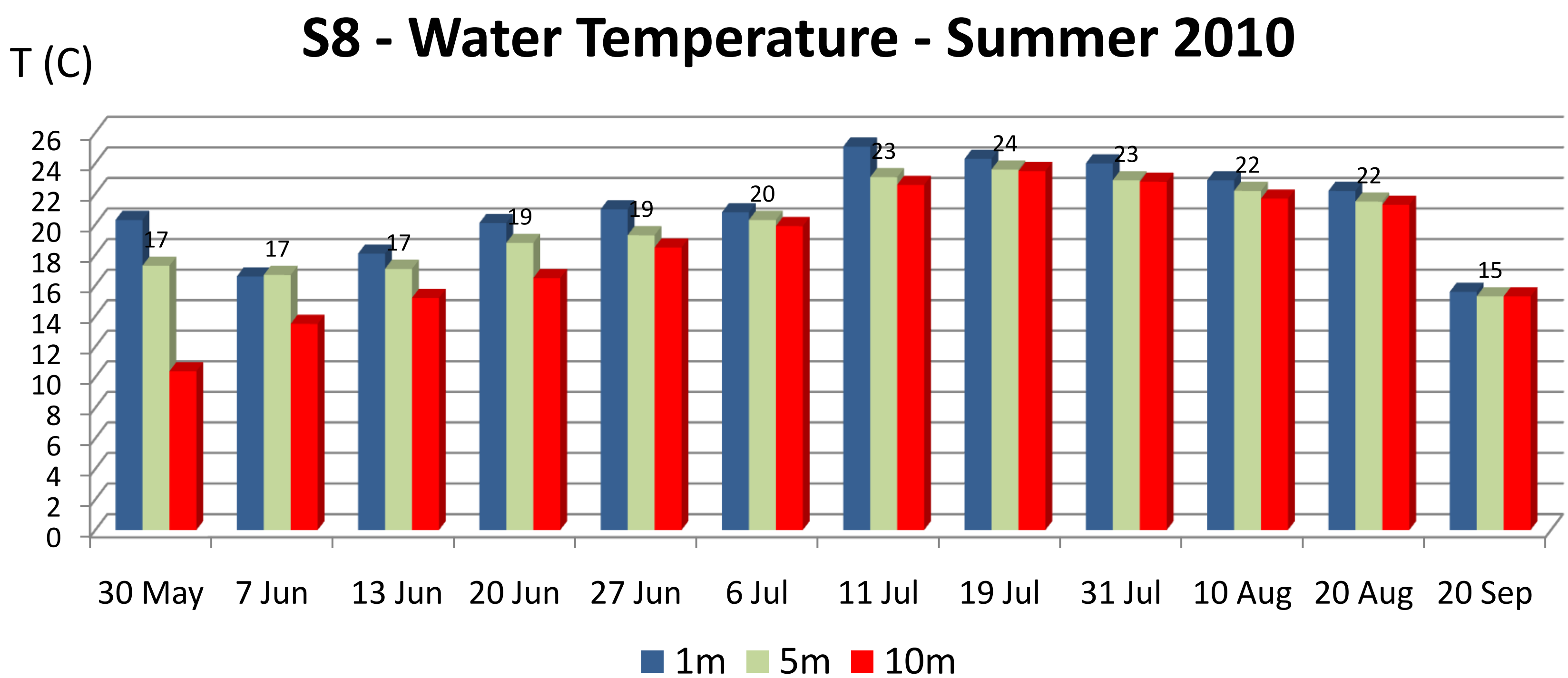
3. *Bythotrephes* may have a potential impact on fish recruitment. In Sikes 2002, we read: "Juvenile fish were major predators of *Daphnia* species prior to the invasion of *Bythotrephes* and its new competition and effective limitation as a prey species for smaller fish due to its tail spine (Barnhisel 1995) could be causing decreases in recruitment potential for fish (Branstrator DK. 1996)."

   In Lake Nipissing there appears to be sufficient *Daphnia* to supply the needs of larval fish until the middle of June at the 10m level and deeper. Is mid-June long enough? The average depth of Lake Nipissing is 4.5m, and it is unknown whether or not sufficient *Daphnia* will be present there to satisfy the needs of larval fish and smaller-sized fish like minnows and larval perch.


Larval fish
0.5 mm
[redacted]
Typical size of food
eaten by larval fish

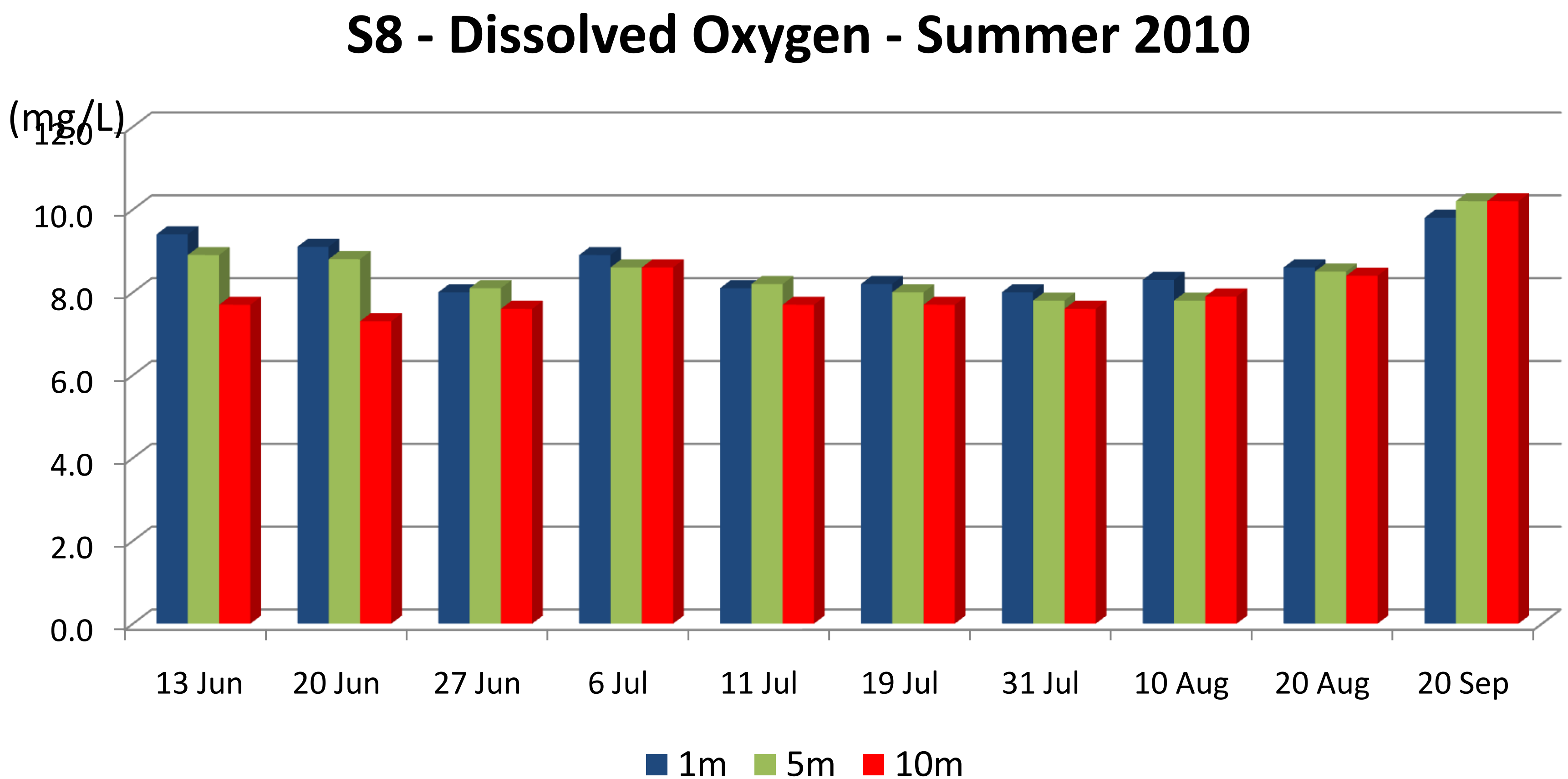
S8

Physical parameters appear ideal for the rapid development of the *Bythotrephes* population



The spiny water flea can survive a wide range of temperatures, but has lowest mortality between 5ºC and 30ºC (Garton 1990) . Its development time is temperature dependent and maximized between 20-25ºC without suffering higher mortality (Yurista 1992). Kim and Yan (2010) report times to first reproduction to be 15, 11, 9, and 7 days at 16, 19, 22 and 25 degrees Celcius with maximum population increases around 22 degrees Celcius.

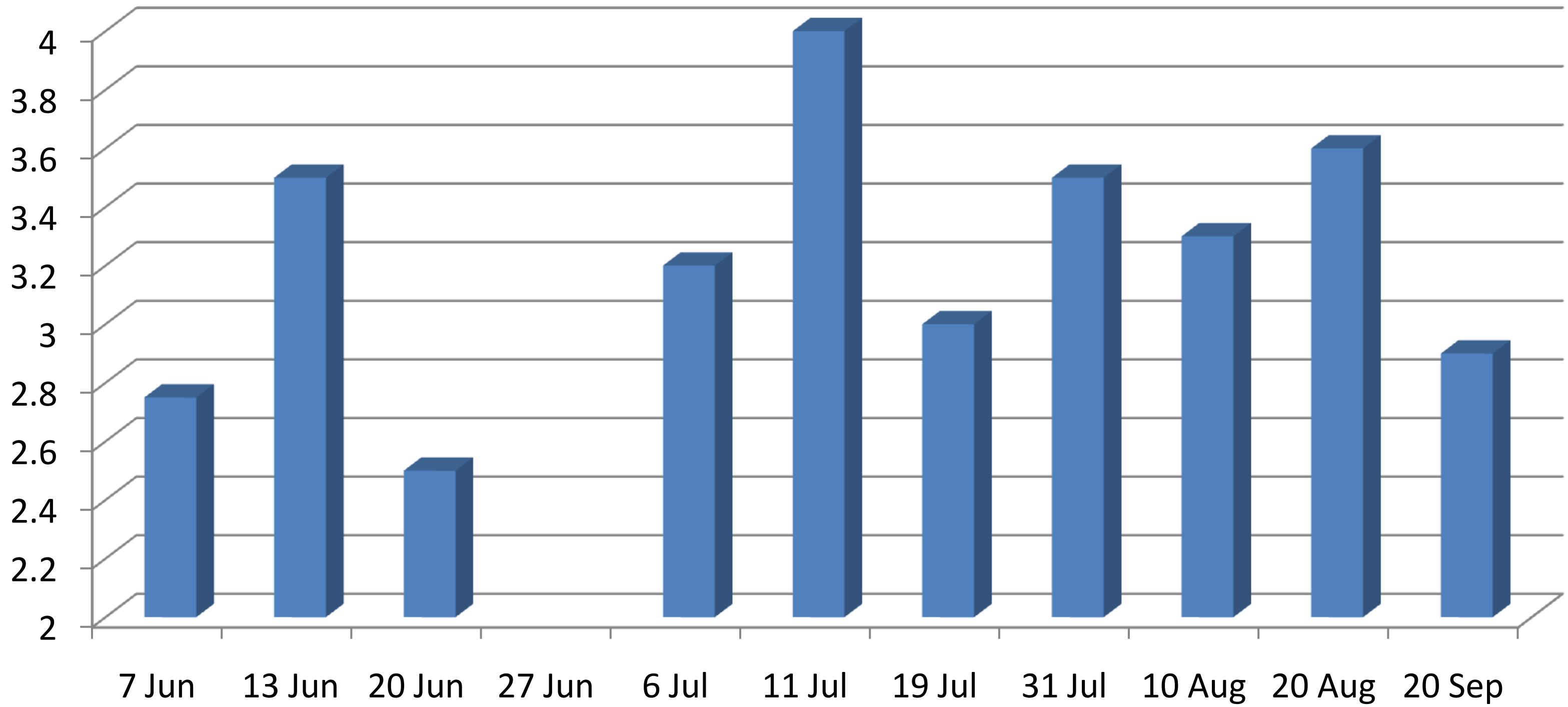
The water temperature at S8 was in the 'ideal' range at all depths for most of the summer of 2010.



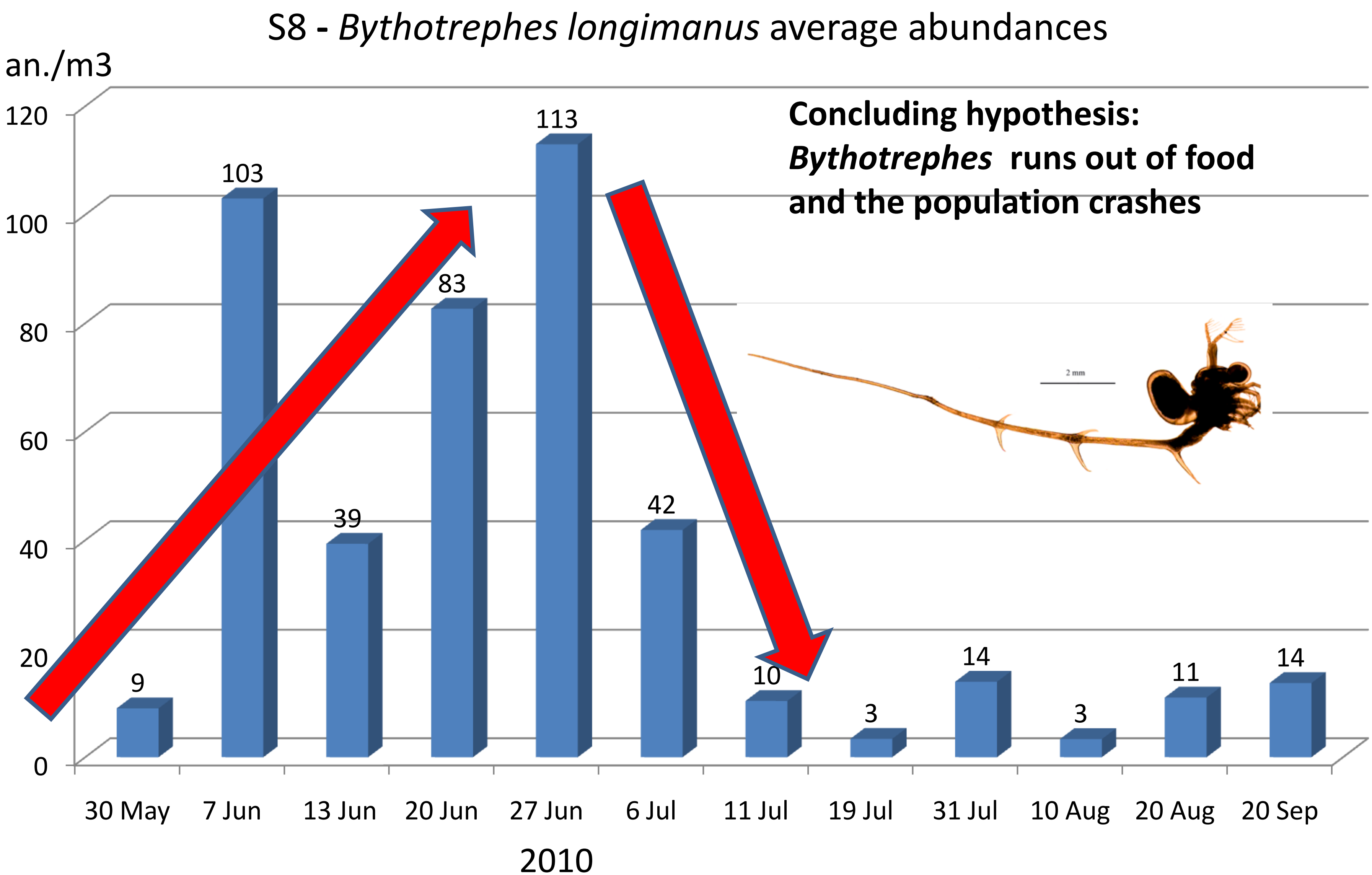
Hatching success and newborn condition is best when dissolved oxygen content is close to saturation and pH is close to neutral (Brown 2008).

Dissolved oxygen remained high and close to saturation in all strata throughout the summer. Lake Nipissing's water is neutral to slightly basic (Neary 1992). These represent ideal conditions for the hatching and development of *Bythotrephes.*

Secchi Depth (m) - Station 8 - 2010



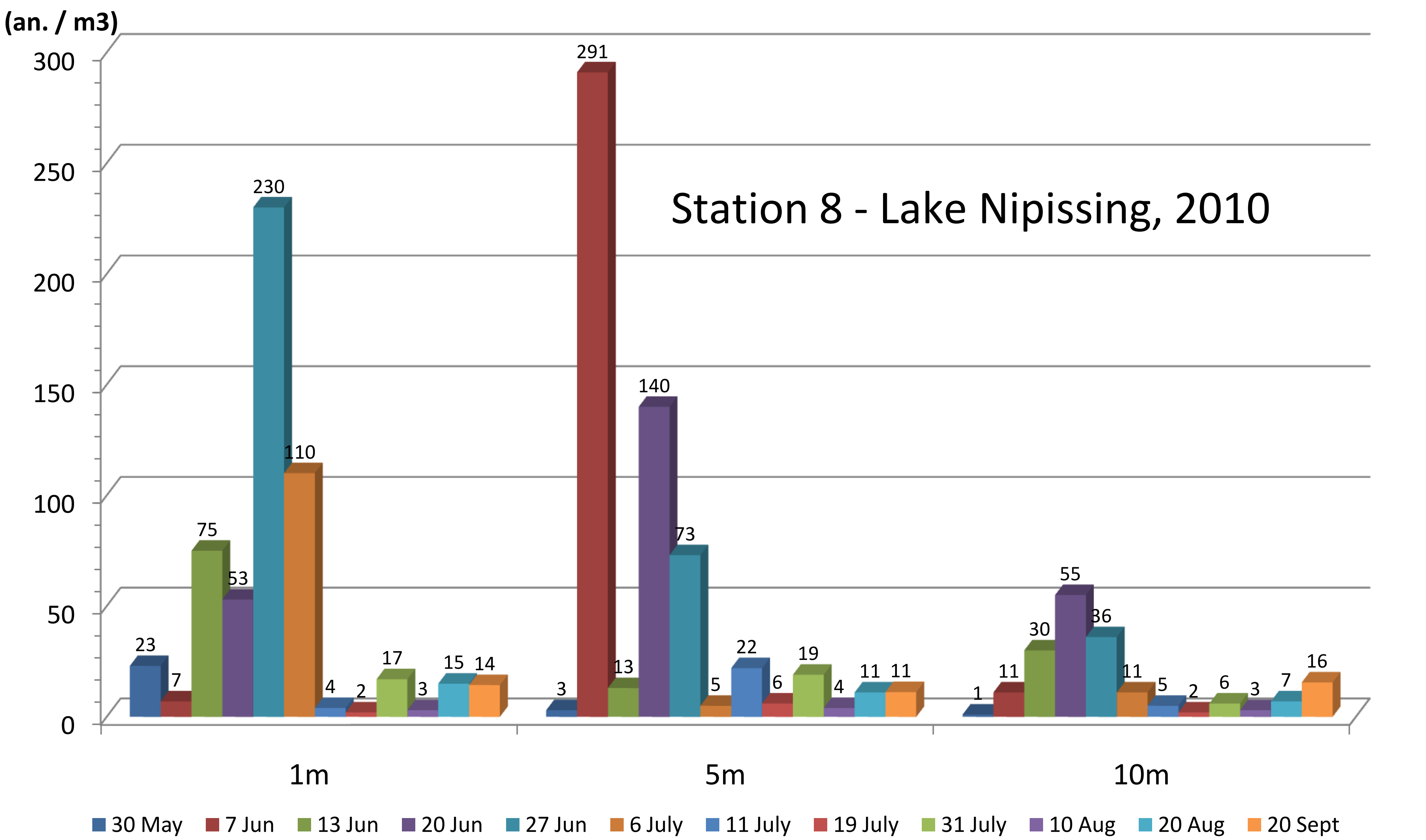
Secchi depth has not changed appreciably from historical averages. Secchi depths are reported to average 2 to 3m for June and 3 to 4m for July and August for the years 1988 to 1990 (Neary 1992).

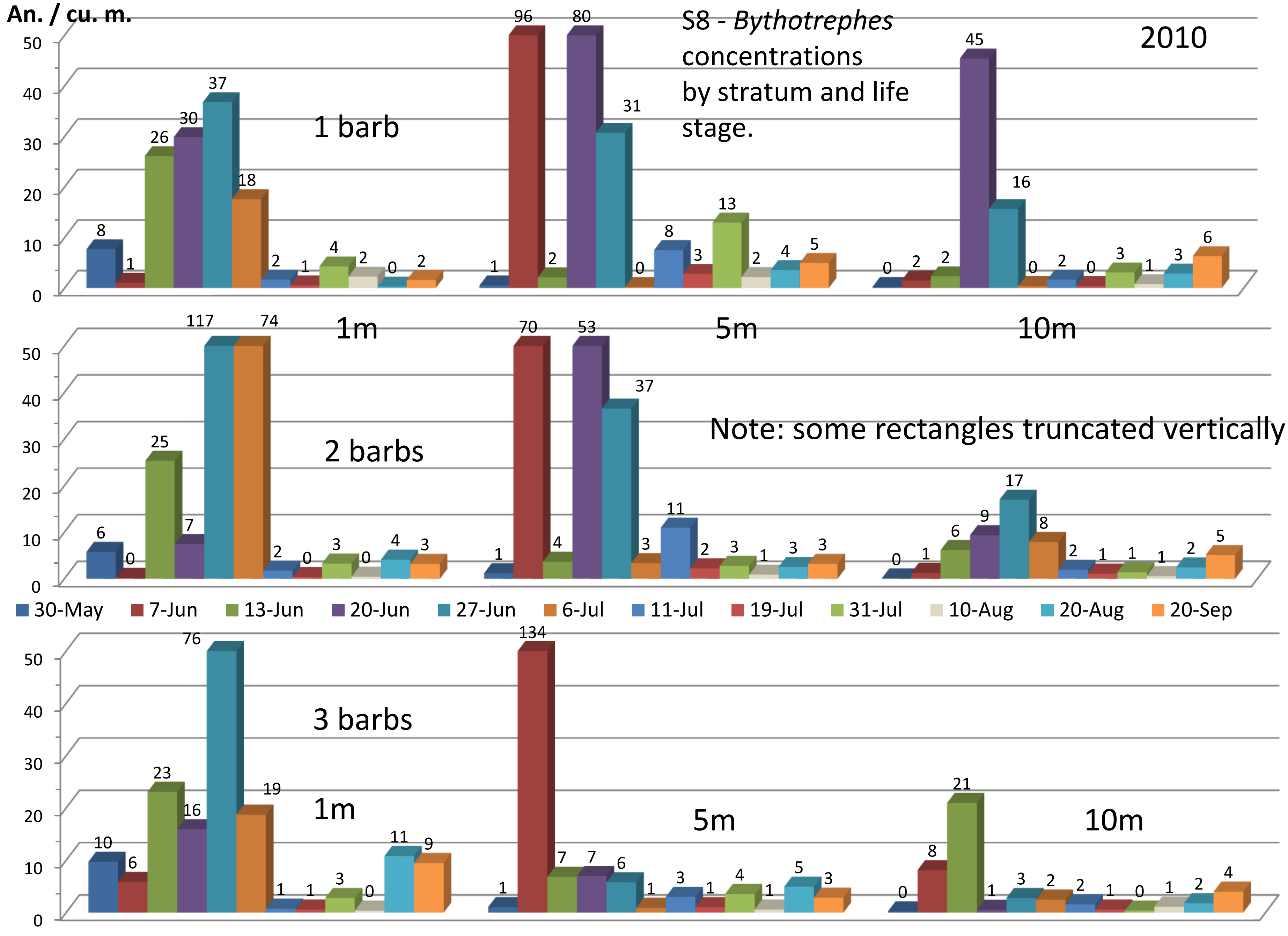

S8 - *Bythotrephes longimanus* average abundances
an./m3
120
100
80
60
40
20
0
9
103
39
83
113
42
10
3
14
3
11
14
30 May
7 Jun
13 Jun
20 Jun
27 Jun
6 Jul
11 Jul
19 Jul
31 Jul
10 Aug
20 Aug
20 Sep
2010
Concluding hypothesis:
***Bythotrephes* runs out of food**
and the population crashes

S8

Bythotrephes population dynamics based on life stages.

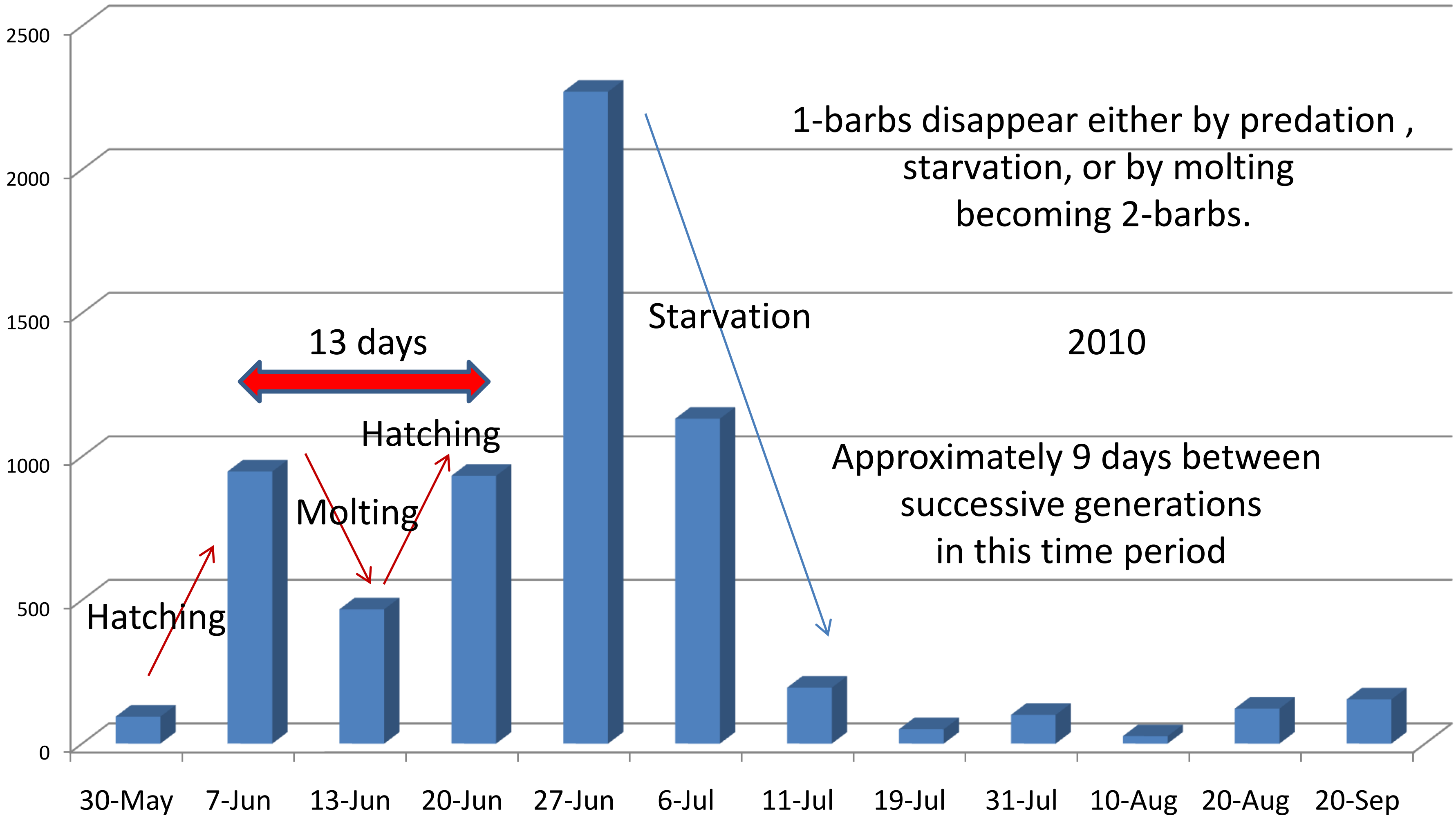
S8 - *Bythotrephes* abundances by strata then by date





An. / cu. m.
S8 - *Bythotrephes* concentrations by stratum and life stage.
2010
1 barb
2 barbs
3 barbs
1m
5m
10m
Note: some rectangles truncated vertically
30-May
7-Jun
13-Jun
20-Jun
27-Jun
6-Jul
11-Jul
19-Jul
31-Jul
10-Aug
20-Aug
20-Sep

S8 –*Bythotrephes* - total number of 1-barbs in all strata



Kim and Yan (2010) report successive generation times of around 9 days at 21/22 C and 15 days at 16C. From June 7 to June 20 the water temperature was around 17C. Our weekly sampling frequency makes it hard to determine, to the day, the successive generation time.

Discussion

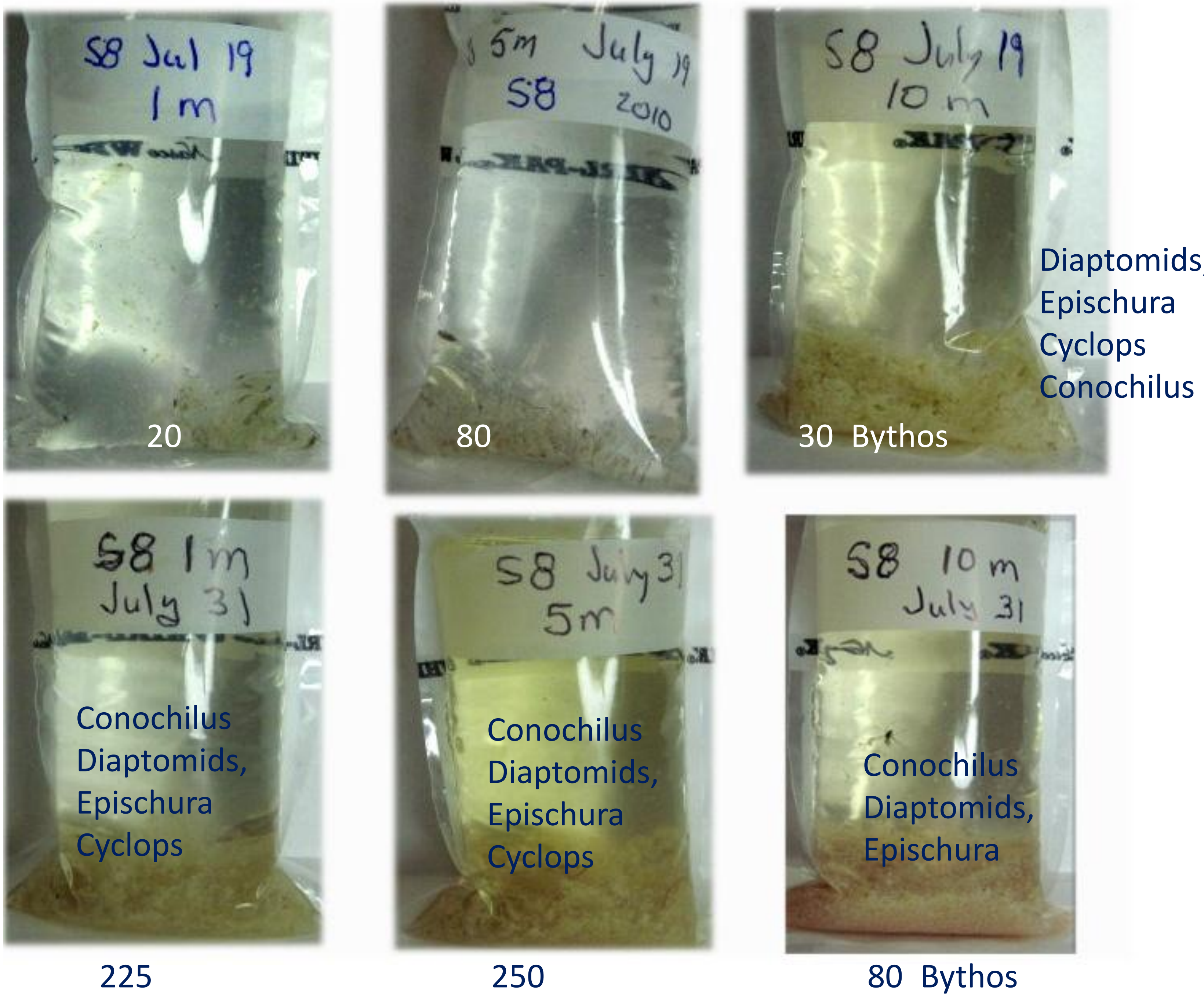
S8 - *Bythotrephes* population dynamics based on life stages.

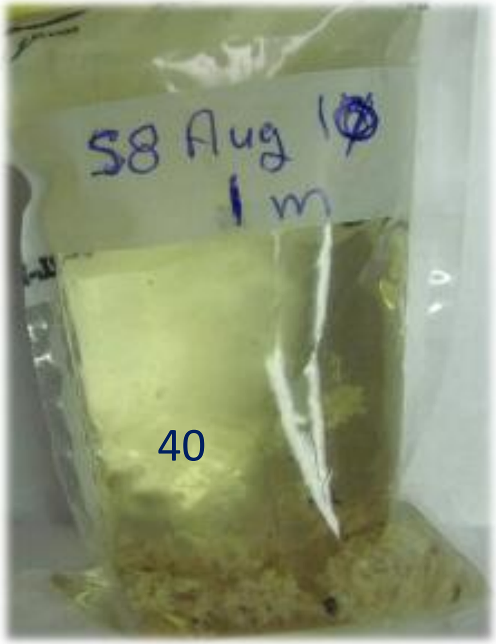
Bythotrephes development time is temperature dependent and maximized between 20-25ºC without suffering higher mortality (Yurista 1992). Kim and Yan (2010) report times to first reproduction to be 15, 11, 9, and 7 days at 16, 19, 22 and 25 degrees Celcius with maximum population increases around 22 degrees Celcius.
It appears that in Lake Nipissing the successive generation time (primaparity) is also in the 2 weeks range in early to mid-June. As the temperature approaches 22C (mid-July), we would expect successive generation times to approach 9 days.

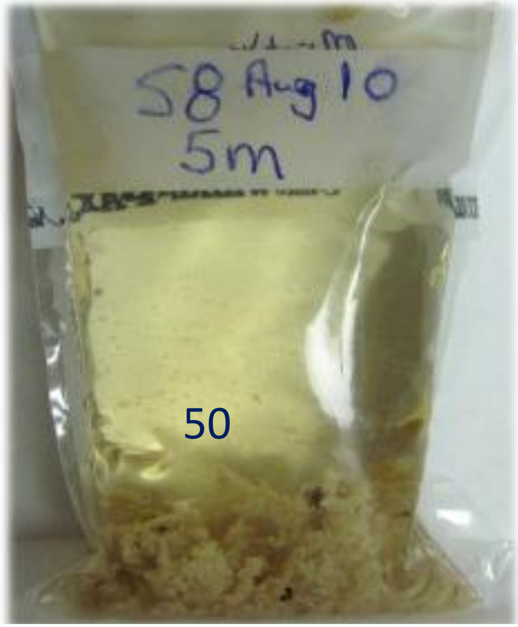
For the first half of June, the 3-barb form was most abundant in all strata and reached an abundance of 134 an./m3 in the 5m stratum on June 7th. This was the highest abundance that was recorded by any form, in any stratum, during the entire sampling period. On that date, again in the 5 m stratum, *B. longimnus* reached an abundance of 291 an./m3 if all forms are included.

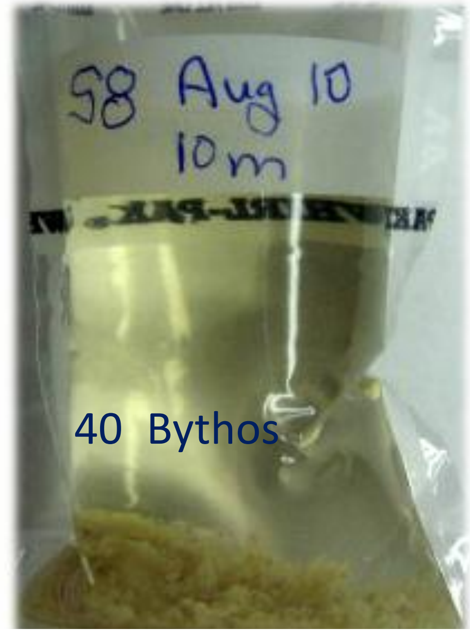
During the collapse of the *Bythotrephes* population, the 3-barb form was the first to collapse. This is probably due to the higher energy requirements of this form. By the 20th of June, the highest abundances were in the 1-barb form, found in the 1m stratum. Later in the summer there appeared to be a good mix of forms, in all strata, albeit at much lower abundances.

As we move into August
the zooplankton samples take on a
more lumpy appearance due to
the presence of new arrivals:
Conochilus unicornis (a colonial rotifer)
and *Geotrichia* (a blue-green algae)

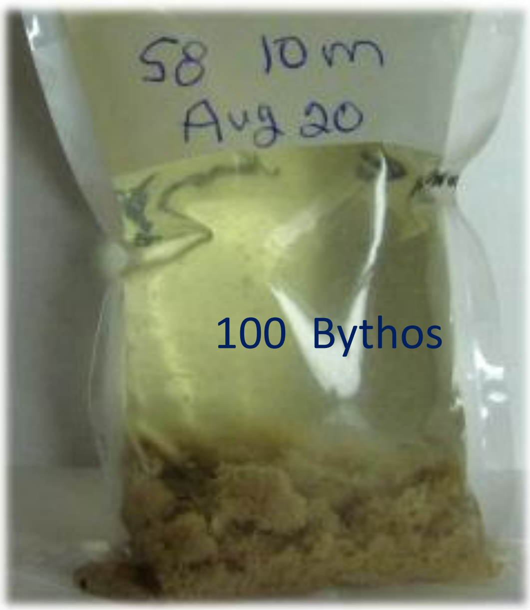

S8 Jul 19
1 m
20
5m July 19
S8 2010
80
S8 July 19
10 m
30 Bythos
Diaptomids,
Epischura
Cyclops
Conochilus
S8 1m
July 31
Conochilus
Diaptomids,
Epischura
Cyclops
225
S8 July 31
5m
Conochilus
Diaptomids,
Epischura
Cyclops
250
S8 10 m
July 31
Conochilus
Diaptomids,
Epischura
80 Bythos





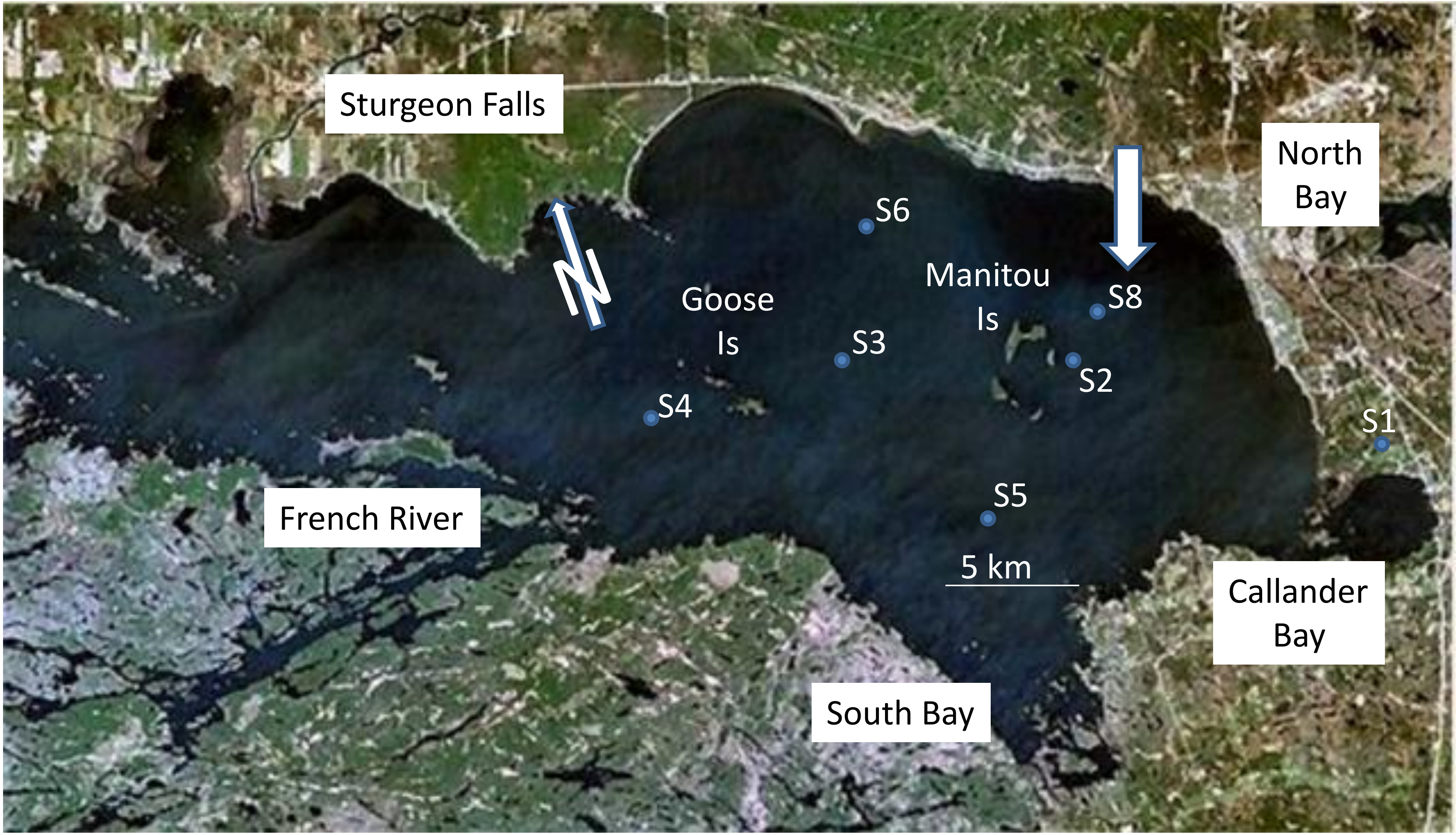


Conochilus and *Geotrichia* change the 'look' of the samples.



S8 - Zooplankton Community Structure

(with comments on changes since the introduction of *Bythotrephes*)



Estimating relative zooplankton abundance in collected samples

Total-Zooplankton-Volume Ranking Score

0 to 1 – zooplankton volume occupies 0 to 10 mL

1 to 2 - occupies 10 to 20 mL

2 to 3 - occupies 20 to 30 mL

3 to 4 occupies 30 to 40 mL

4 to 5 - occupies 40 to 50 mL

6 - occupies more than 50 mL

Volumes exclude *Bythotrepes longimanus*

Estimating within_sample abundance of taxa

Taxon-Abundance Ranking Score

0 – not seen in sample
1 - trace; most of sample must be scanned to find an individual of this species
2 – only a few individuals seen in 10 mL
3 – Individuals of this species require only modest search in 10 mL sample
4 – Individuals of this species common in 10 mL
5 – Individuals dominate sample in percentage abundance

Note: Except for samples with total zooplankton volumes > 50 mL, collected samples were diluted to 50 mL prior to examination, then divided into 10 mL aliquots.

In the Score Ranking charts, increasing intensity of color indicates a higher score.

Total Abundance Score (per taxon, per stratum)	= Zooplankton Volume Ranking score	x	Taxon Relative Abundance Score

Abbreviations used:

zoo = zooplankton volume ranking score
diap = *Diaptomids sp*.
epi = *Epischura lacustris*
orego = *Skistodiaptomus oregonensis*
Lmin = *Leptodiaptomus minutus*
cyc = *Cyclops sp.*
DBT = *Diacyclops bicuspidatus thomasi*
Medax = *Mesocyclops edax*

Legend:
* species positively identified in sample
- species may be present, but not positively identified

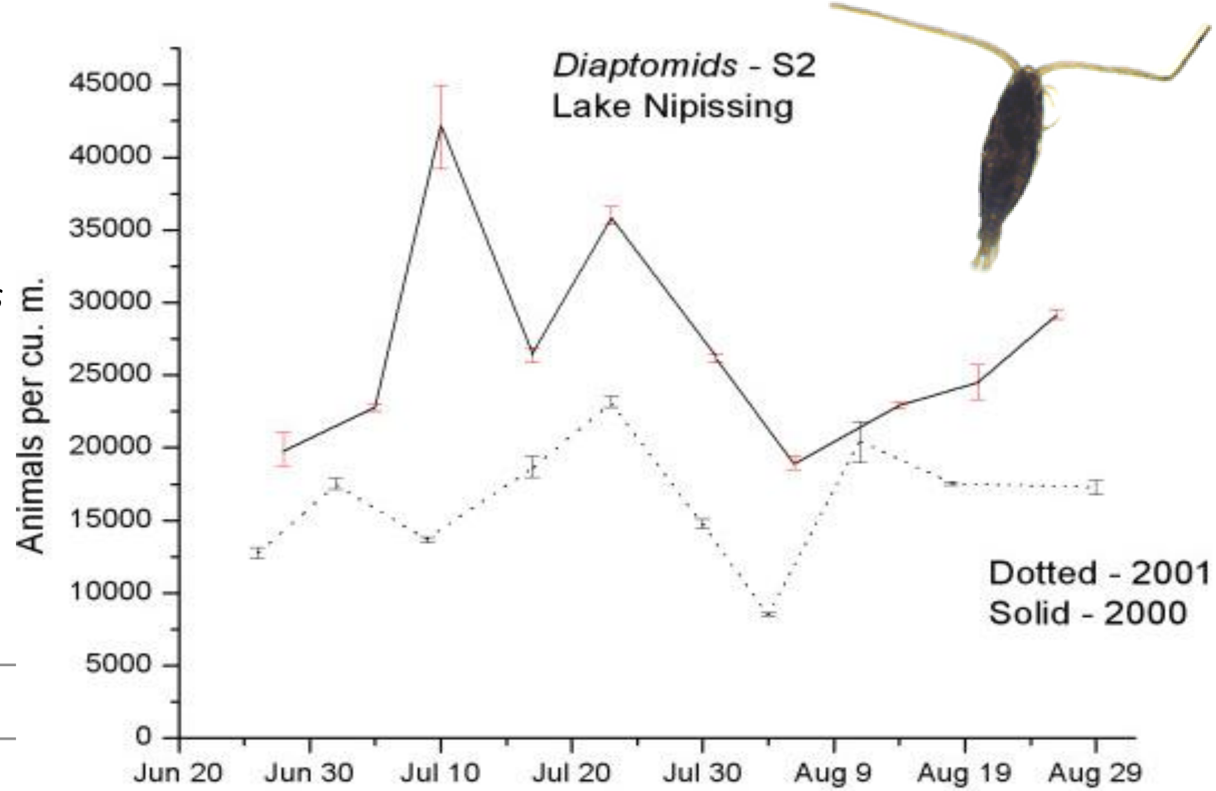
Note: lack of positive identification may be due to scarcity of animals in sample, or due to lack of animals in appropriate life stage

S8 - Copepod ranking scores - 2010

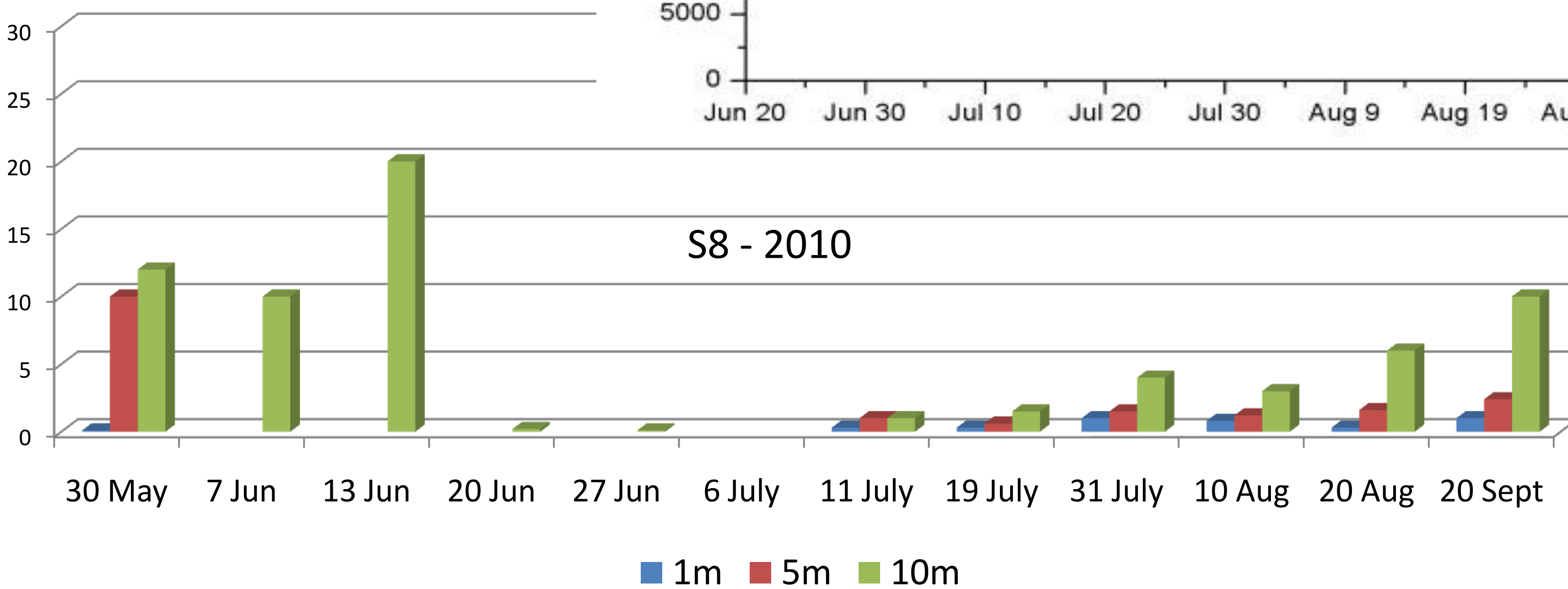
Date	D (m)	an/m3	zoo	Epi	Diap	Orego	Lmin	Cyc	DBT	Medax
30 May	1	23	0.1	0	1	-	-	1	-	-
30 May	5	3	5	3	2	x	x	1	x	-
30 May	10	1	6	2	2	-	-	1	-	-
7 Jun	1	7	0.5	1	0	-	-	1	-	-
7 Jun	5	291	0.1	1	0	-	-	1	-	-
7 Jun	10	11	5	2	2	-	x	1	-	-
13 Jun	1	75	0.1	2	0	-	-	0	-	-
13 Jun	5	13	0.2	0	0	-	-	1	-	x
13 Jun	10	30	5	4	4	x	x	2	x	-
20 Jun	1	53	0.1	2	0	-	-	0	-	-
20 Jun	5	140	0.1	2	0	-	-	0	-	-
20 Jun	10	55	0.1	3	2	x	-	2	-	x
27 Jun	1	230	0.1	1	0	-	-	0	-	-
27 Jun	5	73	0.1	3	0	-	-	0	-	-
27 Jun	10	36	0.1	3	1	x	-	0	-	-
6 Jul	1	110	0.1	2	0	-	-	0	-	-
6 Jul	5	5	0.1	2	0	-	-	1	-	x
6 Jul	10	11	0.1	3	0	-	-	0	-	-
11 Jul	1	4	0.1	3	3	-	-	3	-	x
11 Jul	5	22	0.25	4	4	x	-	3	-	x
11 Jul	10	5	0.25	4	4	x	-	3	x	x
19 Jul	1	2	0.1	3	3	x	-	3	-	x
19 Jul	5	6	0.15	3	4	x	-	4	-	x
19 Jul	10	2	0.3	5	5	x	-	3	-	x
31 Jul	1	17	0.25	4	4	x	-	3	-	x
31 Jul	5	19	0.3	5	5	x	-	4	-	x
31 Jul	10	6	1	4	4	x	-	2	-	x
10 Aug	1	3	0.2	4	4	x	-	2	-	x
10 Aug	5	4	0.3	4	4	x	-	0	-	-
10 Aug	10	3	1	3	3	x	-	2	-	x
20 Aug	1	15	0.1	3	3	x	-	2	-	x
20 Aug	5	11	0.4	4	4	x	-	2	-	x
20 Aug	10	7	1.5	4	4	x	-	2	-	x
20 Sept	1	14	0.25	4	4	x	x	3	-	x
20 Sept	5	11	0.6	4	4	x	-	3	-	x
20 Sept	10	16	2.5	4	4	x	-	2	-	x

S8 - *Diaptomids*

Once the most abundant of zooplankton, by the end of June *Bythotrephes* had driven *Diaptomids* at S8 to trace amounts. The collapse of *Bythotrephes* come July allows some recovery which correlates positively with depth.

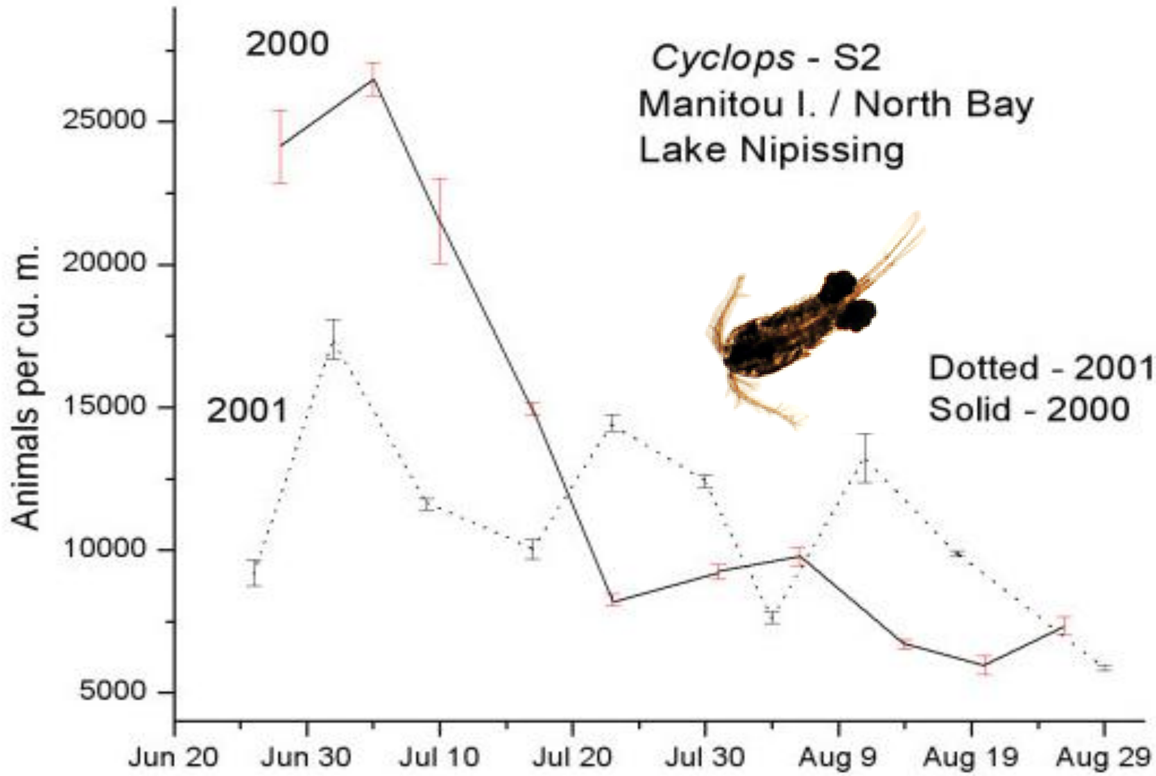


Relative scale

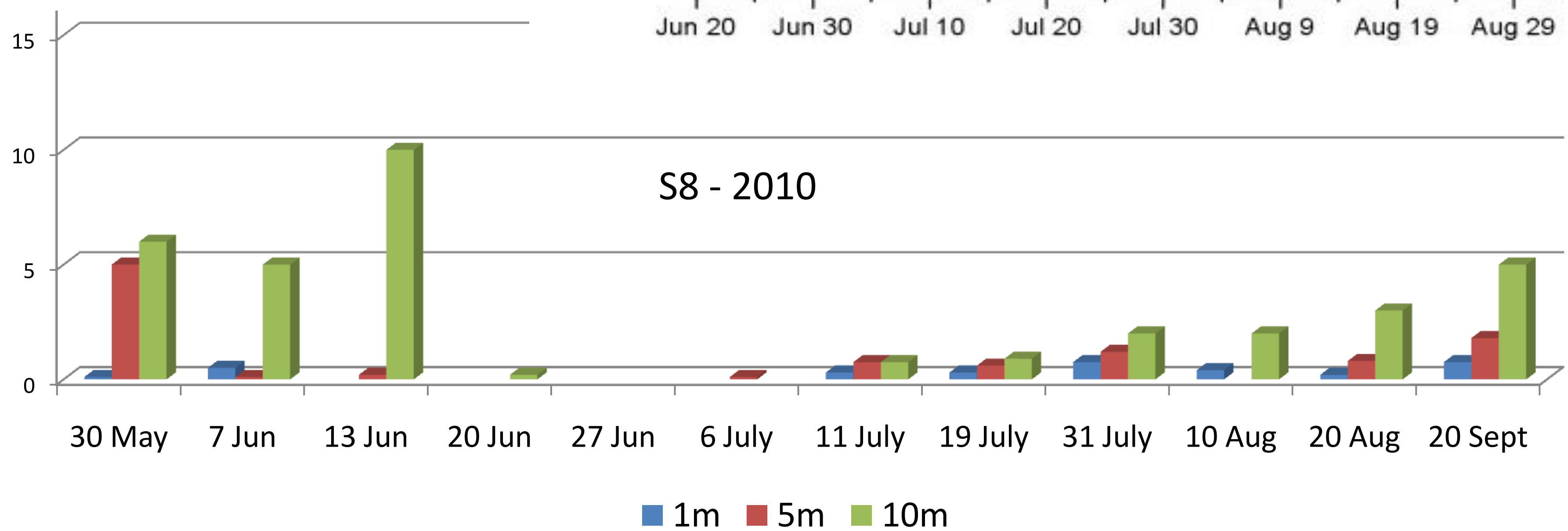


S8 - *Cyclops*

Once the 2nd most abundant Copepod, by the end of June *Bythotrephes* had driven Cyclops at S8 to trace amounts. The collapse of *Bythotrephes* come July allows some recovery which correlates positively with depth.

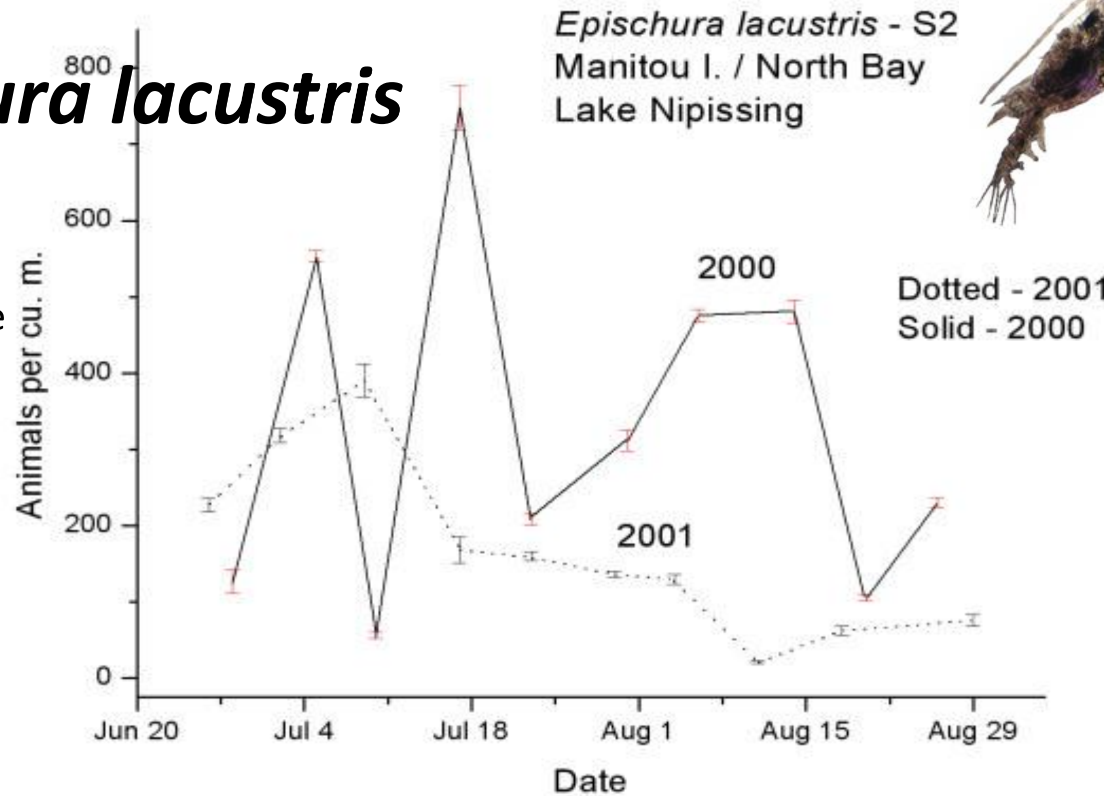


Relative scale

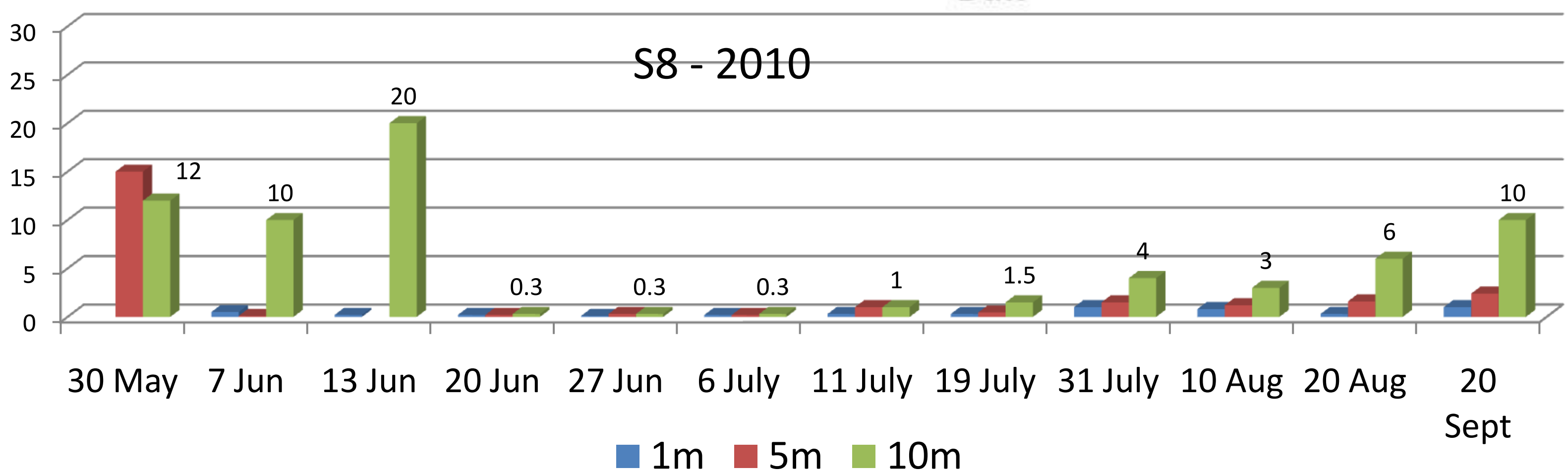


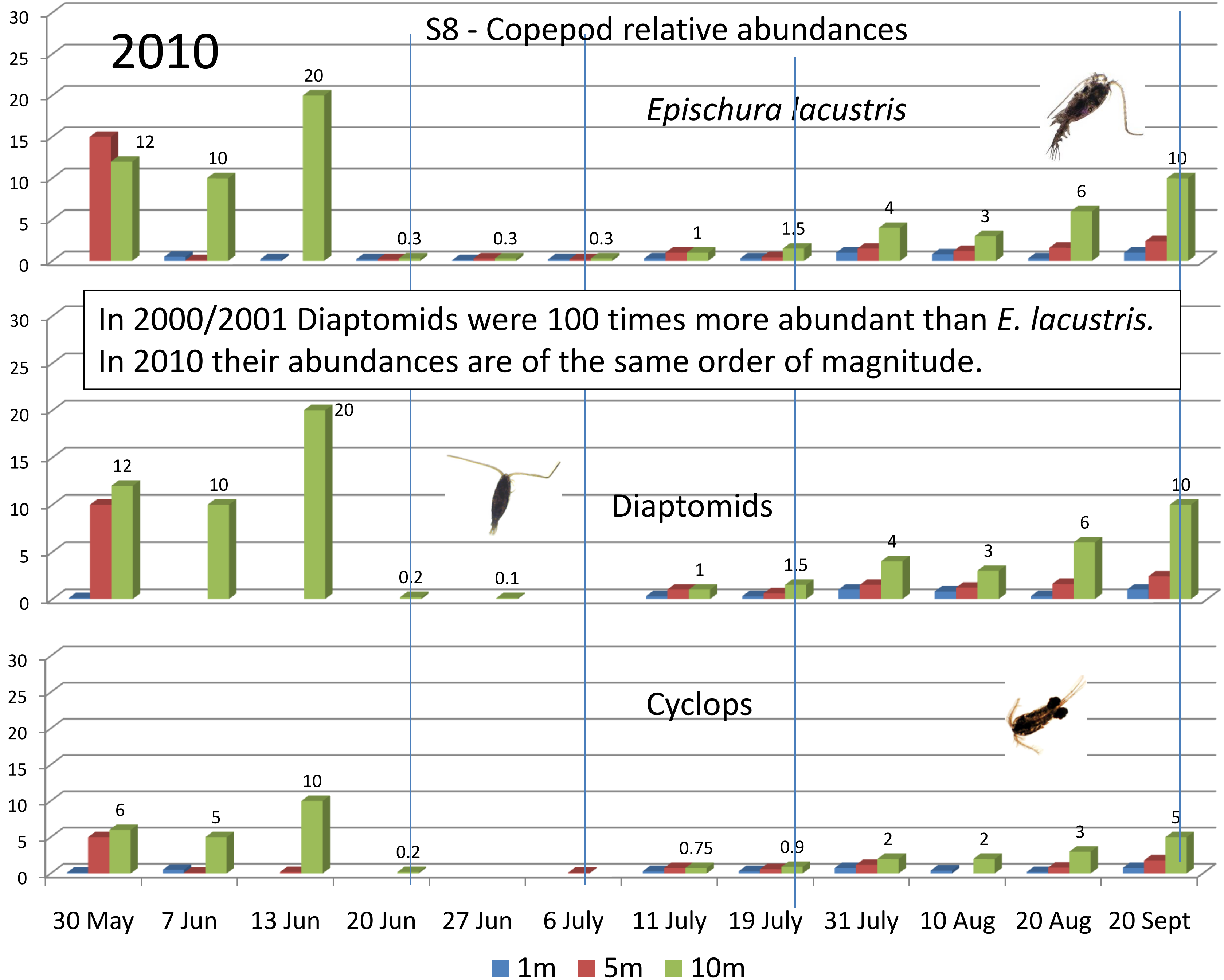
S8 - *Epischura lacustris*

Bythotrephes almost eliminated *E. lacustris* from S8 by the end of June. The collapse of *Bythotrephes* come July allows some recovery which correlates positively with depth.



Relative scale




2010
S8 - Copepod relative abundances
Epischura lacustris
12
10
20
0.3
0.3
0.3
1
1.5
4
3
6
10
In 2000/2001 Diaptomids were 100 times more abundant than E. lacustris.
In 2010 their abundances are of the same order of magnitude.
Diaptomids
12
10
20
0.2
0.1
1
1.5
4
3
6
10
Cyclops
6
5
10
0.2
0.75
0.9
2
2
3
5
30 May
7 Jun
13 Jun
20 Jun
27 Jun
6 July
11 July
19 July
31 July
10 Aug
20 Aug
20 Sept
1m
5m
10m

S8 – Changes in Copepod abundances since 2000/2001

Dipatomids have not faired well with the introduction of *Bythotrephes*. In 2000/2001 *Diaptomid* average abundances oscillated between 15000 and 30000 an./m3 throughout most of the summer. In 2010 *Diaptomids* were present in moderate amounts in early June, then all but disappeared from the collections come the 20th of June. They do not appear in the samples at all in early July. Once *Bythotrephes* collapses, *Diaptomids* begin a very slow recovery with abundances correlating postively with depth. In 2000/2001 the most common species was *Skistodiaptomus oregonensis* with a sporadic encounter of *Leptodiaptomus minutus*. From that perspective, things have remained the same in 2010, albeit at much reduced abundances overall.

Cyclops, back in 2000/2001, were the second most abundant Copepod taxon, with average summer abundances of 10000 an./m3. The impact of the introduction of *Bythotrephes* on *Cyclops* is similar to the impact seen on the *Diaptomids.* In 2000/2001, the most common Copepod species encountered was *Diacyclops bicuspidatus thomasi* in all of Lake Nipissing. *Mesocyclops edax*, was encountered with much less frequency in 2000/2001. In 2010, these two species have changed places, with *M. edax* now being ubiquitous and *D. B. thomasi*, being collected sporadically in small numbers.

S8 – Changes in Copepod abundances since 2000/2001 . . .

In 2000/2001 *Diaptomids* were 100 times more abundant than *E. lacustris.*
In 2010 their abundances are of the same order of magnitude, albeit at much reduced abundance levels. *E. lacustris* is a considerably larger copepod than either of the other two *Diaptomid* species found in Lake Nipissing, and this may give it an advantage in defending itself from *Bythotrephes*. By the end of June 2010, *E. lacustris* is the most abundant copepod at S8, albeit at very low abundances.

Taken together these changes imply a major ecosystem-wide impact on the food-web which may have a ripple effect higher up the food web that may interfere with the historical feeding habits of predatory species that used to rely on this very abundant, ubiquitous food source. In particularly, historically the bulk of these copepods were herbivores. Curiously their disappearance to trace levels did not lead to algal blooms in Lake Nipissing during the summer of 2010.

Bythotrephes

CLADOCERA

Date 2010	D (m)	an/m3	zoo	DGM	Bos	Diaph	Lepto	Holo	Cono	Geo
30-May	1	23	0.1	2	0	0	0	4	0	0
30-May	5	3	5	5	1	0	0	2	0	0
30-May	10	1	6	5	2	0	0	2	0	0
7-Jun	1	7	0.5	4	0	0	0	4	4	0
7-Jun	5	291	0.1	4	1	0	0	3	4	0
7-Jun	10	11	5	5	2	0	0	2	0	0
13-Jun	1	75	0.1	3	0	0	0	3	4	2
13-Jun	5	13	0.2	3	0	0	0	3	4	0
13-Jun	10	30	5	5	0	0	0	1	0	0
20-Jun	1	53	0.1	1	0	0	0	4	1	0
20-Jun	5	140	0.1	2	1	0	0	3	2	0
20-Jun	10	55	0.1	2	1	0	0	1	2	0
27-Jun	1	230	0.1	0	0	0	0	1	1	0
27-Jun	5	73	0.1	0	0	0	0	3	3	0
27-Jun	10	36	0.1	0	0	0	0	2	3	0
6-Jul	1	110	0.1	2	0	0	0	0	1	0
6-Jul	5	5	0.1	1	0	0	0	1	2	0
6-Jul	10	11	0.1	2	1	0	0	1	1	1
11-Jul	1	4	0.1	1	2	3	0	1	2	3
11-Jul	5	22	0.25	1	3	2	0	0	2	2
11-Jul	10	5	0.25	0	0	0	0	0	1	0
19-Jul	1	2	0.1	0	4	4	4	0	2	3
19-Jul	5	6	0.15	1	3	0	4	0	3	2
19-Jul	10	2	0.3	0	2	0	0	0	4	0
31-Jul	1	17	0.25	1	0	4	1	0	4	2
31-Jul	5	19	0.3	0	0	3	0	0	5	1
31-Jul	10	6	1	2	0	2	0	0	3	0
10-Aug	1	3	0.2	3	0	2	0	0	4	1
10-Aug	5	4	0.3	3	0	0	0	0	4	0
10-Aug	10	3	1	1	0	0	0	0	4	0
20-Aug	1	15	0.1	0	1	0	0	0	3	3
20-Aug	5	11	0.4	0	1	0	0	0	4	2
20-Aug	10	7	1.5	0	0	0	0	0	4	1
20-Sep	1	14	0.25	0	1	2	2	2	3	2
20-Sep	5	11	0.6	2	1	2	0	3	4	2
20-Sep	10	16	2.5	2	1	1	0	2	3	2

Cladocera chart

Abbreviations used:

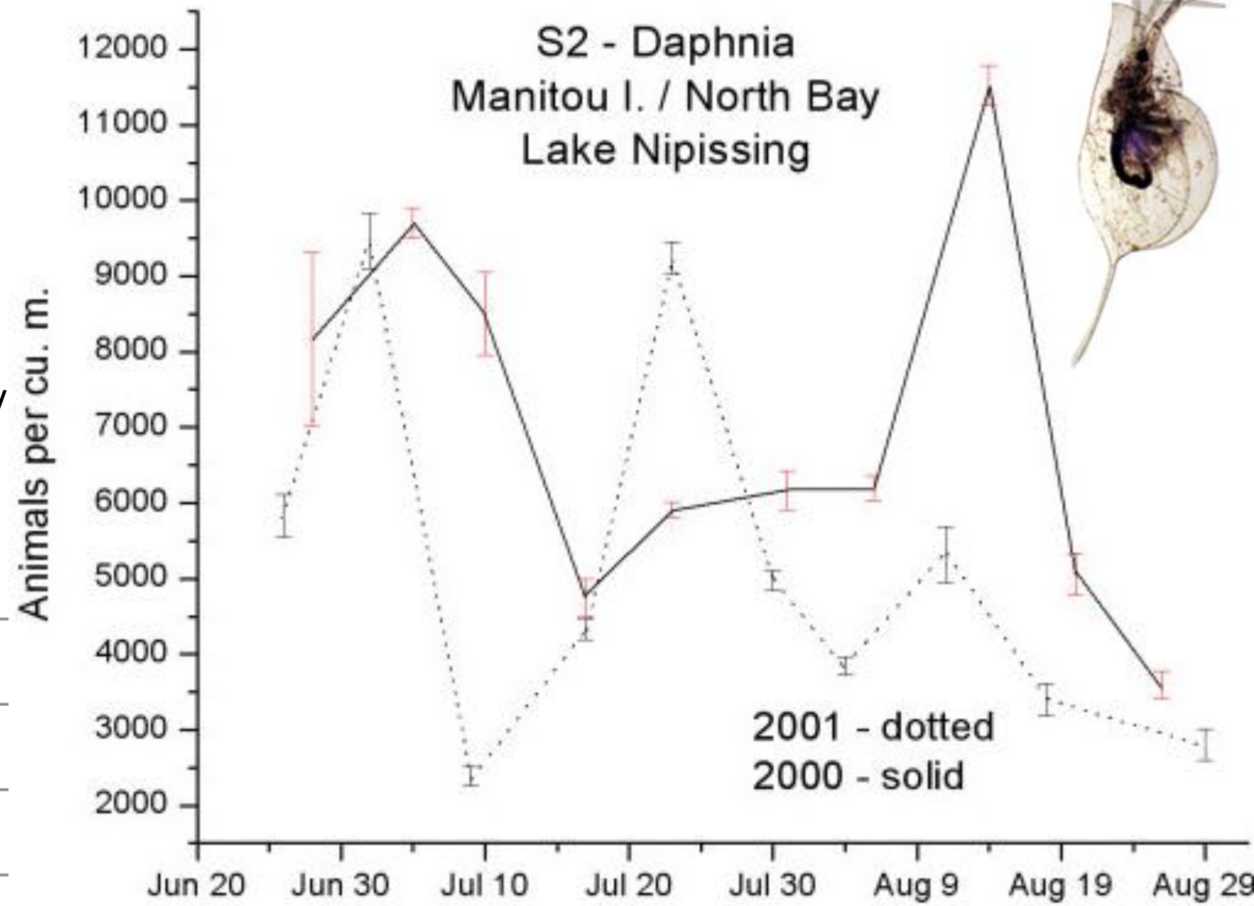
zoo = volume ranking score
DGM = *Daphnia galeata mendotae*
Bos = *Bosmina sp.*
Diaph = *Diaphanasoma birgei*
Lepto = *Leptodora kindtii*
Holo = *Holopedium gibberum*
Cono = *Conochilus unicornis*
Geo = *Geotrichia*

Legend: * species positively identified in sample
- species may be present, but not positively identified

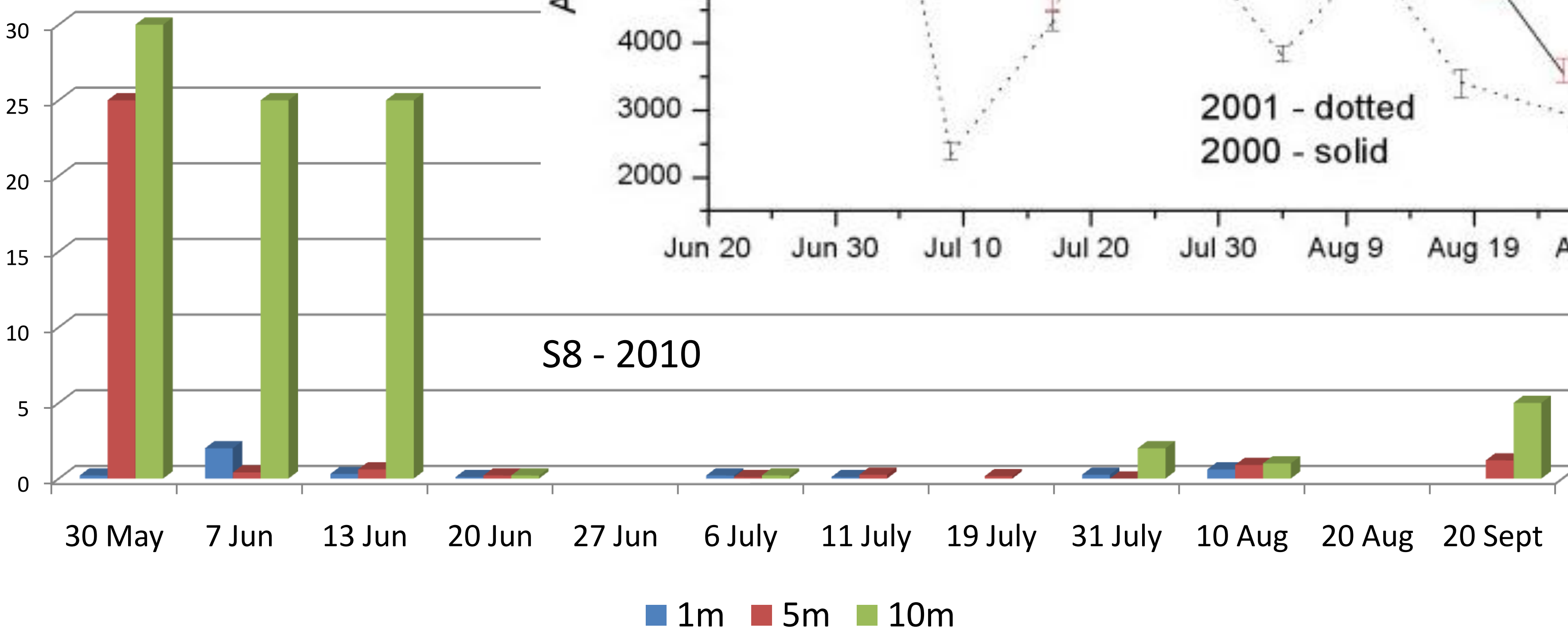
Note: lack of positive identification may be due to scarcity of animals in sample, or due to lack of animals in appropriate life stage

S8 - *Daphnia*

Very abundant in May to early June, by the 20th of June 2010 *Bythotrephes* had driven *Daphnia* at S8 to trace amounts. Very small remnant populations continue to exist from July to Sept. 20th. The collapse of *Bythotrephes* come July does lead to much *Daphnia* recovery.



Relative scale



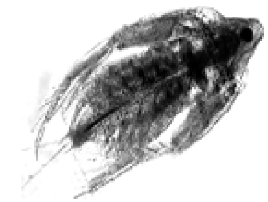
S8 – Changes in Cladocera abundances since 2000/2001

Daphnia have not faired well with the introduction of *Bythotrephes*.

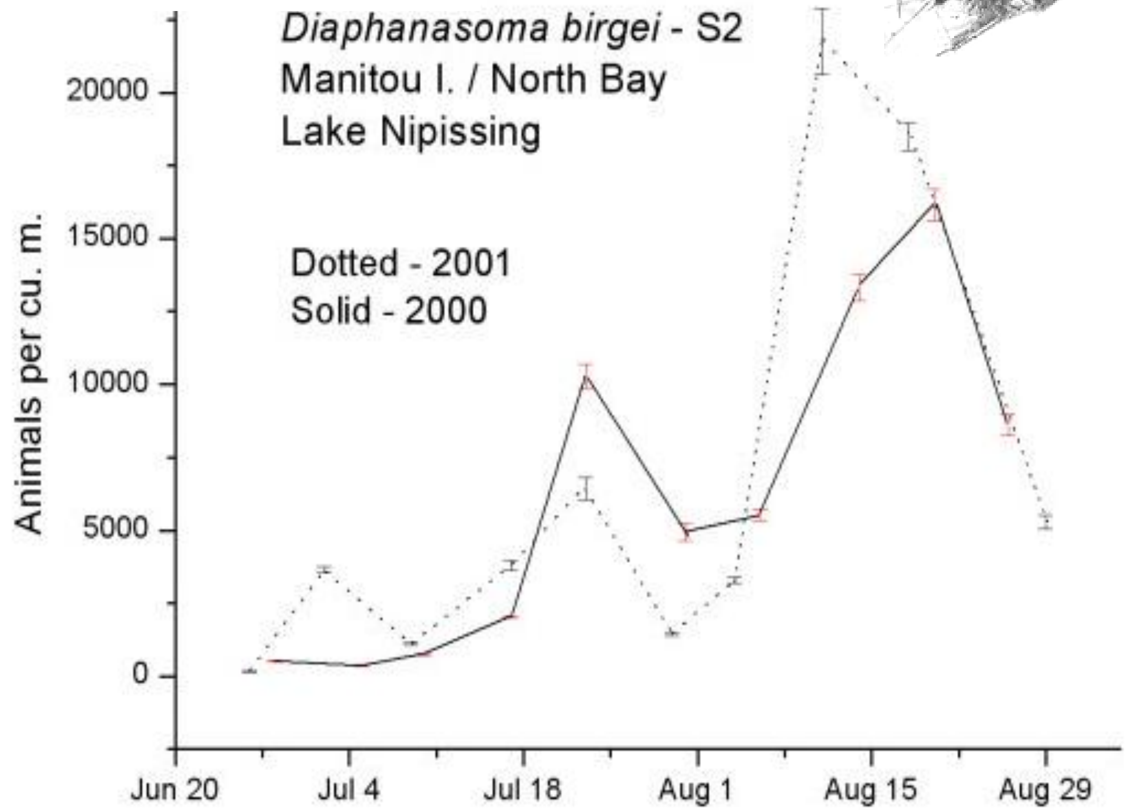
Daphnia
In 2000/2001 *Daphnia* average abundances averaged around 6000 an./m3 throughout most of the summer. In 2010 *Daphnia* at S8 were very abundant in May to early June particularly in the 10 m stratum (all *D.G. mendotae)*. By the 20th of June *Bythotrephes* had driven *Daphnia* at S8 to trace amounts. Very small remnant populations continue to exist from July to Sept. 20th. The collapse of *Bythotrephes* come July does not lead to much *Daphnia* recovery.

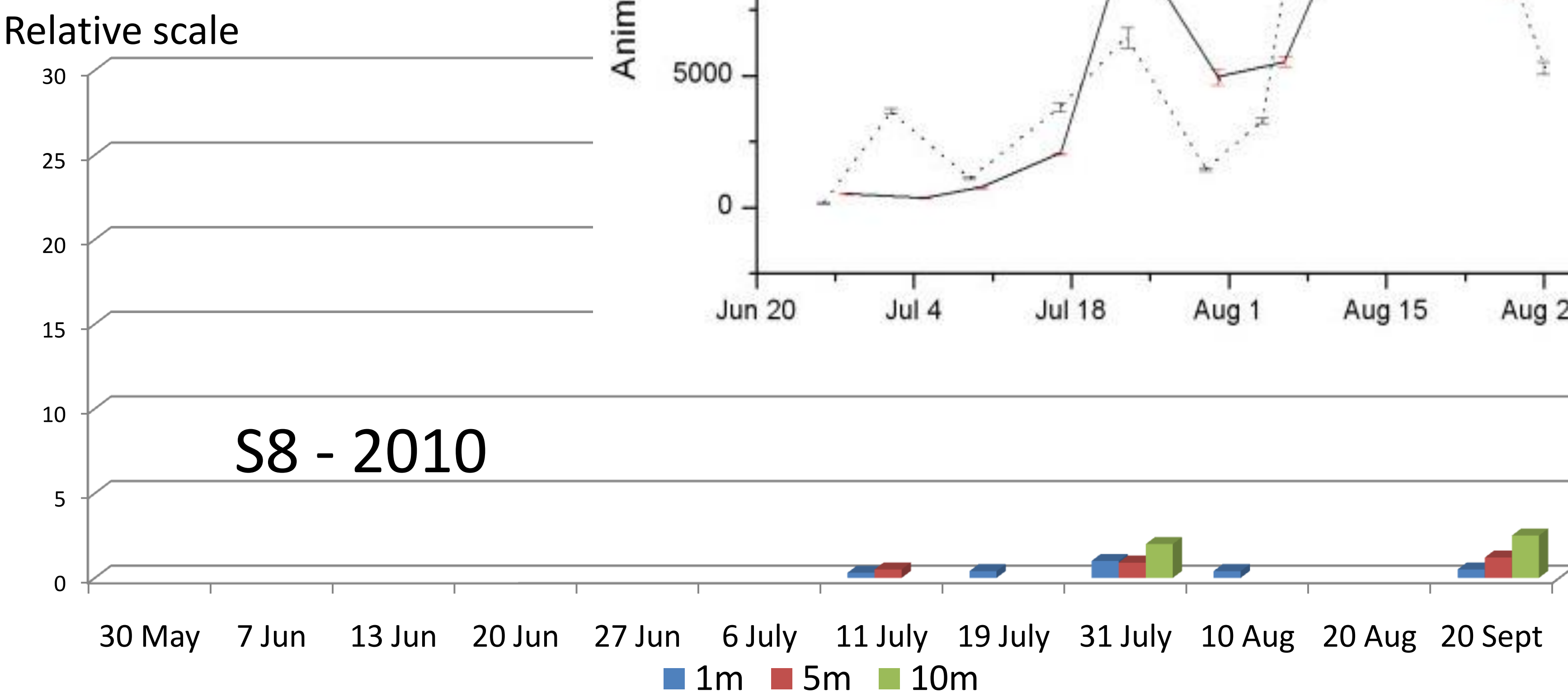
Whereas in 2000/2001 nearly all *Daphnia* collected were of the species *Daphnia retrocurva*, all *Daphnia* collected at S8 during the 2010 study were of the species *Daphnia galeata mendotae.* In fact, in all of the 2010 collections, only one *D. retrocurva* individual was identified (at S1 – Callander Bay). *D. retrocurva* may well be on its way to being extirpated from Lake Nipissing due to the introduction of *Bythotrephes.*

S8 – *Diaphanasoma birgei*



Very abundant in mid-August in 2000/2001, in 2010 *D. birgei* was either not collected at S8 in mid-August or collected in trace amounts. Overall it has become a trace species collected only sporadically.





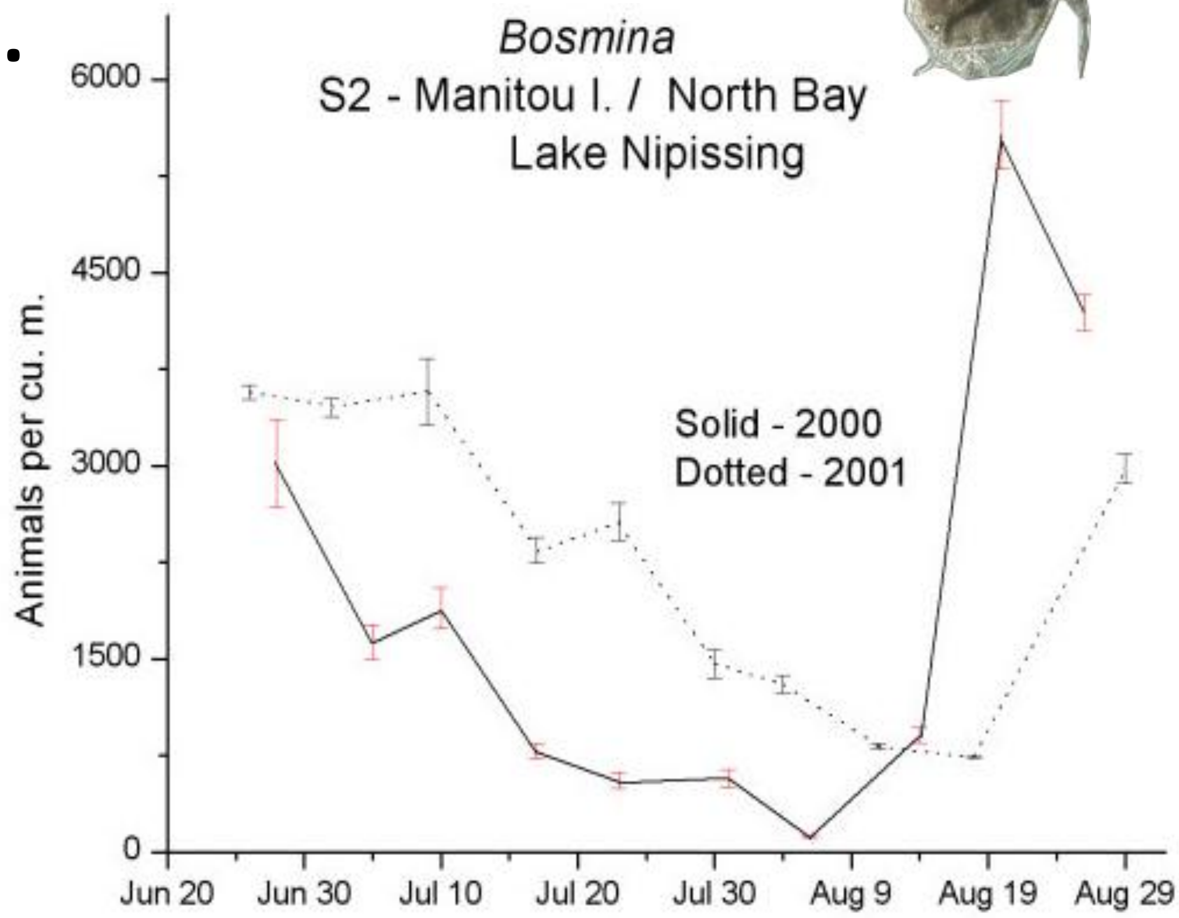
S8 – Changes in Cladocera abundances since 2000/2001

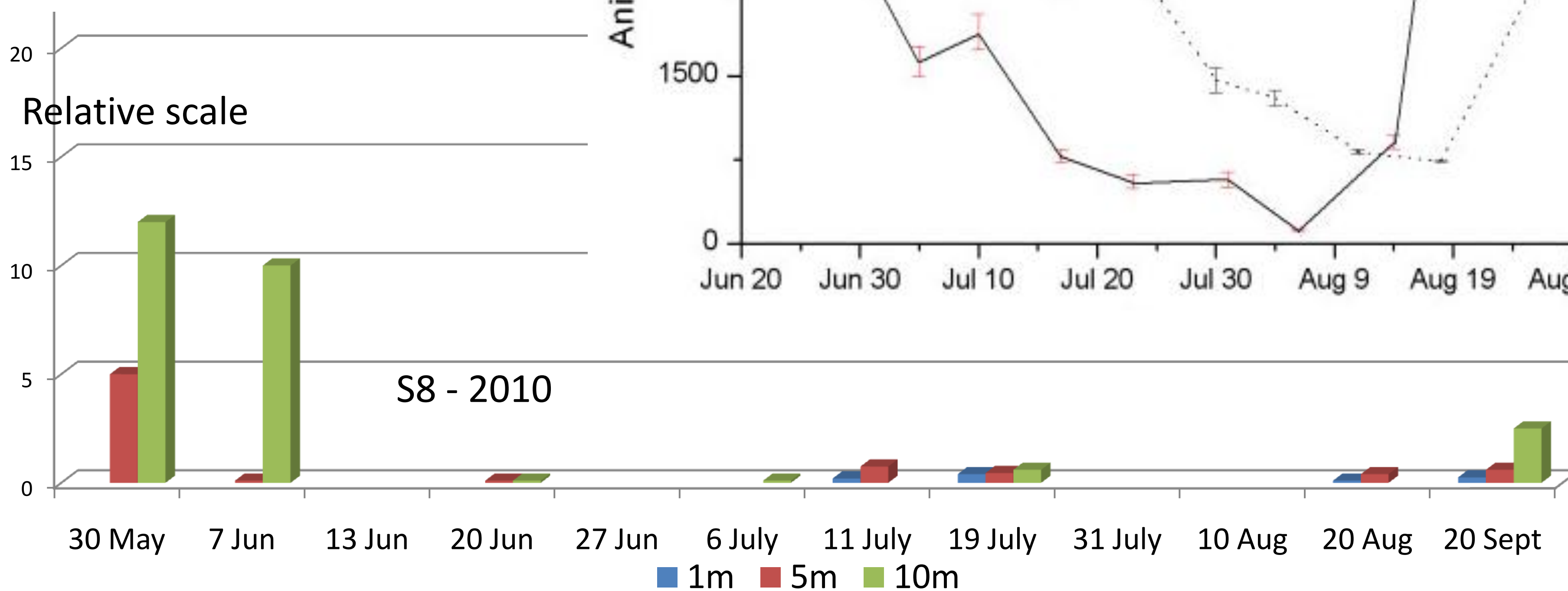
Diaphanasoma birgei

In 2000/2001 *D. Birgei* average abundances increased throughout the summer reaching 15000 an./m3 by mid-August. This made *D. Birgei* an important part of the mid to late summer zooplankton community back in 2000/2001. In 2010 *D. Birgei* at S8 only appears in trace amounts come mid-July, and from then on is only present in trace amounts for the rest of the summer. Given its small size, the loss of *D. birgei* may stress those predators that have evolved over time to target Cladocera of this size in mid-summer.

S8 – *Bosmina* spp.

Common in May 2010 to very early June, by mid-June *Bythotrephes* had eliminated *Bosmina* at S8. Trace populations continue to exist from then to Sept. 20th. The collapse of *Bythotrephes* come July does not make way for much *Bosmina* recovery. In 2000/2001 it was common throughout the summer.





S8 – Changes in Cladocera abundances since 2000/2001

***Bosmina* spp.**

For the purposes of this study, *Bosmina* and *Eubosmina* have been combined into the *Bosmina spp.* taxon.

In 2000/2001 *Bosmina* abundances displayed a distinctive U-shaped curve. Due its small size (approximately 0.5 mm in diameter), we hypothesize that the initial drop in abundance was caused by size-specific predation early-on during the summer by large populations of larval and juvenile fish (possibly perch and minnows). In one study, *Bosmina longirostris* was found to be present in 25% of all perch stomachs for perch up to 20 cm in total length (Stenson 1976). The expansion of the *Bosmina* population come August in Lake Nipissing in 2000/2001 is thought to be caused by predators switching to larger-sized prey as they reach a larger size as summer progresses. If this hypothesis is true, then *Bosmina* plays an important role in the larval / juvenile fish diet of Lake Nipissing.

S8 – Changes in Cladocera abundances since 2000/2001

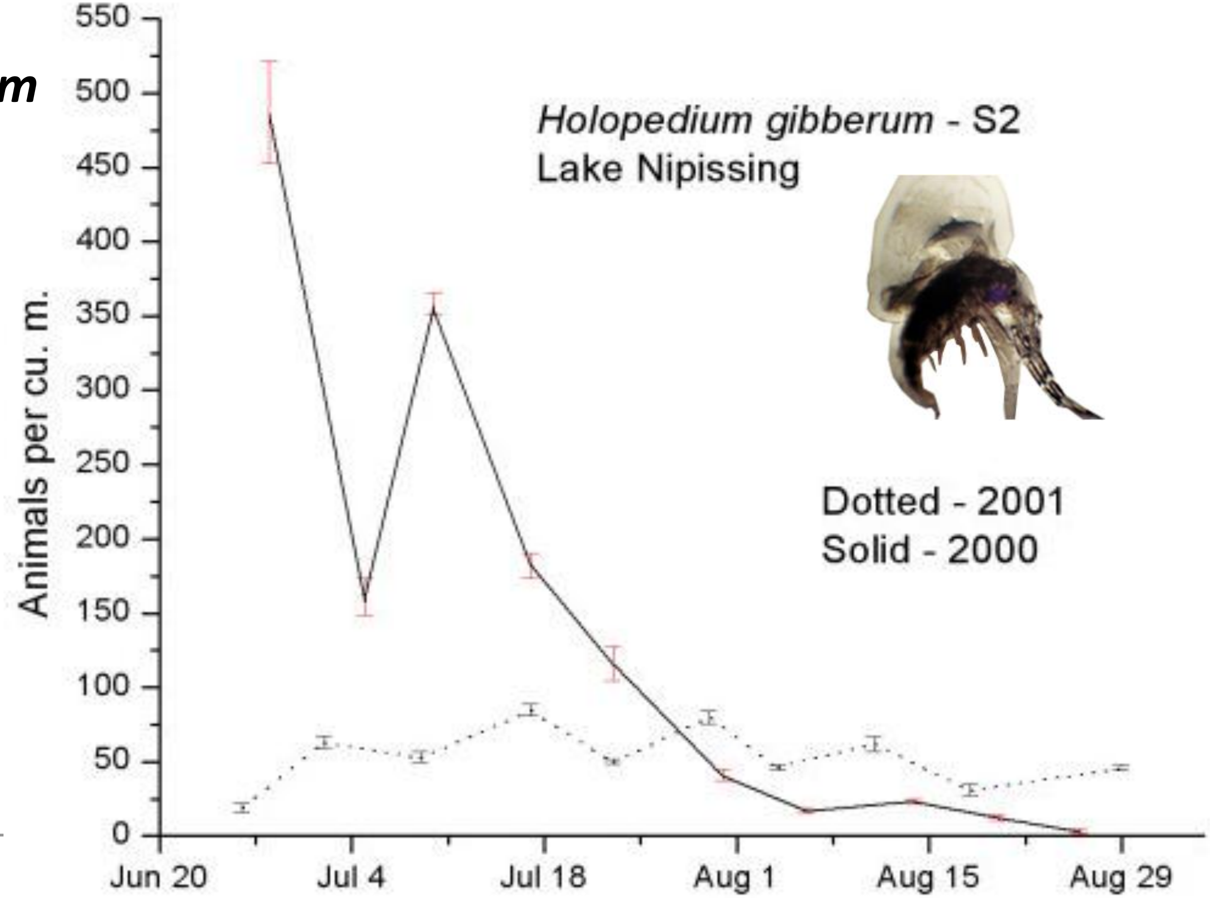
Bosmina spp. (page 2)

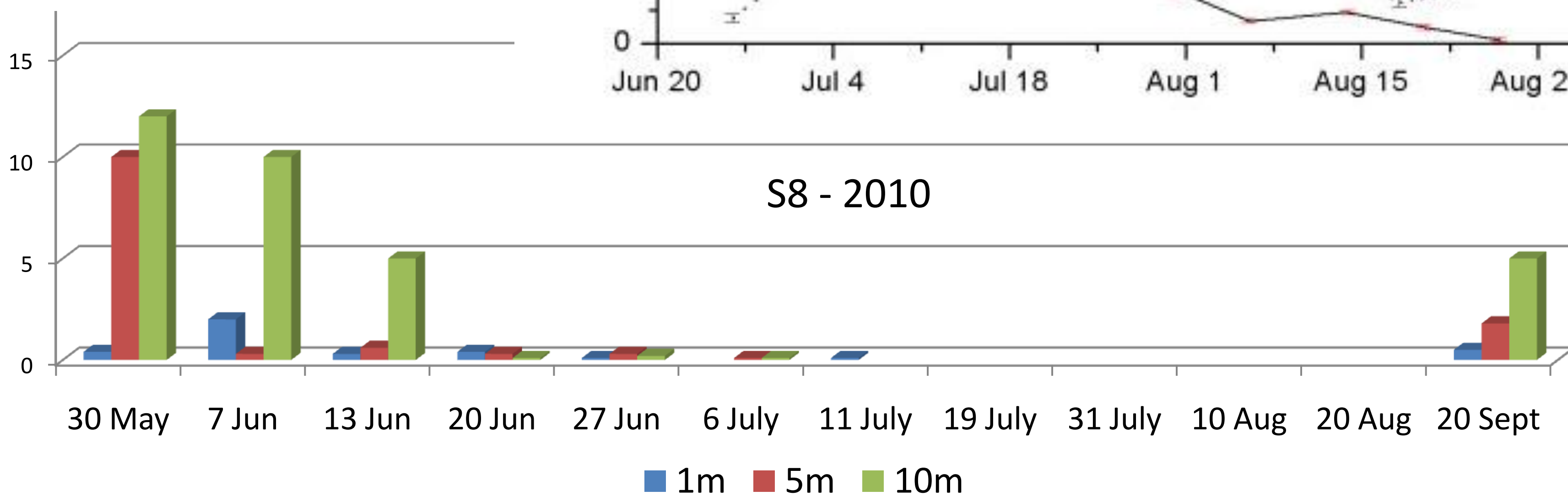
Common in May 2010 to very early June, by mid-June *Bythotrephes* had eliminated *Bosmina* at S8. Trace populations continue to exist from then to Sept. 20th. The collapse of *Bythotrephes* come July does not make way for much *Bosmina* recovery. In 2000/2001 it was common throughout the summer.

According to the *Bosmina* abundance curves of 2000/2001 larval / juvenile fish predation on *Bosmina* may continue to be important until the end of the first week in August where reported average abundances were in the 1000 to 3000 an./m3 range 10 years previous to this study. The loss of the *Bosmina* population from mid-June on (in 2010) could have a negative impact on larval / juvenile fish recruitment in Lake Nipissing.

S8 – *Holopedium gibberum*

In 2010 *H. gibberum* follows somewhat the same trend as in 2000/01 with decreasing abundances as summer progresses. The presence of *Bythotrephes* relegates *H. gibberum* to trace amounts earlier than in 2000/01 (by late June). It reappears in small amounts at depth in September.





S8 – Changes in Cladocera abundances since 2000/2001

Holopedium gibberum

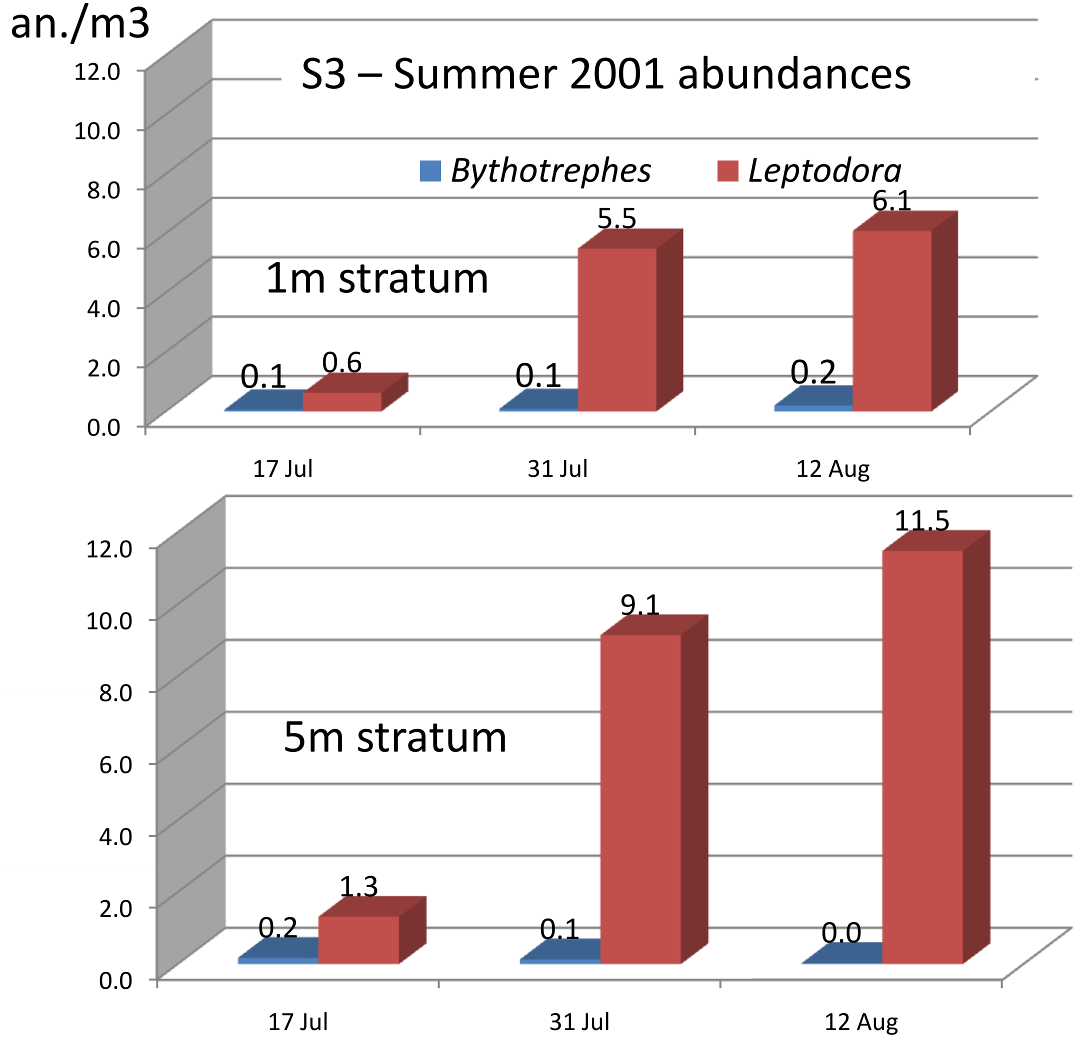
In 2010 *H. gibberum* abundance curves follow somewhat the same trend as in 2000/01 with decreasing abundances as summer progresses. In 2000/2001 *H. gibberum* was present in small to moderate amounts in the collections until the end of August. In 2010 the presence of *Bythotrephes* relegates *H. gibberum* to trace amounts by the middle of June. It disappears completely from the collections from mid-July to late August, reappearing in small amounts at depth in September.

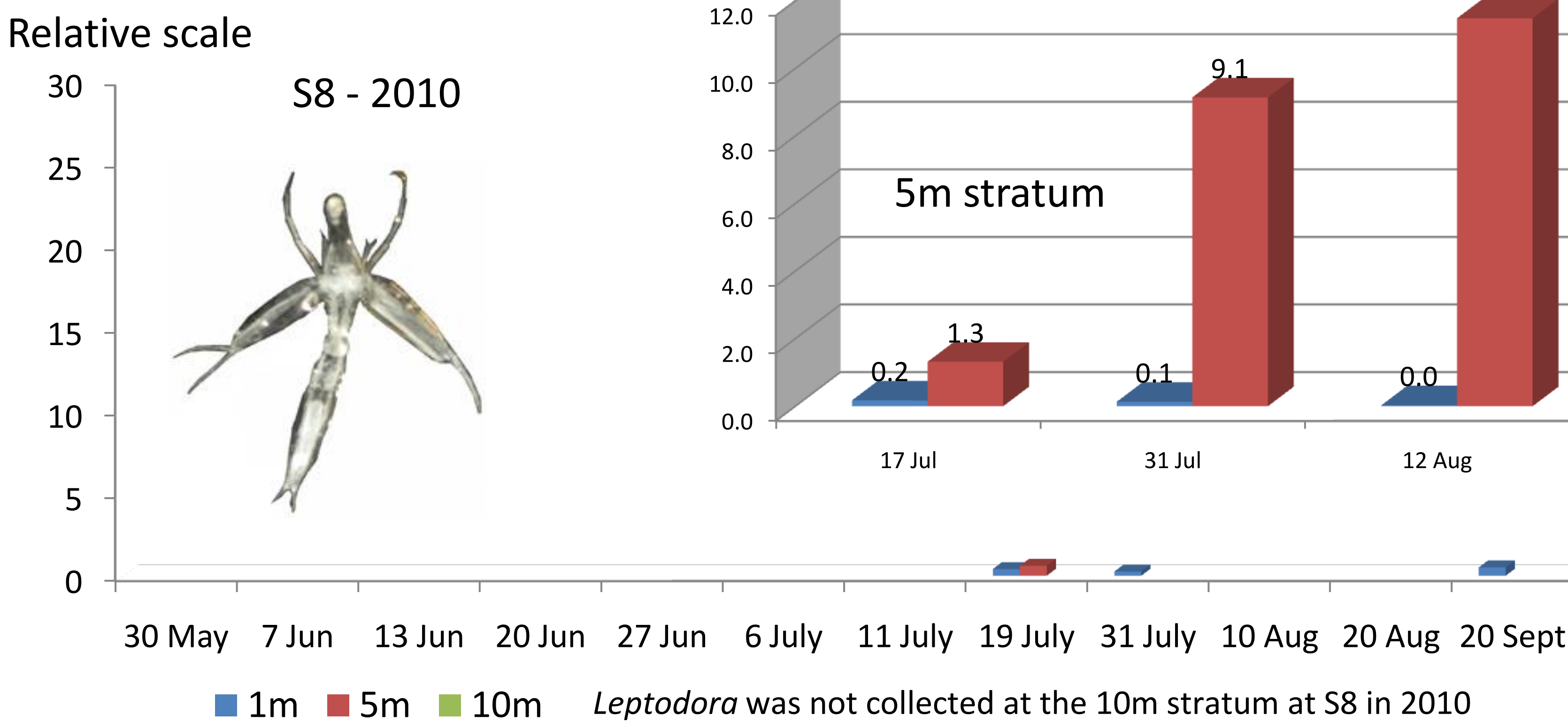
Lake Nipissing may not provide the best of habitat for this cladoceran.
"*H. gibberum* prefer mainly cool, oligotrophic, soft-water lakes with low pH (4.8-7.5) - Zooplankton of the Great Lakes, Central Michigan University, Internet Reference: http://www.cst.cmich.edu/users/mcnau1as/zooplankton%20web/holopedium /holopedium.html

Lake Nipissing is a mesotrophic lake with a pH that is neutral to slightly basic (Neary 1992).

S8 – *Leptodora kindtii*

In 2000/2001 *L. kindtii* was common in the collections. It has now been relegated to trace amounts, only collected subsequent to the collapse of the *Bythotrephes* population in 2010.





Leptodora was not collected at the 10m stratum at S8 in 2010

S8 – Changes in Cladocera abundances since 2000/2001

Leptodora kindtii

In 2000/2001 *Leptodora* was common in the collections with *Bythotrephes* only collected in trace amounts. In 2010, only 9 years later, *Leptodora* has been relegated to trace amounts, being collected sporadically beginning in mid-July subsequent to the collapse of the *Bythotrephes* population in late June.

This observation agrees with the results of a recent study:

"The abundance of the native, pelagic macroinvertebrate predator, *Leptodora kindtii,* is negatively correlated with the abundance of *Bythotrephes longimanus,* in a small number (166) of Canadian Shield lakes . . . We believe this is the first account of the widespread replacement of a native, pelagic macroinvertebrate predator by *Bythotrephes* in North America, and it does not bode well for *Leptodora* given the rapid, ongoing spread of *Bythotrephes*" - (Weisz/Yan 2010)

S8 – Changes in Cladocera abundances since 2000/2001

Leptodora kindtii (continued)

In his article "Food-Web Response to Species Invasion by a Predatory Invertebrate: **Bythotrephes** in Lake Michigan", Lehman writes:

"In addition to the loss of *D. retrocurva,* abundances of both *Daphnia pulicaria* and *Leptodora* declined in Lake Michigan after the invasion of *Bythotrephes* and have not recovered in the offshore regions of the lake. The loss of *Leptodora* is believed to have triggered further changes, including increased abundances of both *Conochilus and Bosmina*, which had been important prey items for *Leptodora (*Sandgren and Lehman 1990, Branstrator and Lehman 1991)"

In Lake Nipissing we have seen the severe decline of *Bosmina,* probably due to direct predation by *Bythotrephes.* We surmise that the predation that was taking place on *Bosmina* by *Leptodora* pales in comparison with the predation going on by *Bythotrephes.* We do note a large increase in *Conochilus* since 2001 however, and Lehman may have pinpointed one of the causes.

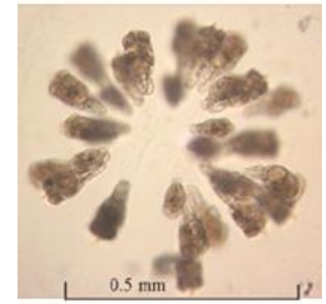
S8 – Changes in Cladocera abundances since 2000/2001

Decline in Biodiversity

Bythotrephes appeared in Harp Lake (Muskoka, Ontario) in 1993. The following changes in zooplankton community structure and biodiversity are reported (Yan 1997).
"Several small species either declined dramatically in abundance (e.g. *Bosmina longirostris*, *Tropocyclops extensus*) or disappeared (*Chydorus sphaericus*, *Diaphanosoma birgei*, *Bosmina* (*Neobosmina*) *tubicen*). In contrast the abundance of the larger cladocerans *Holopedium gibberum* and *Daphnia galeata mendotae* and the hypolimnetic copepod *Leptodiaptomus sicilis* increased."

In Lake Nipissing, *Bythotrephes* was first collected in 1998. It was found to exist in very low abundances in 2000/2001. By 2010 it had managed to turn the zooplankton community upside down. By the end of June 2010, all species of zooplankton, big and small, were driven to trace amounts to depths of 10m. *Chydorus sphaericus, Daphnia retrocurva, Ceriodaphnia* have pretty well disappeared from the collections. *Daphnia pulicaria* now is only collected at depth at S4, and in trace amounts at a few other sites. *Daphnia galeata mendotae,* collected sporadically in 2000/2001, is now the dominant *Daphnia.* It is abundant to 10 m in early June then is present only in trace amounts for the rest of the summer.

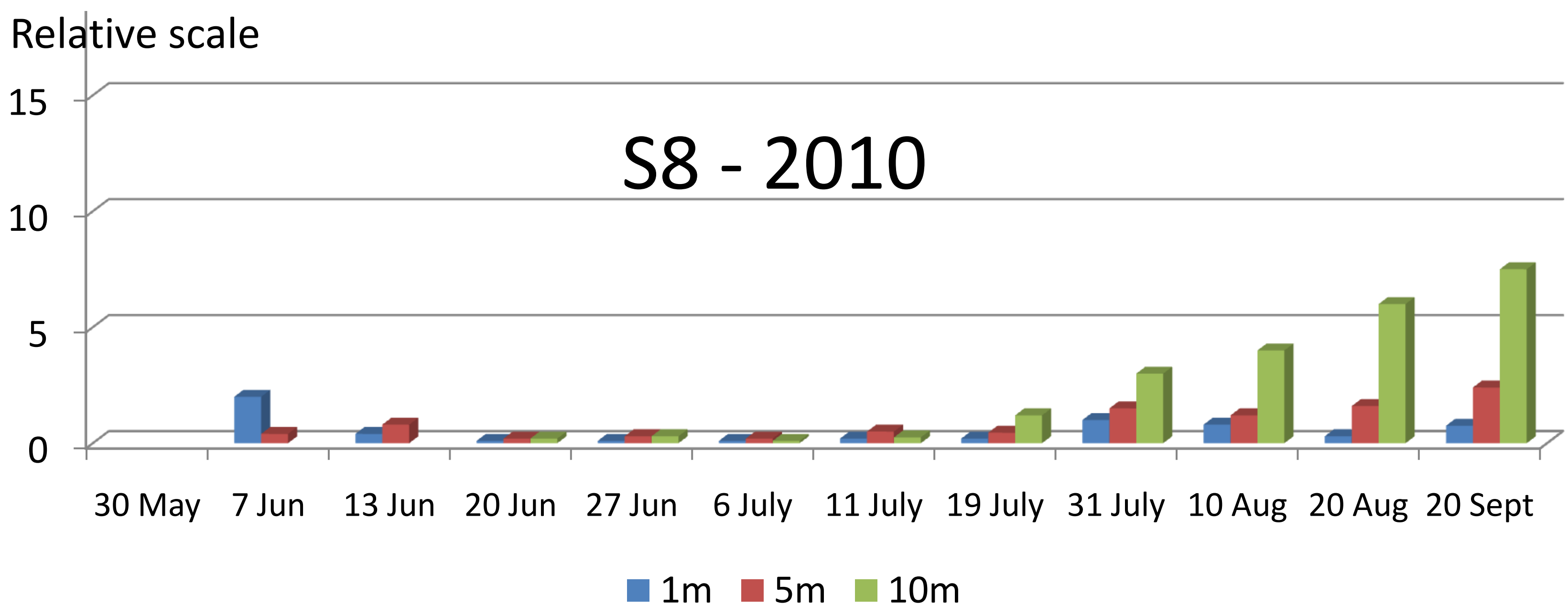
S8 – *Conochilus unicornis*



Conochilus unicornis, a colonial rotifer, was not collected in any appreciable amounts in 2000 /2001. It has become common in 2010, increasing in abundance as summer progresses. The importance of the appearance of this colonial rotifer must not be underestimated.

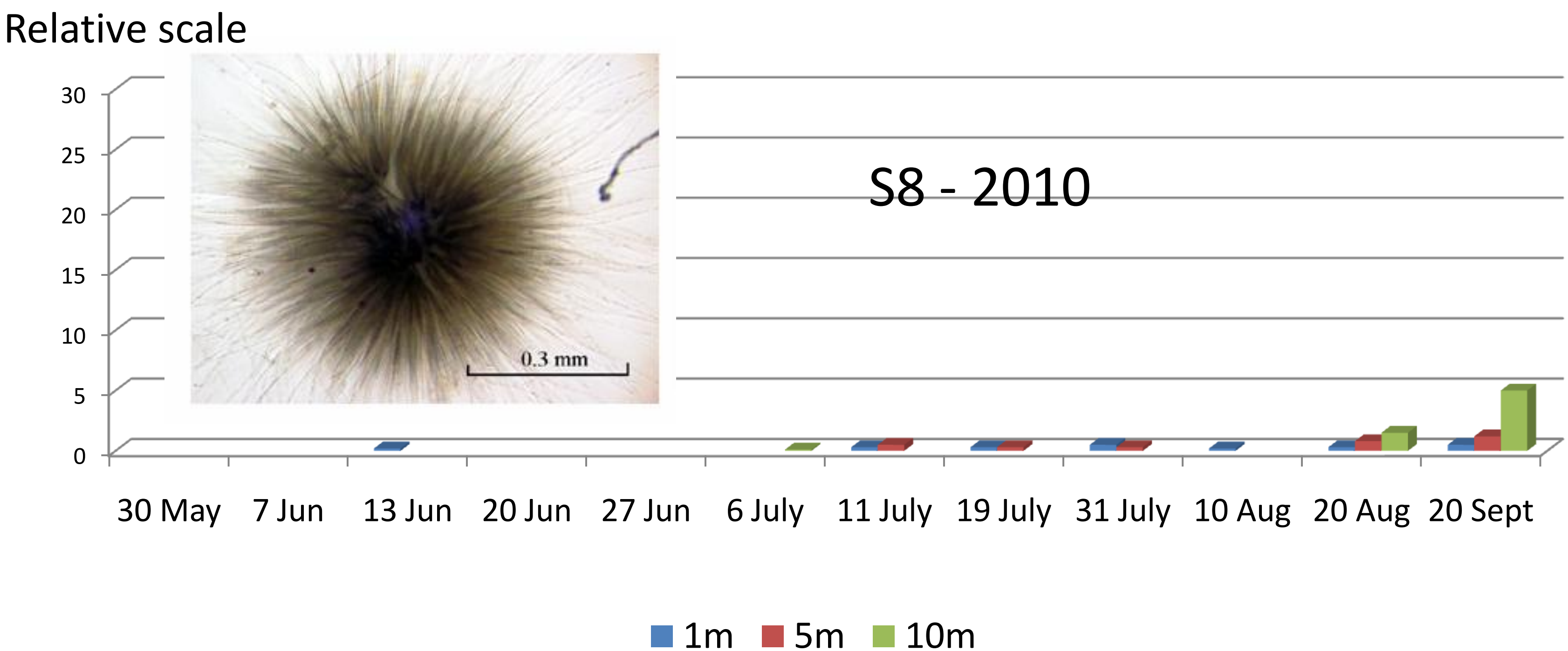
"*Grazing by C. unicornis was more important than grazing by crustaceans in the community, at least on particles ≤9µm*" – Hydrobiologia ISSN 0018-8158 CODEN HYDRB8 .

Conochilus may have a role to play in preventing algal blooms in Lake Nipissing. Harp Lake in Muskoka, Ontario also saw a rise in *Conochilus* subsequent to the introduction of *Bythotrephes* (Hovius et al 2007).



S8 – *Geotrichia*

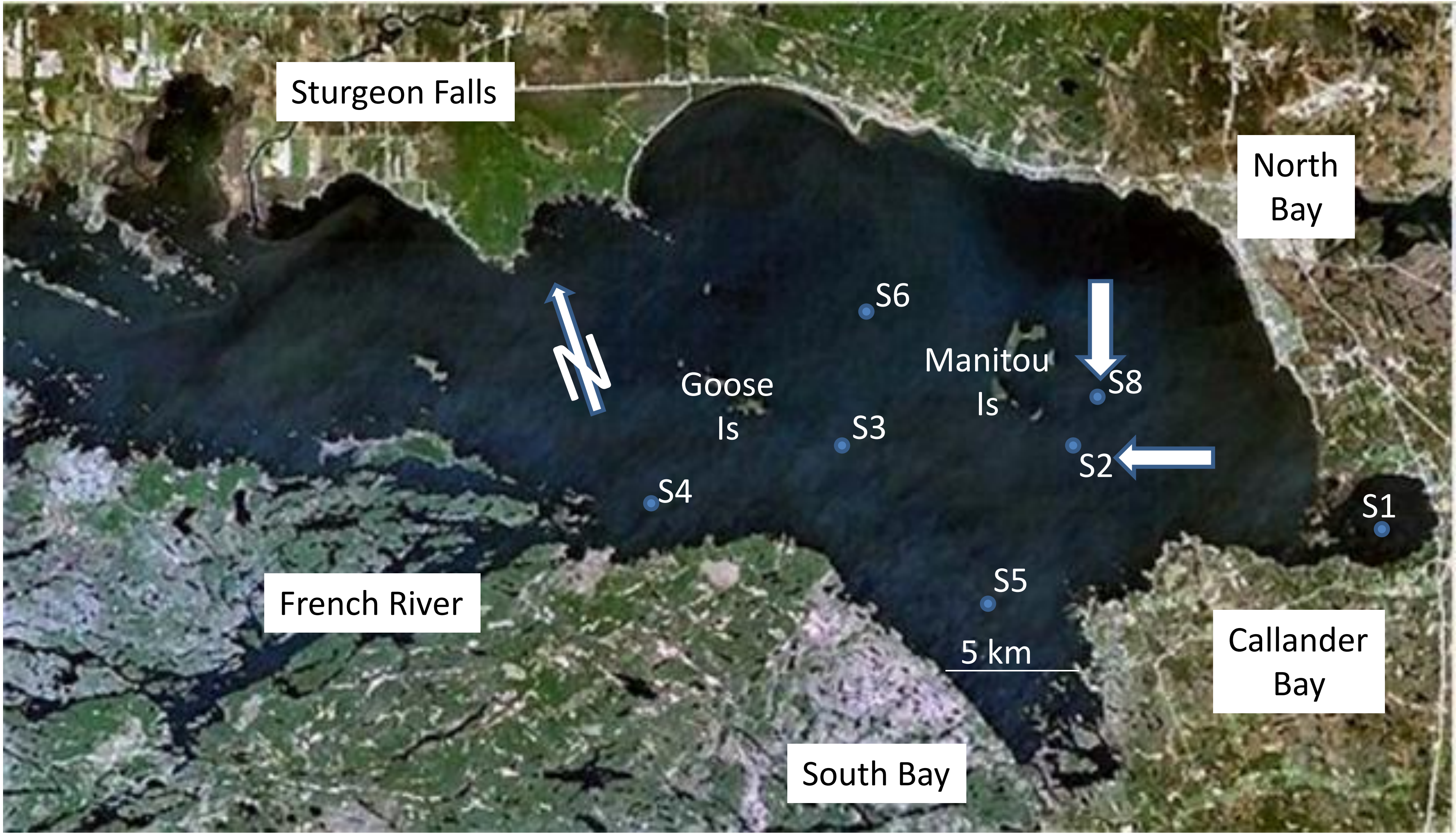
Geotrichia is a blue-green algae. It was responsible for a ‘bloom alert’ in the marina area of Callander Bay in the summer of 2010. *Geotrichia* may be taking advantage of the fact that much of the herbivorous zooplankton is cropped by *Bythotrephes* at S8 come late June. It becomes slightly more abundant as summer progresses. It was not commonly collected in 2000/01.



S8 / S2
Abundance comparisons

Station S2 was sampled five times during the summer of 2010 to determine if the observations from sampling station S8 could be extrapolated to the other sampling stations which were to only be sampled once. S2 is 15m deep whereas S8 is 12m deep. They are separated by a distance of 3 km.

2010 – Sampling Stations – Lake Nipissing



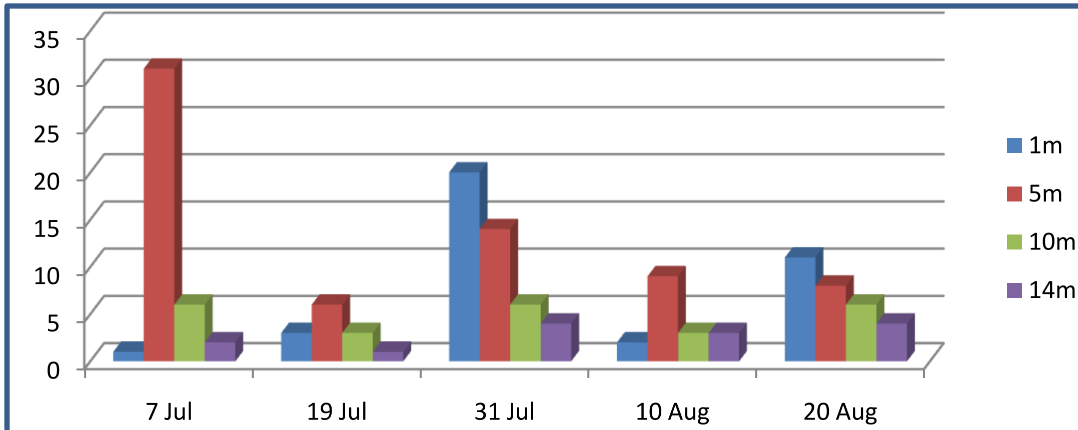
S2 / S8 *Bythotrephes* abundance comparisons

Bythotrephes abundances at both S8 and S2 appear to be ‘in-step’ with each other and of the same order of magnitude.

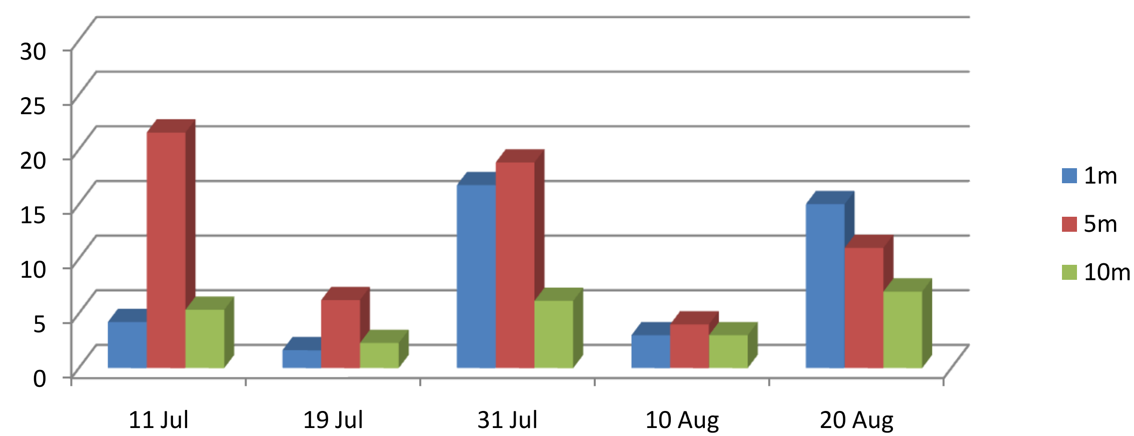
S2 is a little deeper than S8. It was sampled five times.

Note: The stations appear close to one another on the map but they are actually three km apart.

S2 - *Bythotrephes* abundance from July 11 to Aug. 20 , 2010



S8 - *Bythotrephes* abundance from July 11 to Aug. 20 , 2010



S2 -2010 – Zooplankton community specifics – SE of Manitou Islands

Copepods & others

Date	D (m)	zoo	Cono	Geo	Epi	Diap	Orego	Lmin	Cyc	Medax
7-Jul	1	0.05	0	2	2	2	-	-	0	-
7-Jul	5	0.05	0	2	4	3	x	-	0	-
7-Jul	10	0.05	0	0	4	3	-	-	0	-
7-Jul	14	0.3	0	0	4	4	x	-	0	-
19-Jul	1	0.1	2	4	4	3	-	-	2	x
19-Jul	5	0.1	3	4	4	4	x	-	4	x
19-Jul	10	0.25	0	1	4	4	x	-	3	x
19-Jul	14	2.5	0	0	4	4	x	-	2	x
31-Jul	1	1	4	2	2	3	x	-	2	x
31-Jul	5	1	3	1	3	3	x	-	2	x
31-Jul	10	0.1	3	0	3	3	x	-	2	x
31-Jul	14	2.5	3	0	4	4	x	-	2	x
10-Aug	1	0.4	4	3	3	3	x	-	3	x
10-Aug	5	2	4	1	3	3	x	-	2	x
10-Aug	10	0.6	4	1	3	3	x	-	2	x
10-Aug	14	1	2	0	4	4	x	-	0	-
20-Aug	1	0.2	4	3	2	2	x	-	2	x
20-Aug	5	0.8	4	3	3	3	x	x	3	x
20-Aug	10	0.3	4	3	2	2	x	-	2	x
20-Aug	14	0.2	3	2	2	2	x	-	2	x

Cono – *Conochilus unicornis*
Geo – *Geotrichia*

Epi – *Epischura lacustris*
Diap – *Diaptomus*
Orego – *Skistodiaptomus oregonensis*
Lmin – *Leptodiaptomus minutus*

Cyc – *Cyclops sp.*
Medax – *Mesocyclops edax*

S2 -2010 – Zooplankton community specifics – SE of Manitou Islands

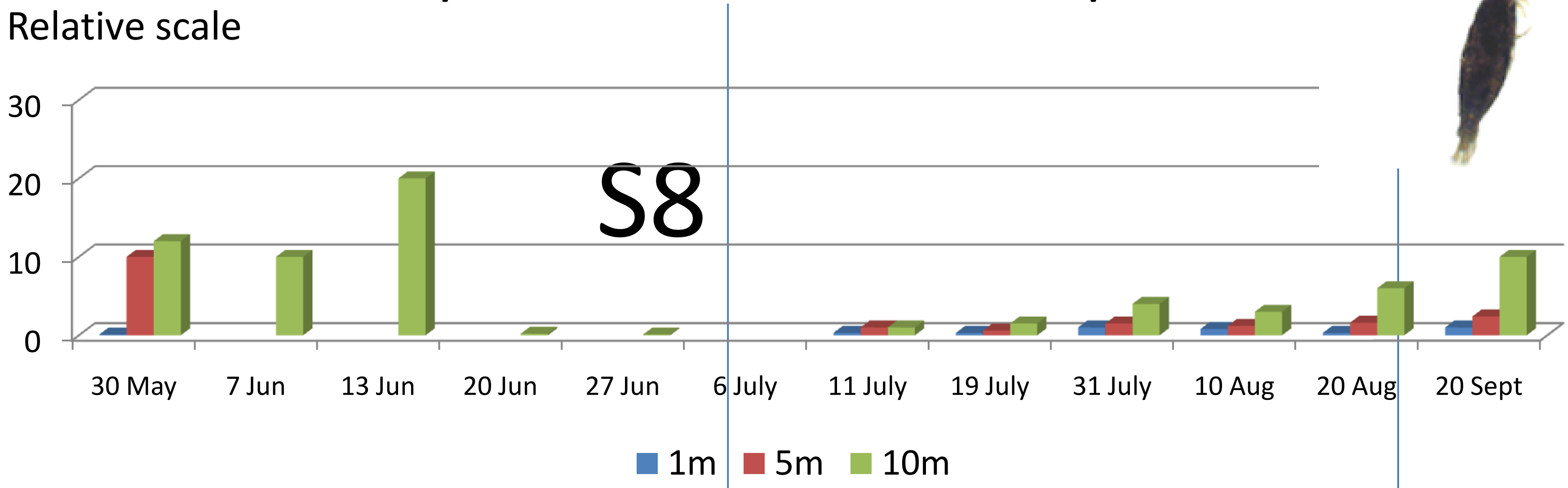
Cladocera

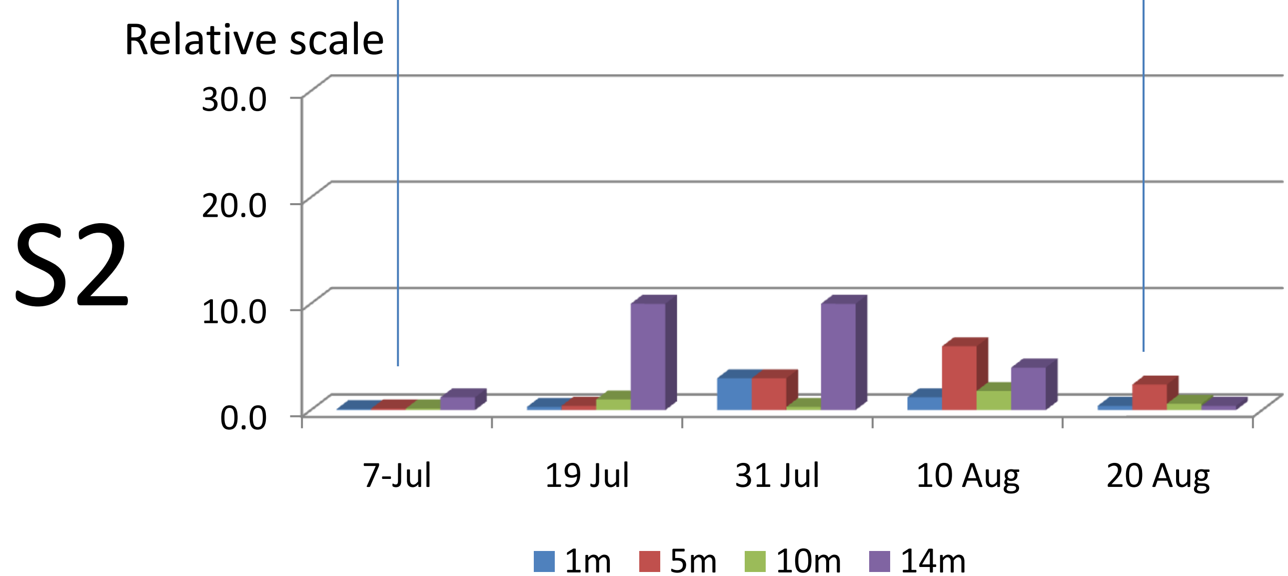
Date	D (m)	zoo	DGM	Bos	Lepto	Diaph	Lat	Sida
7-Jul	1	0.05	0	0	0	0	0	0
7-Jul	5	0.05	1	0	1	0	0	0
7-Jul	10	0.05	0	0	0	0	0	0
7-Jul	14	0.3	1	0	0	0	0	0
19-Jul	1	0.1	0	3	3	4	0	0
19-Jul	5	0.1	0	0	4	4	1	1
19-Jul	10	0.25	0	1	1	1	0	0
19-Jul	14	2.5	0	0	0	0	0	0
31-Jul	1	1	0	0	3	2	0	0
31-Jul	5	1	0	0	3	1	0	0
31-Jul	10	0.1	0	0	2	0	0	0
31-Jul	14	2.5	1	1	0	0	0	0
10-Aug	1	0.4	2	0	0	1	0	0
10-Aug	5	2	2	0	0	0	0	0
10-Aug	10	0.6	0	0	0	0	0	0
10-Aug	14	1	0	0	0	0	0	0
20-Aug	1	0.2	2	0	0	0	0	0
20-Aug	5	0.8	0	0	1	0	0	0
20-Aug	10	0.3	0	0	0	0	0	0
20-Aug	14	0.2	0	0	0	0	0	0

Daph – *Daphnia sp.*
DGM – *Daphnia galeata mendotae*
Bos – *Bosmina sp.*
Lepto – *Leptodora kindtii*

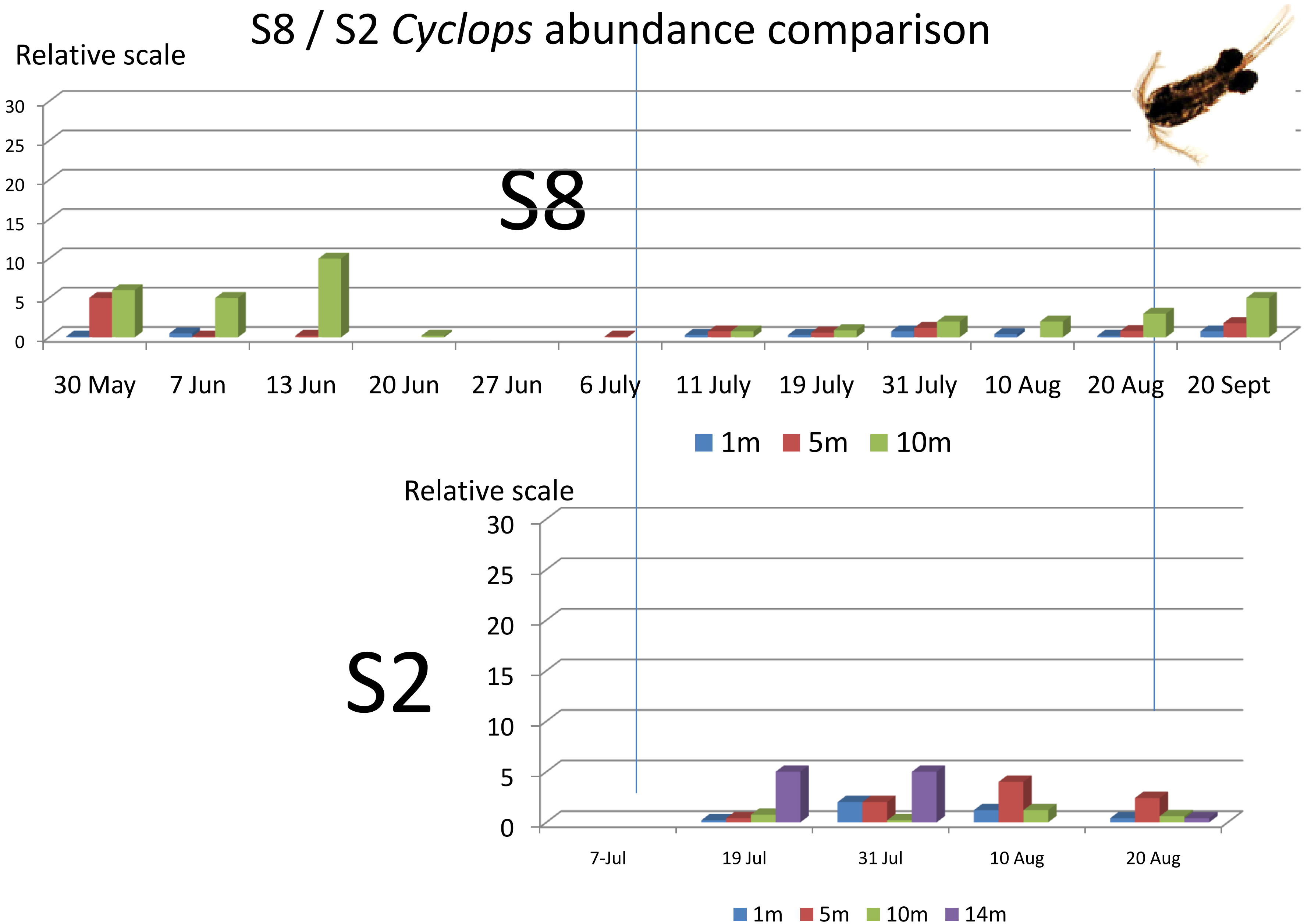
Diaph – *Diaphanasoma birgei*
Lat – *Latona setifera*
Sida – *Sida cristallina*

S8 / S2 *Diaptomid* abundance comparison

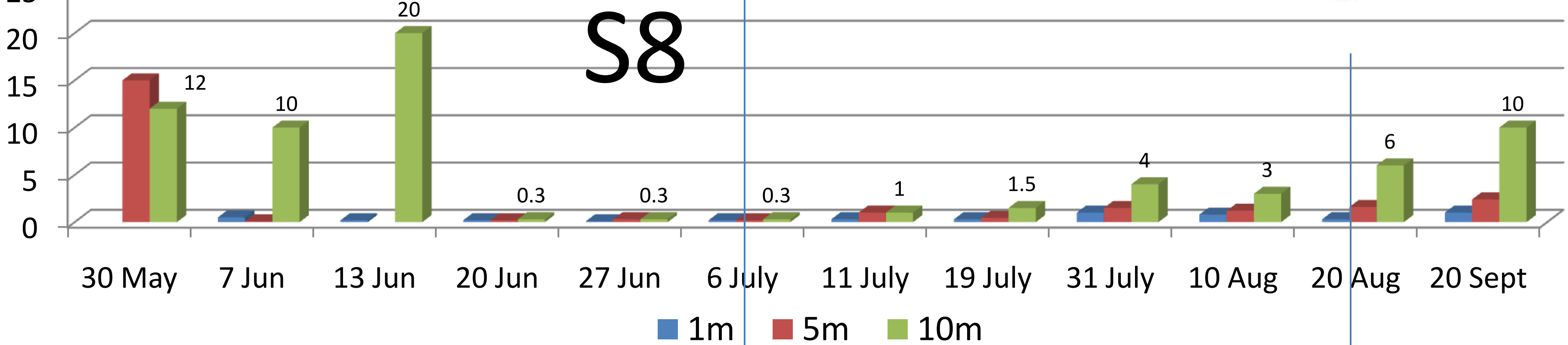


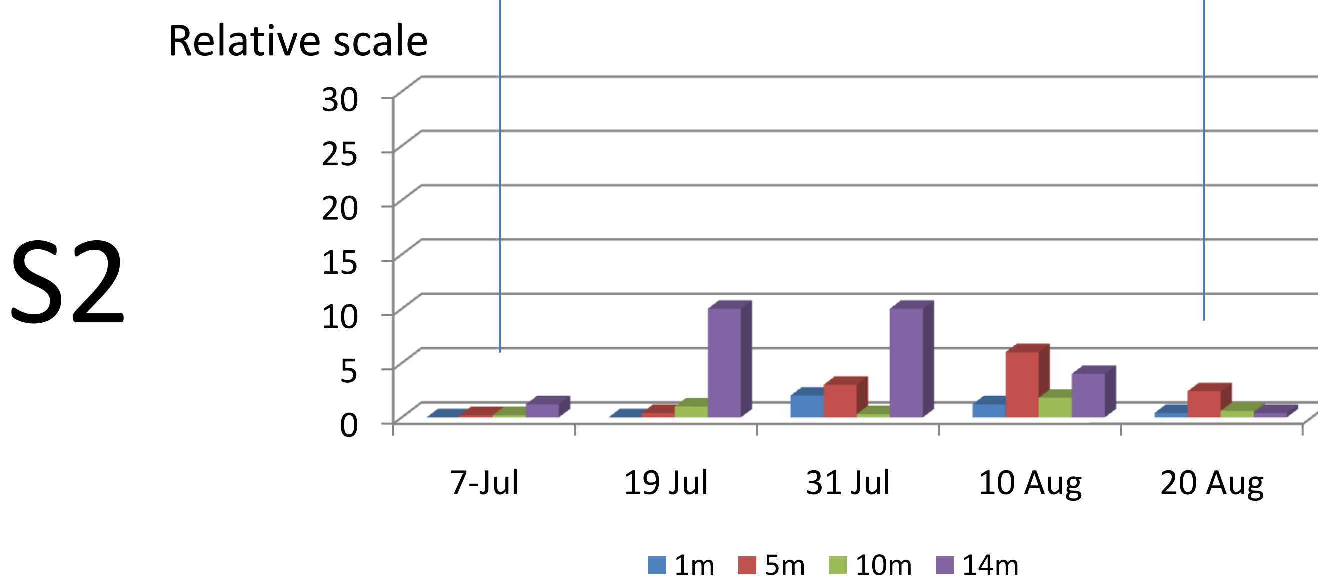


S8 / S2 *Cyclops* abundance comparison

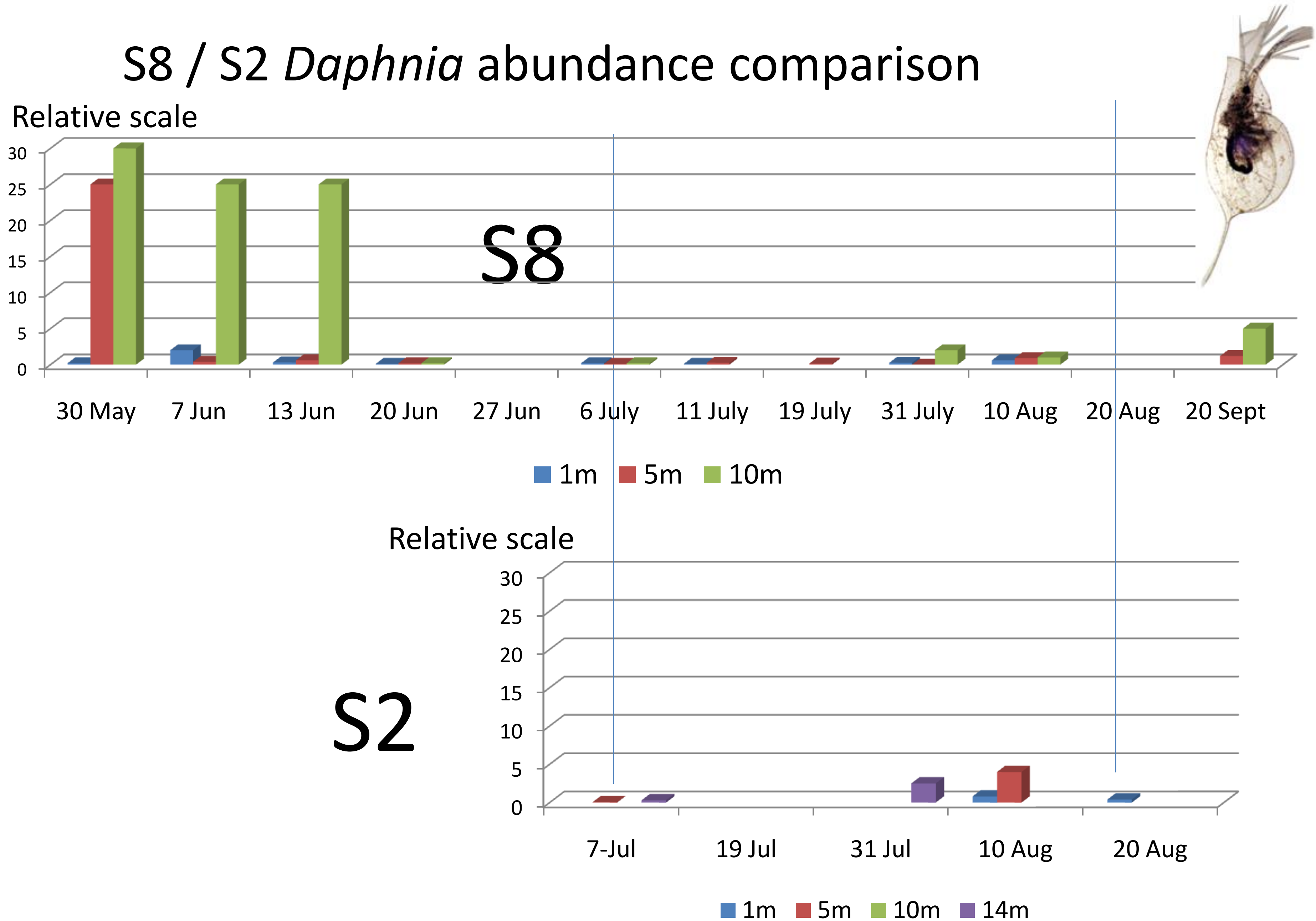


S8 / S2 *Epishcura lacustris* abundance comparison

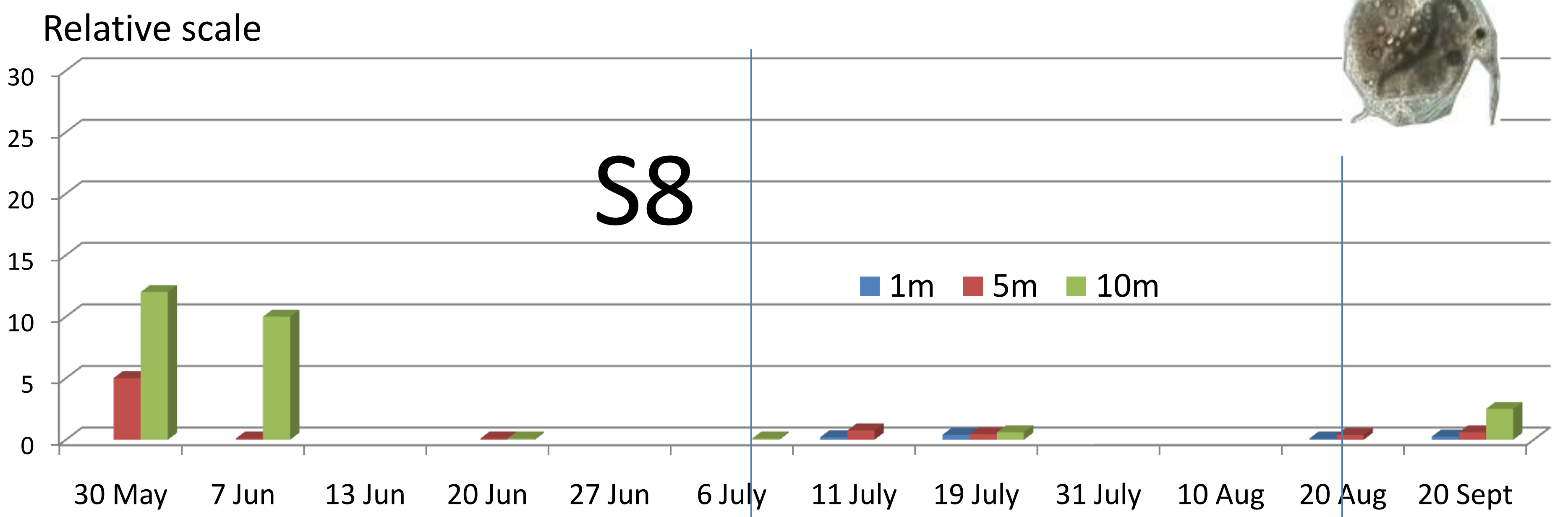


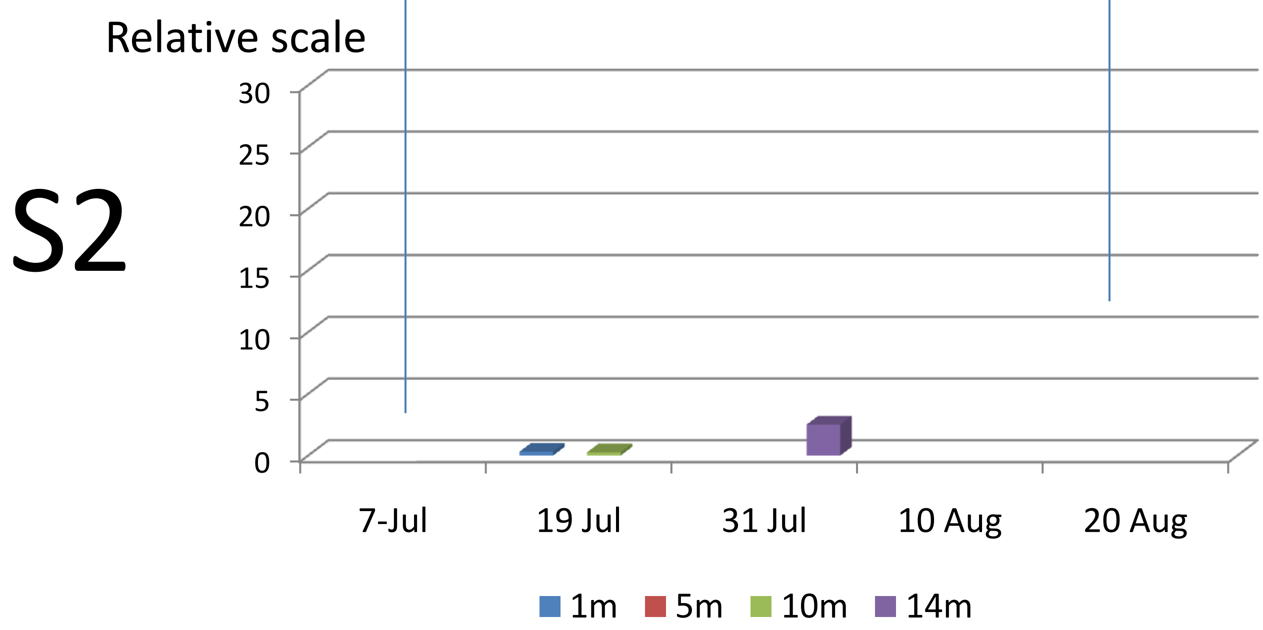


S8 / S2 *Daphnia* abundance comparison

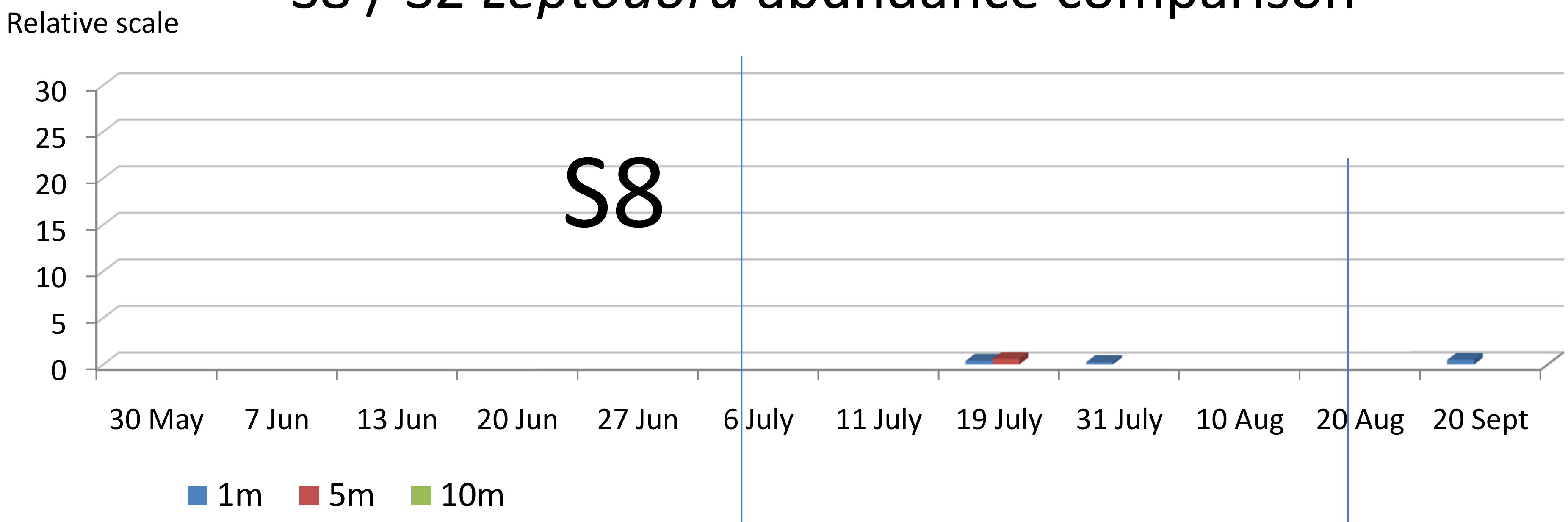


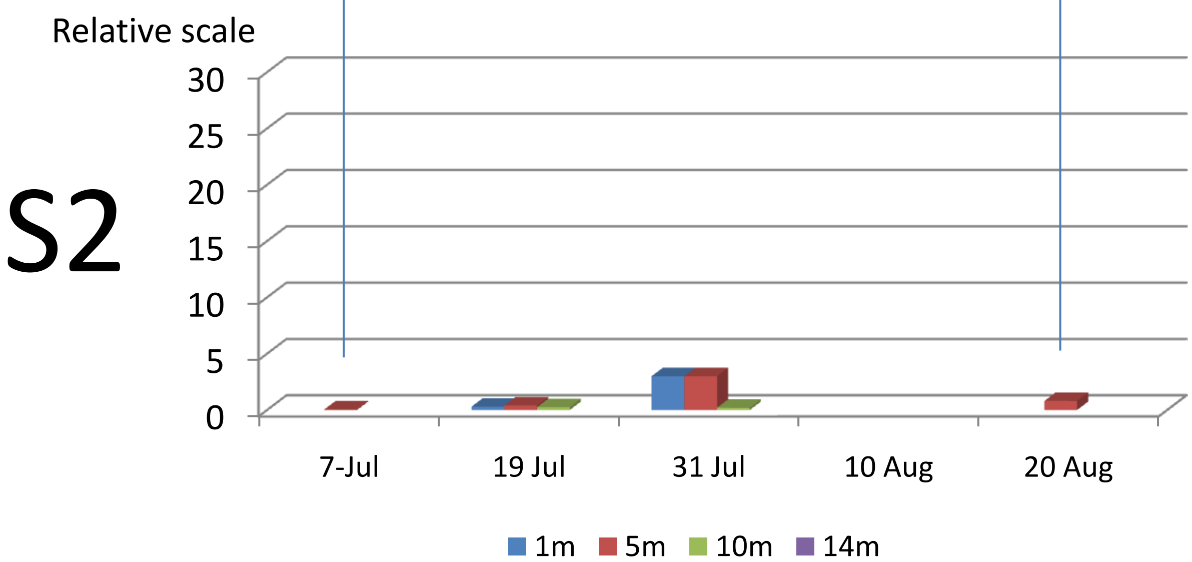
S8 / S2 *Bosmina* abundance comparison



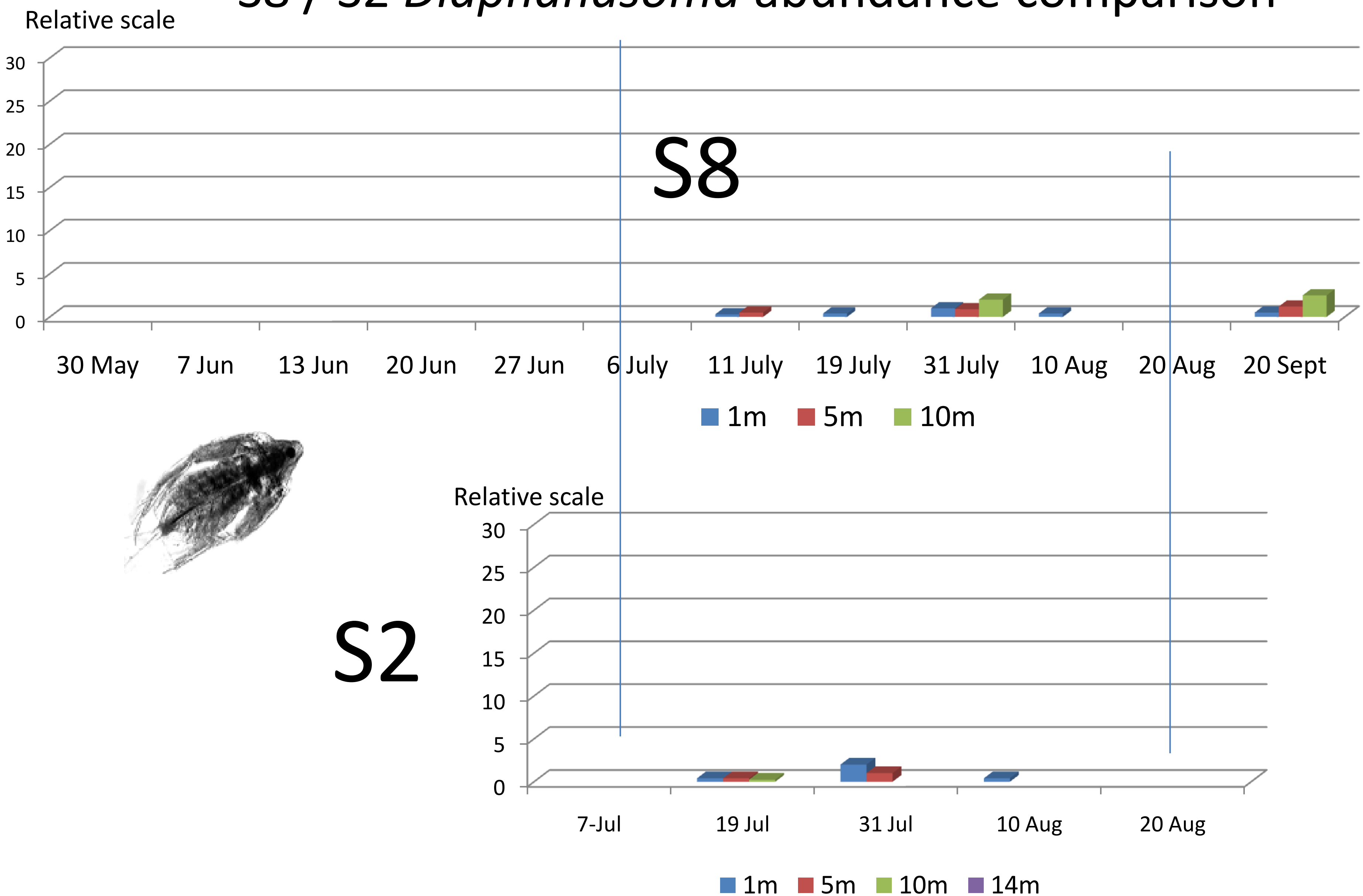


S8 / S2 *Leptodora* abundance comparison

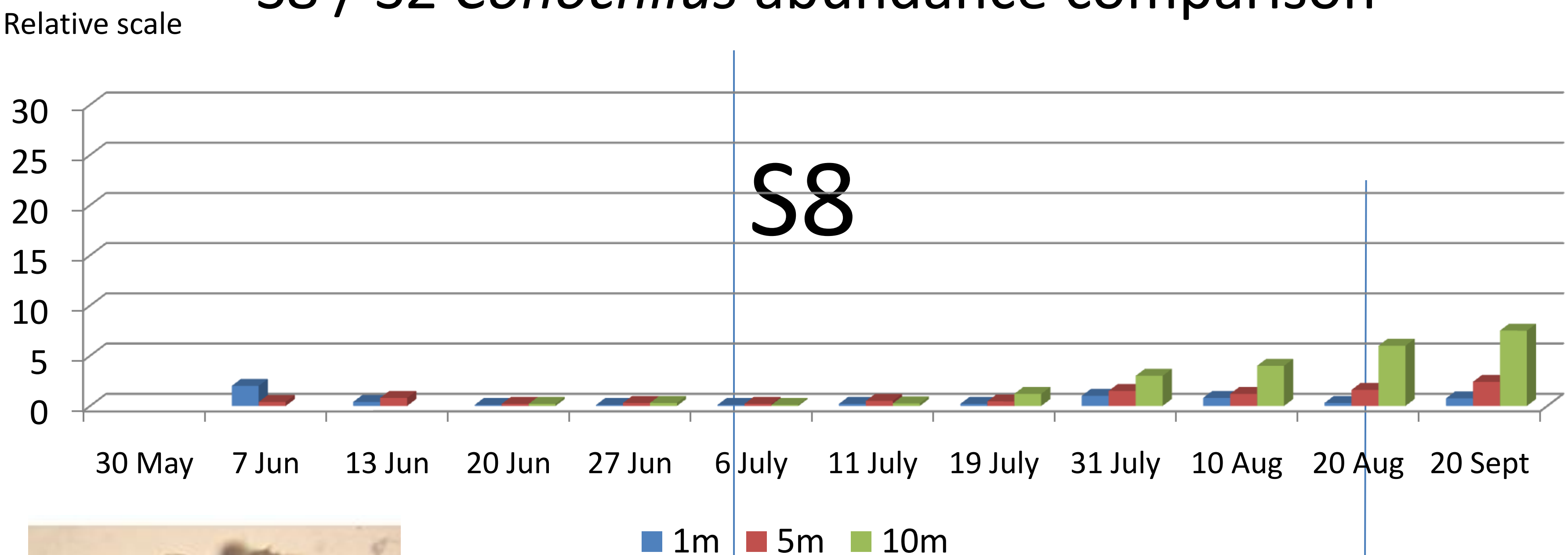


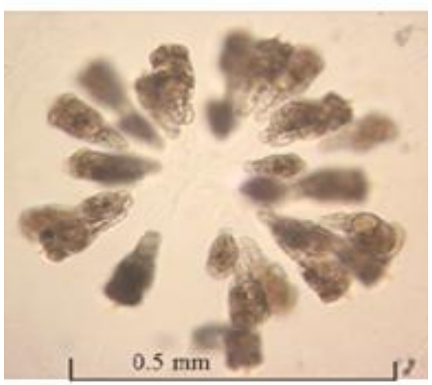


S8 / S2 *Diaphanasoma* abundance comparison

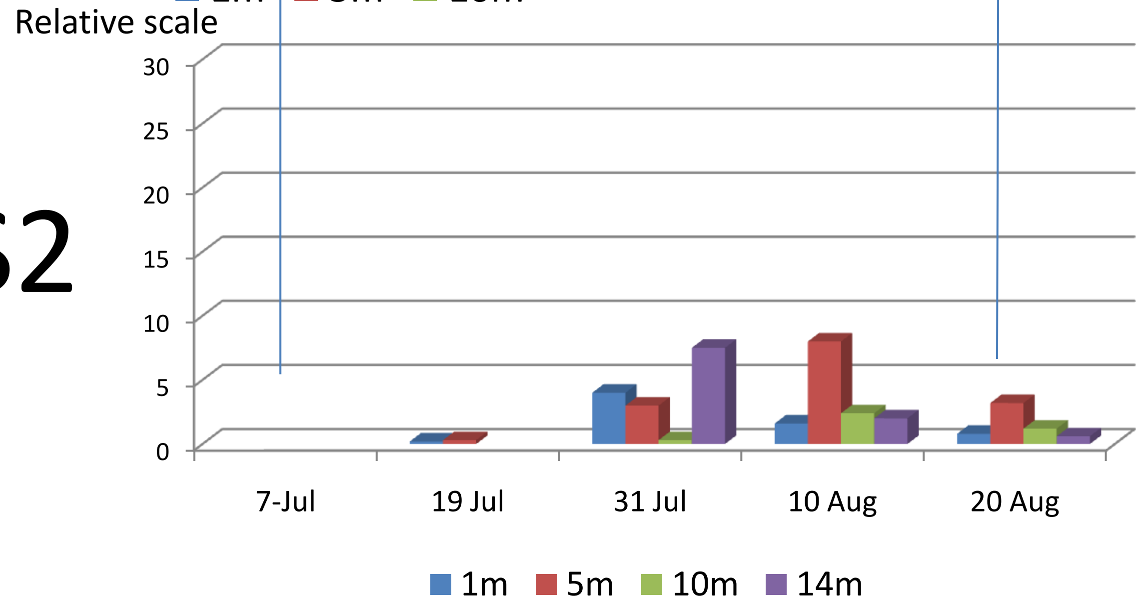


S8 / S2 *Conochilus* abundance comparison

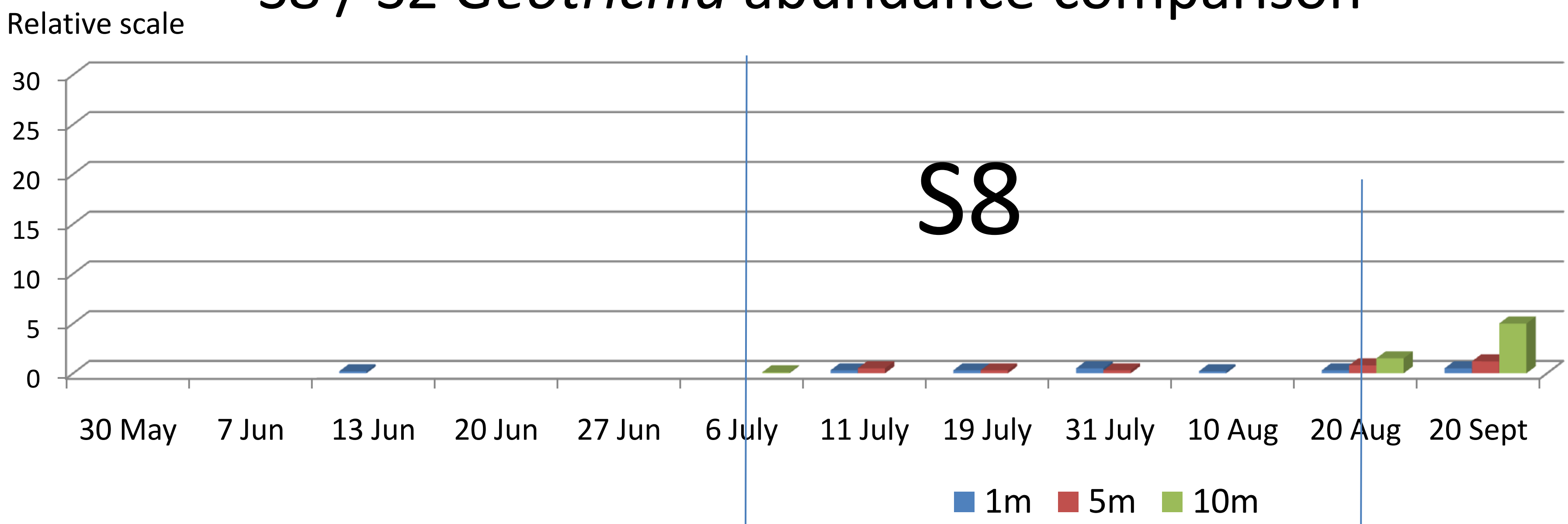


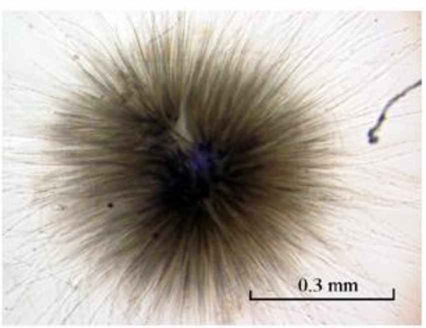


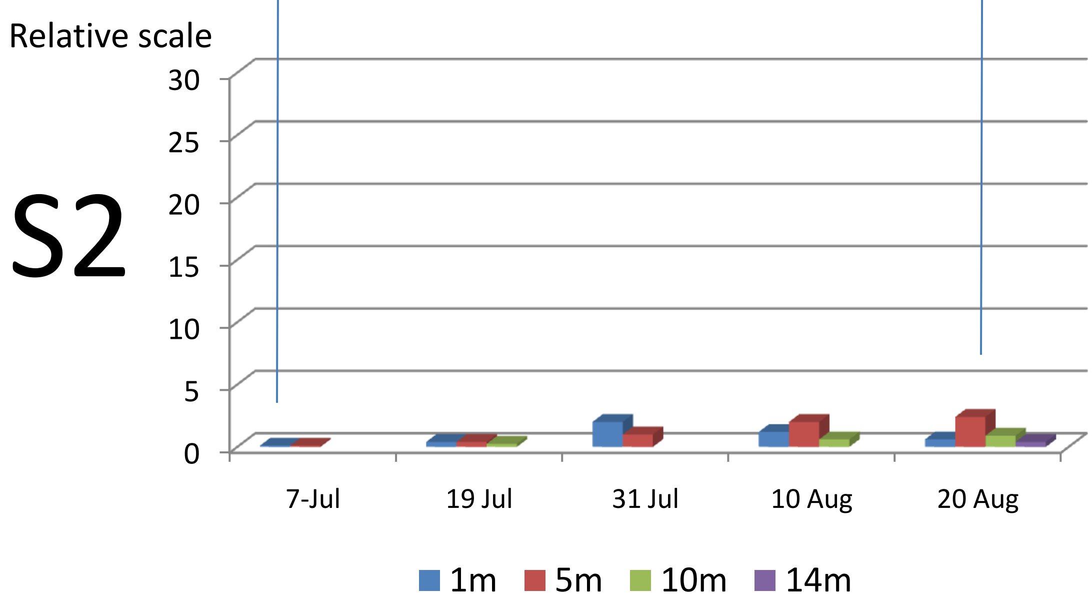
S2



S8 / S2 *Geotrichia* abundance comparison







S8 / S2
Abundance comparisons

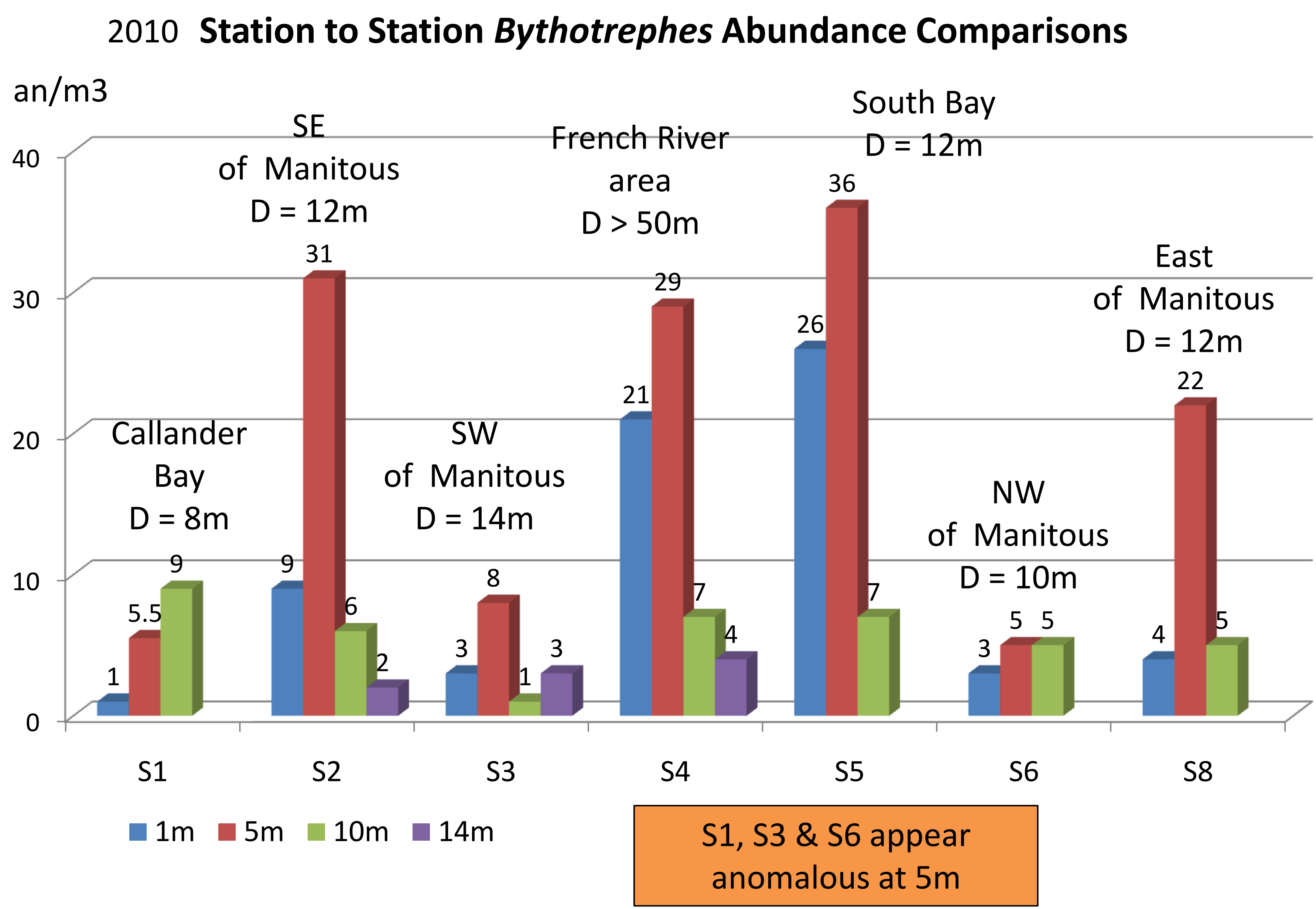
Discussion

1. The *Bythotrephes* abundances determined at S8 and S2 are comparable in magnitude in all strata. The 14 m stratum could not be sampled at S8 as it is only 12 m deep.
2. The decimation of the zooplankton community by *Bythotrephes* that occurred at S8 also occurred at S2. The addition of a few meters of depth at S2 has allowed the copepods (*Epischura lacustris, Skitodiaptomus oregonensis, Mesocyclops Edax)* to attain a slightly higher abundance in mid to late July, at depth, at S2. Subsequently they are comparable to S8 in abundance.
3. *Bosmina, Daphnia* (all *Daphnia galeata mendotae), Diaphanasoma birgei, Leptodora kindtii* all continue to be collected in trace to very small abundances throughout the period in which S2 was sampled (June 7^{th} to August 20
4. *Conochilus unicornis* was a little more abundant at S2, whereas *Geotrichia* was not.
5. We hypothesize that the zooplankton community dynamics described in some detail in our S8 discussion most likely apply to the bulk of the lake, in equivalent strata.

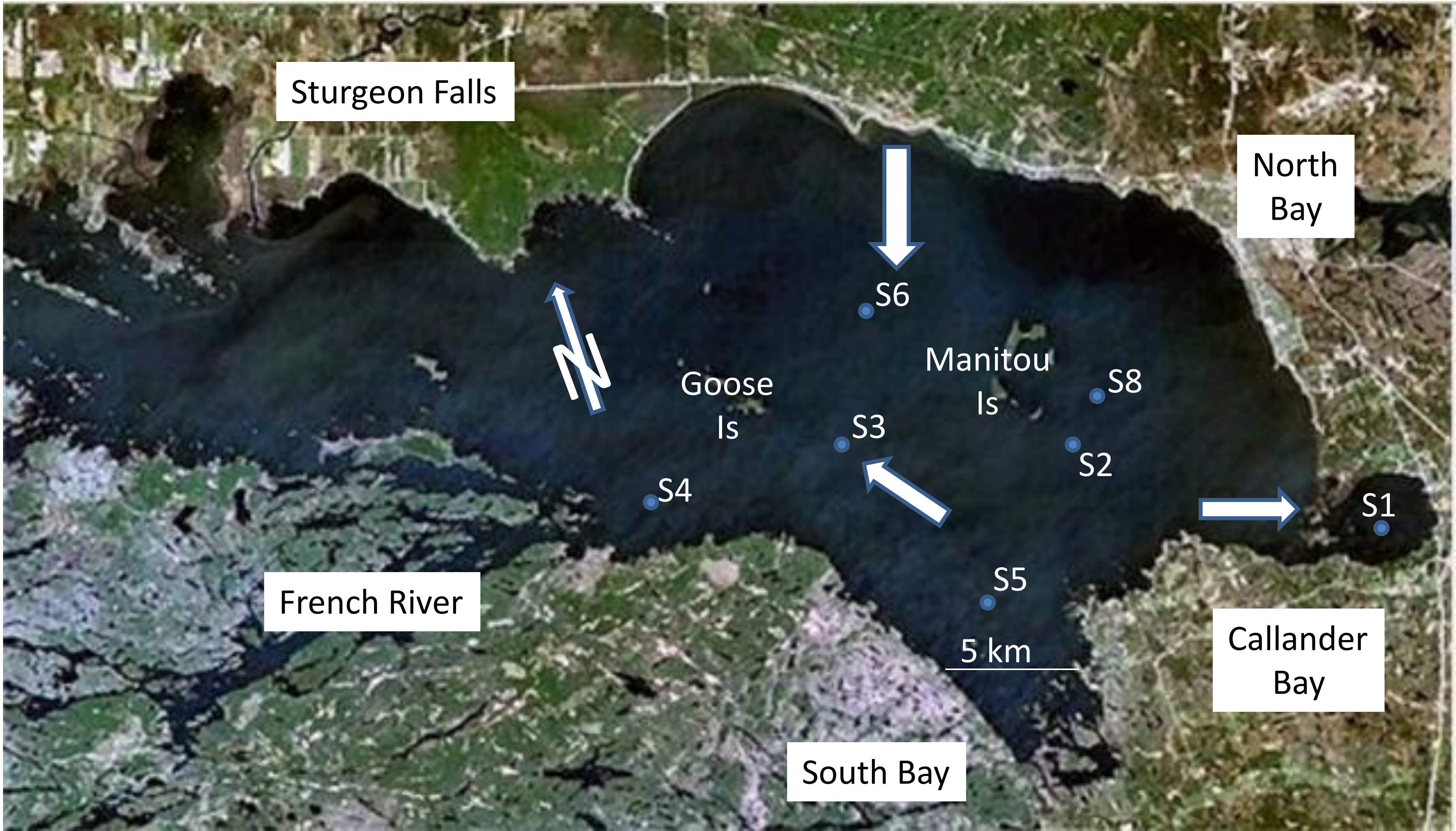
2010 Station to Station *Bythotrephes* Abundance Comparisons

Introduction

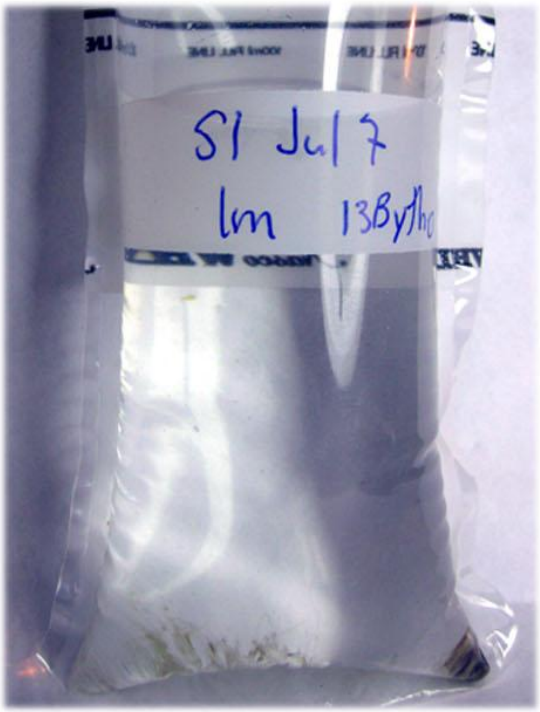
The *Bythotrephes* and other zooplankton dynamics at S2 appear similar to the dynamics taking place at S8. We hypothesize that similar dynamics were also occurring at the other sampling stations. Stations other than S2 and S8 were all sampled between the 7th and 11th of July to try and obtain a 'picture' of what was happening on a larger scale. The sudden crash of *Bythotrephes* in Lake Nipissing in late June was unexpected, and as far as we know, represents the first time such an event has been reported. The following analysis looks at and compares the *Bythotrephes* abundances of all stations sampled in 2010.


2010 Station to Station Bythotrephes Abundance Comparisons
an/m3
40
30
20
10
0
Callander Bay D = 8m
SE of Manitous D = 12m
SW of Manitous D = 14m
French River area D > 50m
South Bay D = 12m
NW of Manitous D = 10m
East of Manitous D = 12m
1
5.5
9
9
31
6
2
3
8
1
3
21
29
7
4
26
36
7
3
5
5
4
22
5
S1
S2
S3
S4
S5
S6
S8
1m
5m
10m
14m
S1, S3 & S6 appear anomalous at 5m

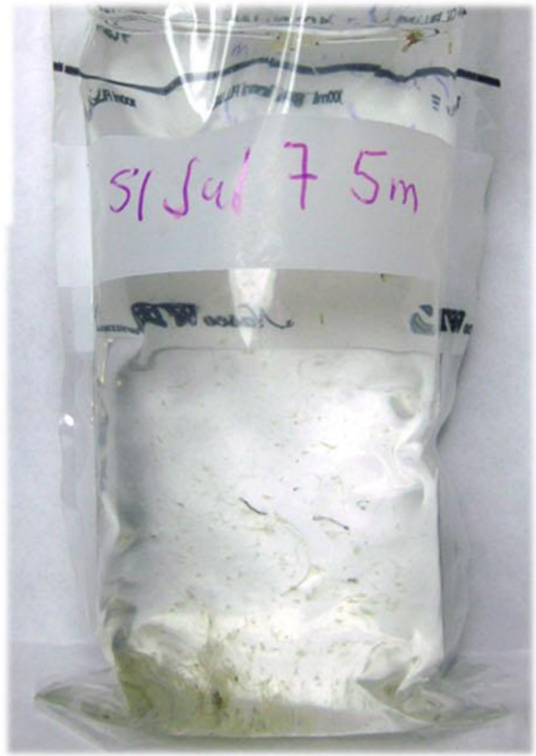
By July 9 or thereabouts, S1, S3 and S6 have smaller concentrations of *Bythotrephes* at 5m than the other stations.



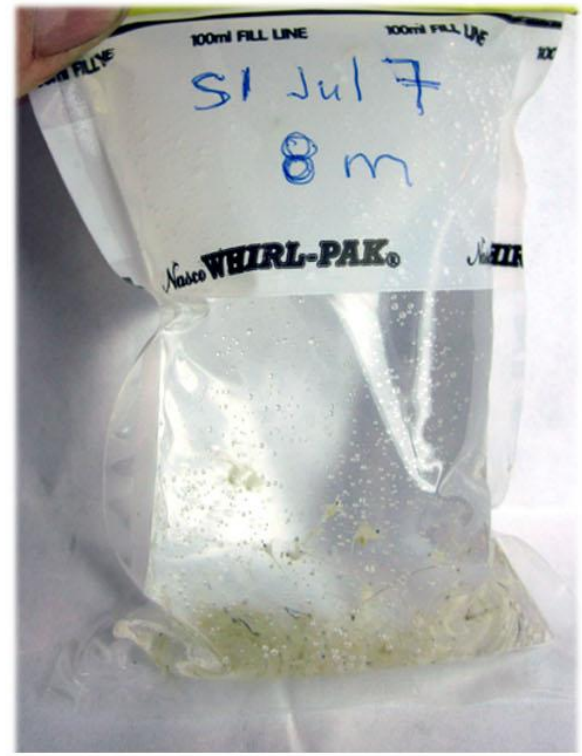
S1 - Callander Bay, July 7, 2010



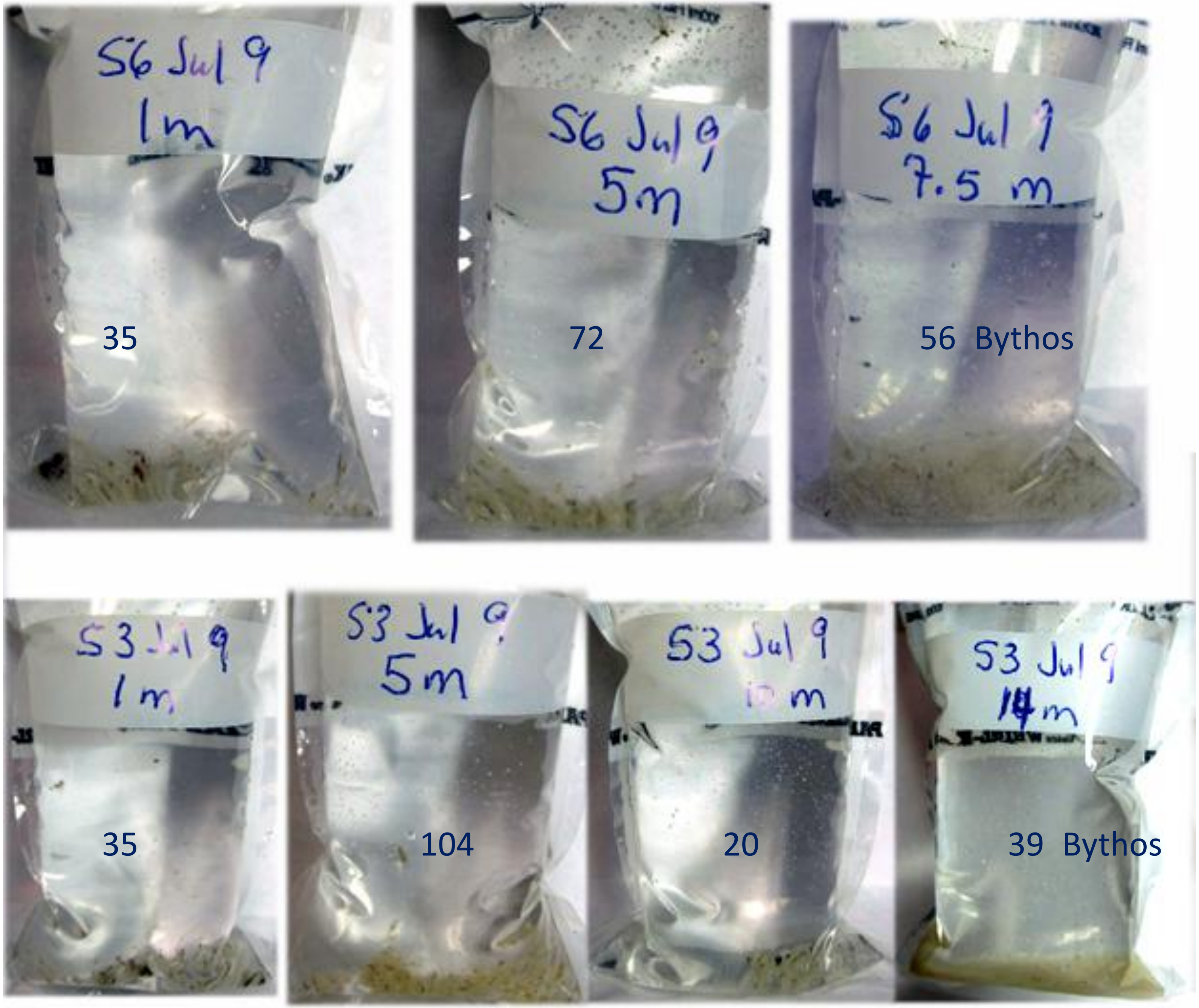
1m



5m



8m


S6 Jul 9
1m
35
S6 Jul 9
5m
72
S6 Jul 9
7.5 m
56 Bythos
S3 Jul 9
1m
35
S3 Jul 9
5m
104
S3 Jul 9
10 m
20
S3 Jul 9
14m
39 Bythos

Station to Station *Bythotrephes* Abundance Comparisons

Discussion

1. It appears from the samples that at S1, S3 and S6 the zooplankton population has been cropped by *Bythotrephes* and *Bythotrephes* populations have already collapsed subsequent to running out of food. The same processes at work at S2 and S8 appear to be at work at S1, S3 and S6 also, they are just occurring a little faster in time.
2. Despite large variations in station depths (S4 has a depth > 50m), *Bythotrephes* abundances are surprisingly similar to one another in similar strata despite station to station separation distances of up to 20 km. This we attribute to *Bythotrephes* limiting its forays into deeper strata due to poor visibility limiting its hunting ability/success (Pangle and Peacor 2009).
3. *Bythotrephes* abundances correlate negatively with increasing depth.

Station to Station *Bythotrephes* Abundance Comparisons

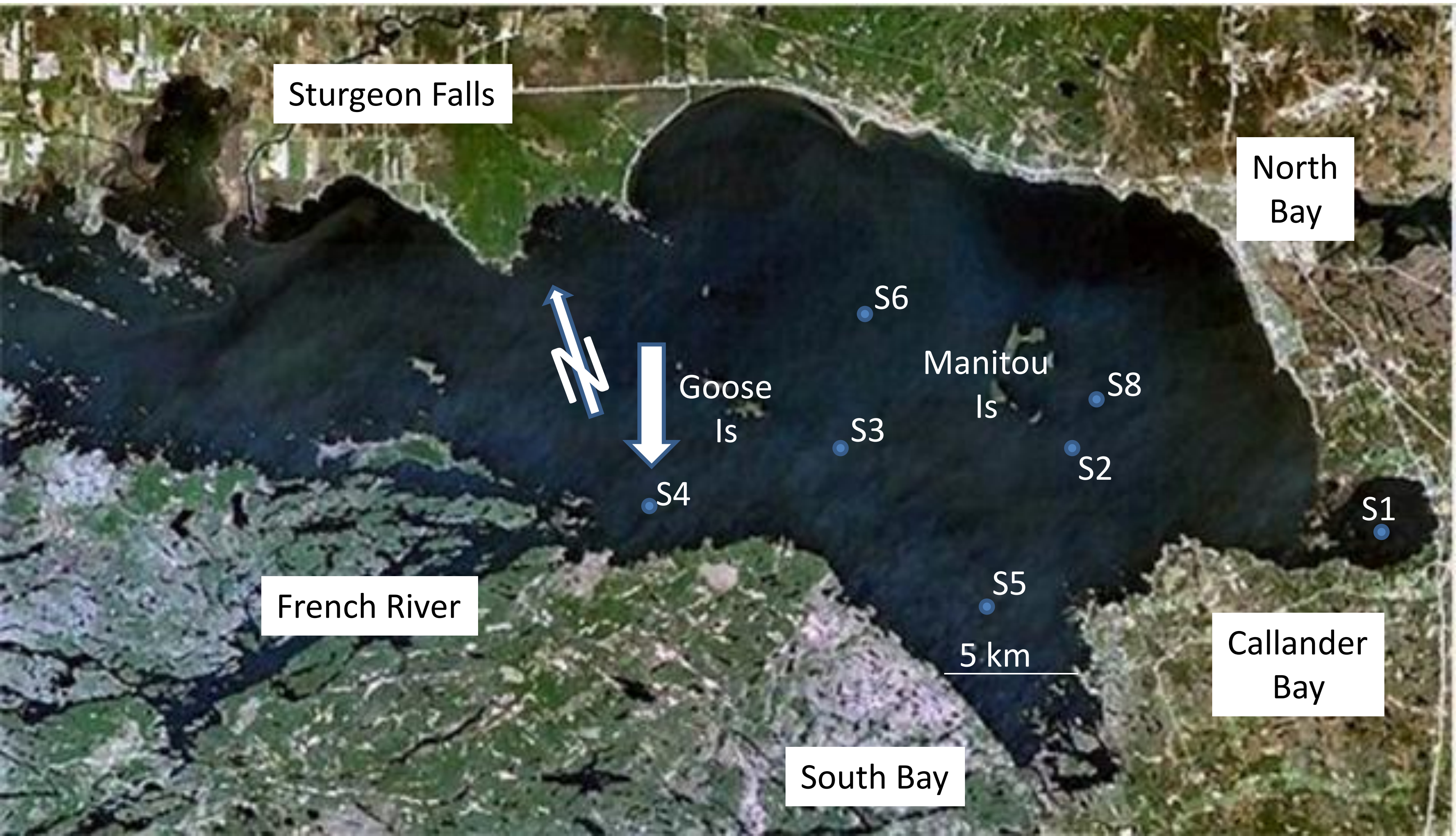
Discussion (page 2)

4. Given the shallow nature of Lake Nipissing (average depth is only 4.5 m) we hypothesize that *Bythotrephes,* during the month of June, was liquidating most of the zooplankton throughout the vast expanse of Lake Nipissing at depths to 10m. Come July most of the zooplankton in Lake Nipissing had probably been consumed. Such an event may have ecosystem-wide implications.

   Faced with a depletion of their traditional zooplankton food source come early June small fish may be forced to modify their behaviour in a number of ways. They could perhaps change food source and possibly depend more on the invertebrate population found in the sediments (mayfly naiads, snails, chaoborus larvae, chironomid larvae and the like). A change in behaviour in the small-sized fish population would also have implications in the predators that find themselves higher up the food chain, as they would have to “follow” their prey.

S4 - Zooplankton community structure

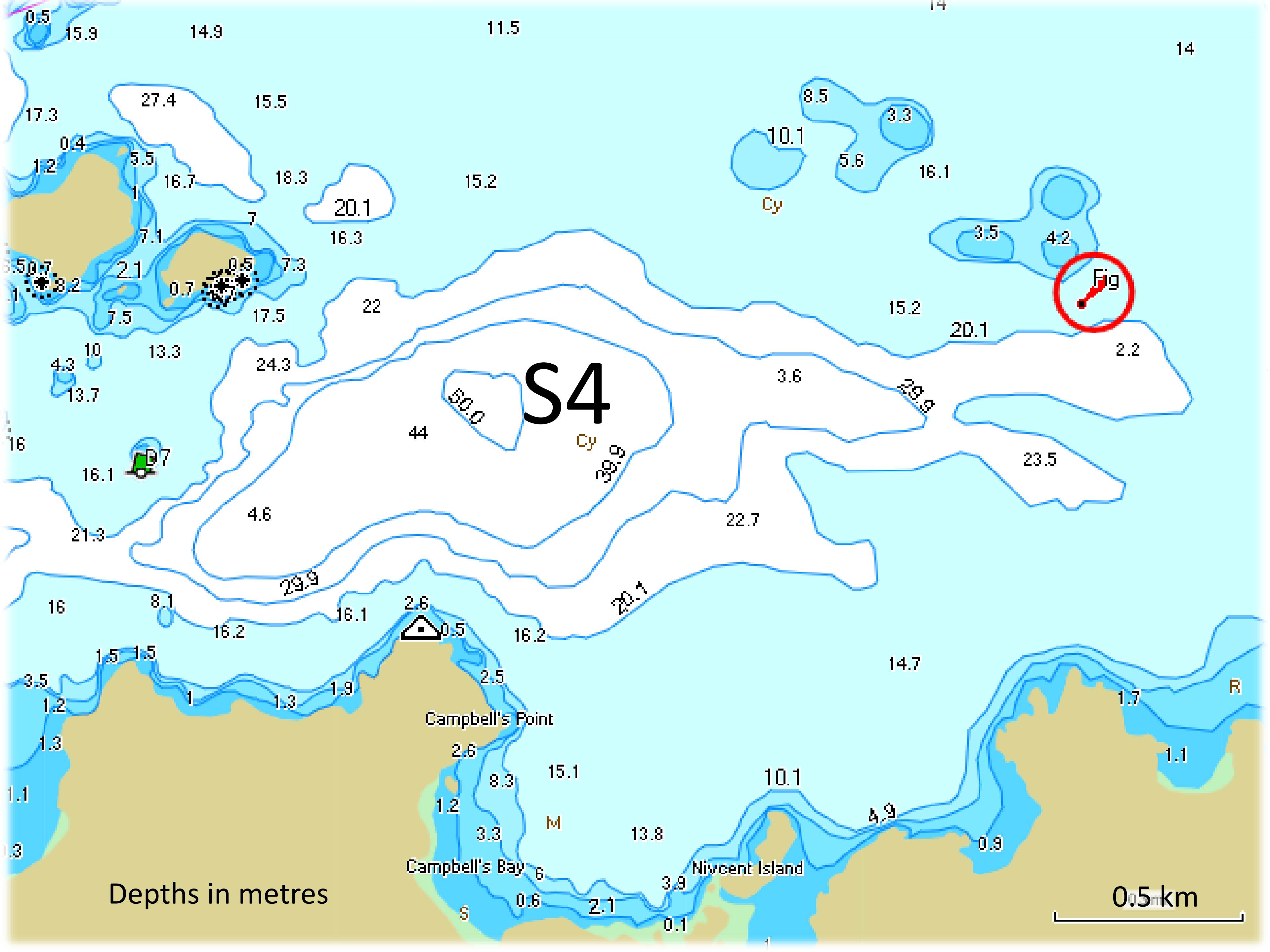
Lake Nipissing Outlet – French River Headwaters

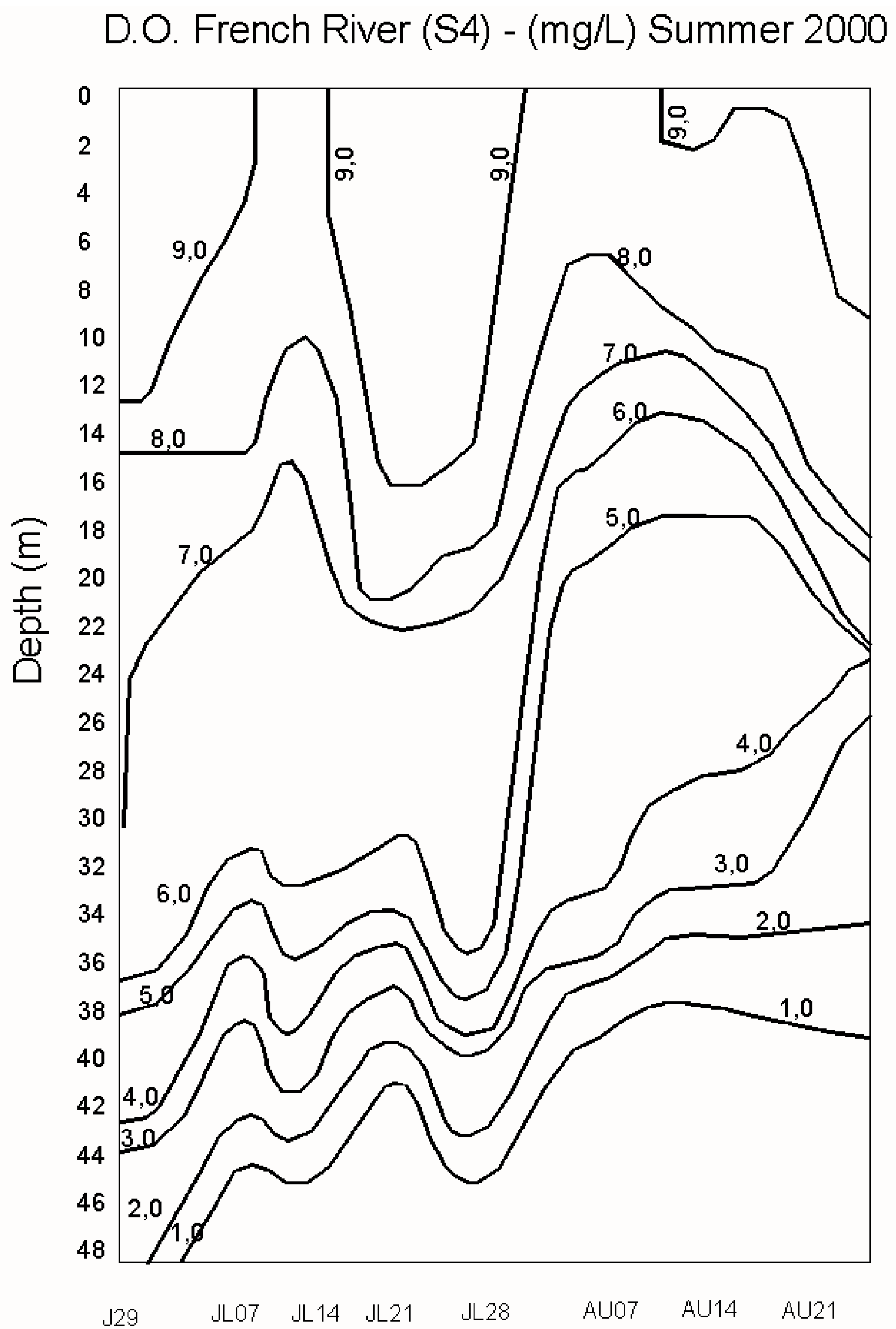


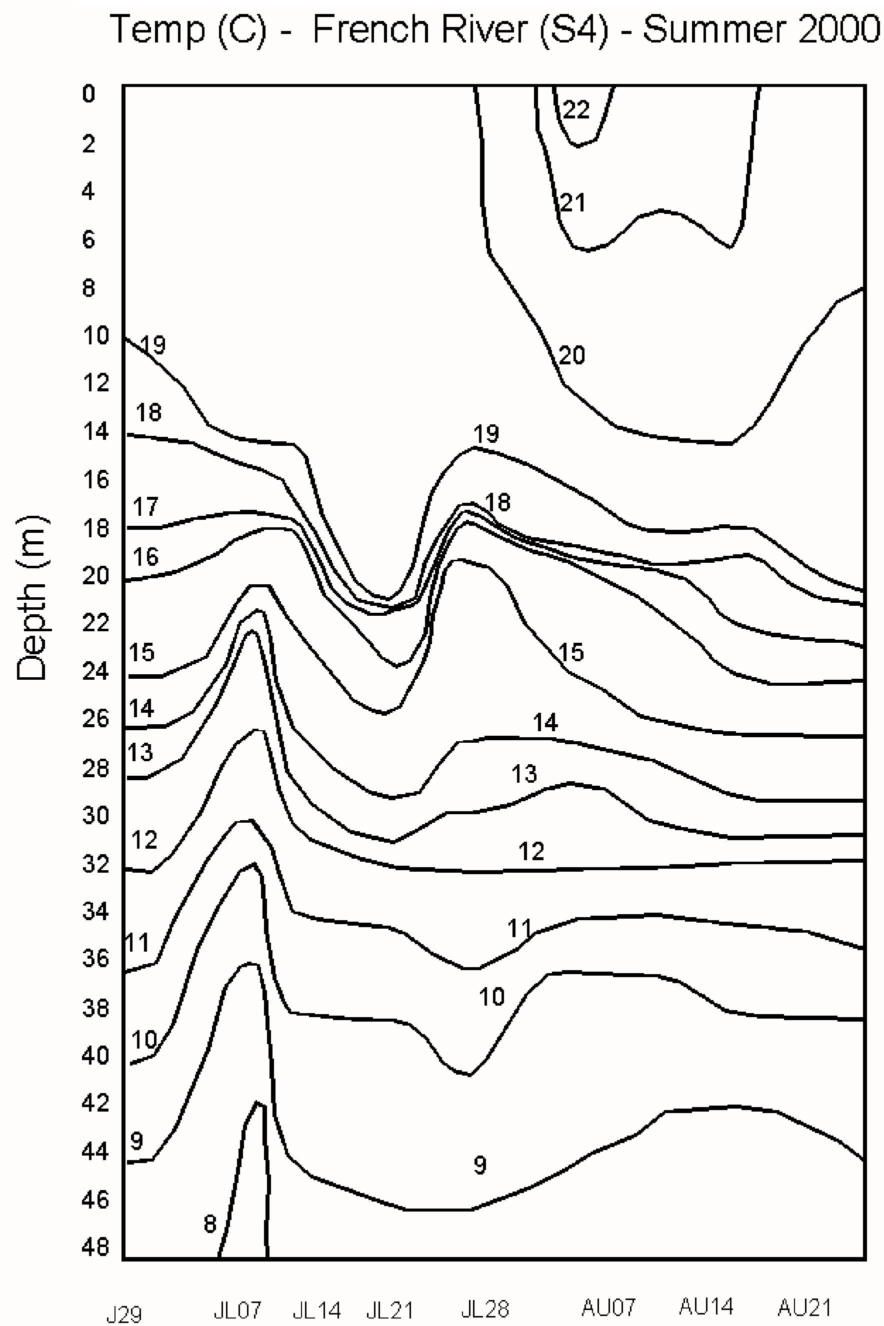
S4 – A biodiversity refuge

S4 is located in an area of crucial importance to Lake Nipissing as it serves as both a fish and zooplankton refuge, thus helping to preserve biodiversity. It is near the outlet of Lake Nipissing, which drains in a southwesterly direction via the French River. The bathymetry of this area is unusual in that a cold water refuge is available due to the deeper waters available in this location. The maximum depth that we were able to find using our Hummingbird depth sounder was 54m.

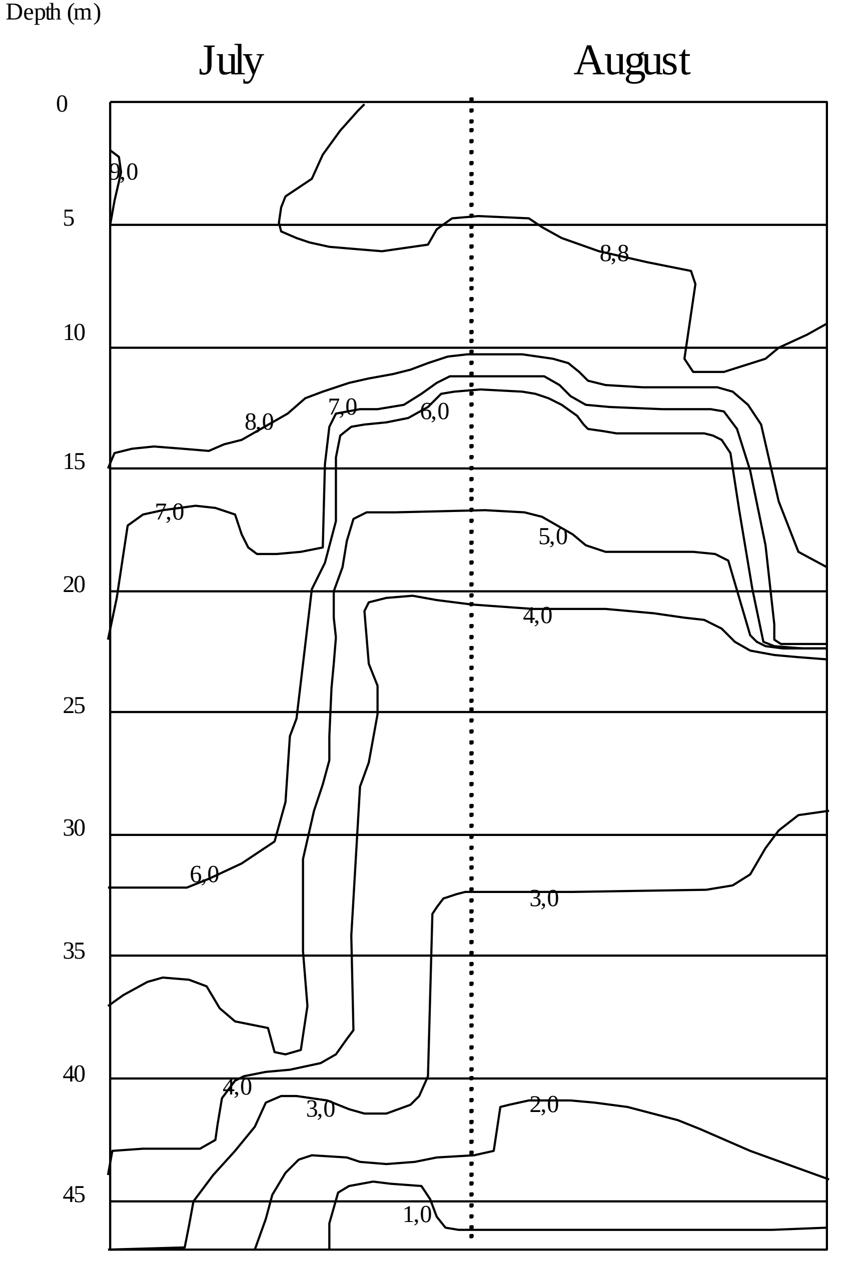
In the summer this area becomes a cold water refuge for the lake herring (cisco) and the smelt. Warmer waters on top and oxygen depletion at depth keep the fish sandwiched in a definite band, as indicated by this picture taken of our Hummingbird sonar unit.


S4
Fig
Cy
Cy
Campbell's Point
Campbell's Bay
Nivcent Island
M
S
R
Depths in metres
0.5 km

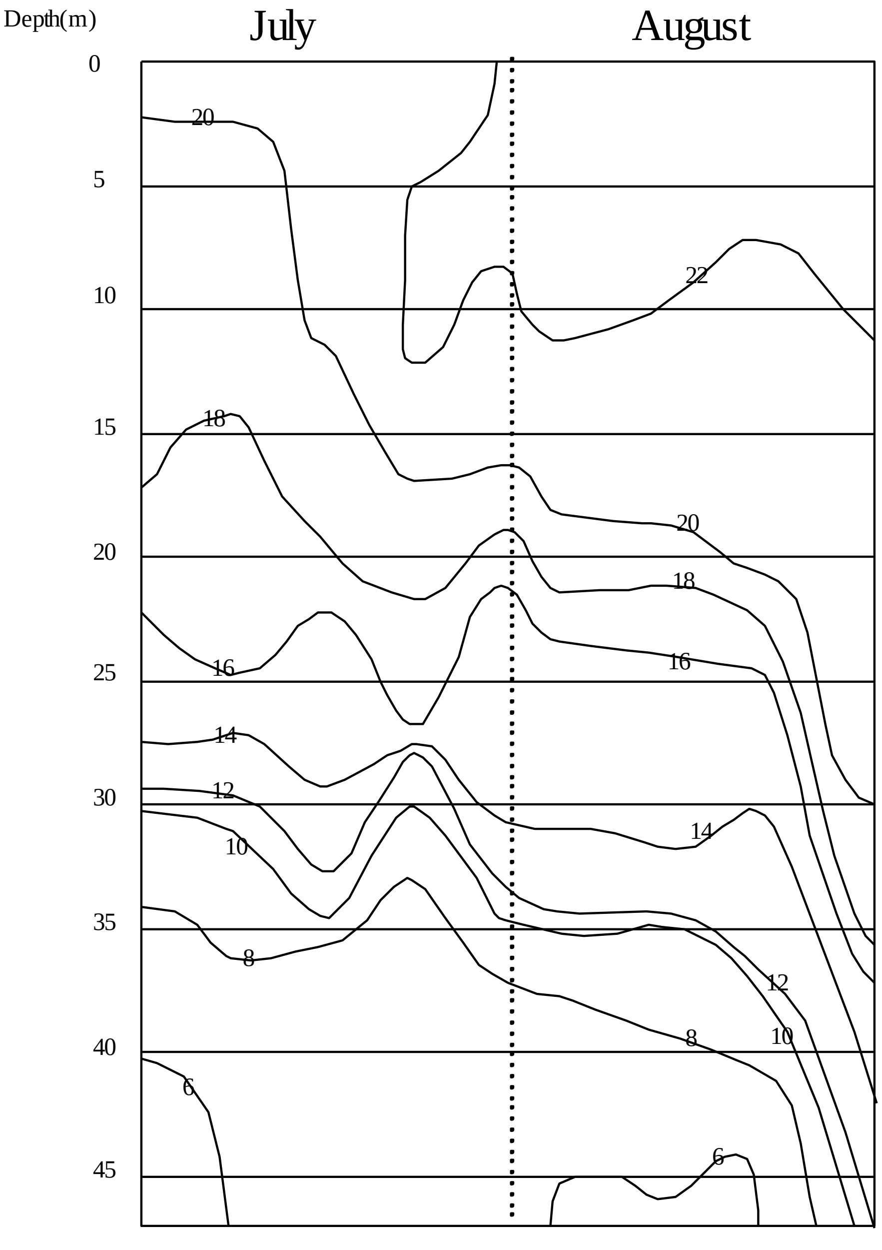

D.O. French River (S4) - (mg/L) Summer 2000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
J29
JL07
JL14
JL21
JL28
AU07
AU14
AU21


Temp (C) - French River (S4) - Summer 2000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
J29
JL07
JL14
JL21
JL28
AU07
AU14
AU21

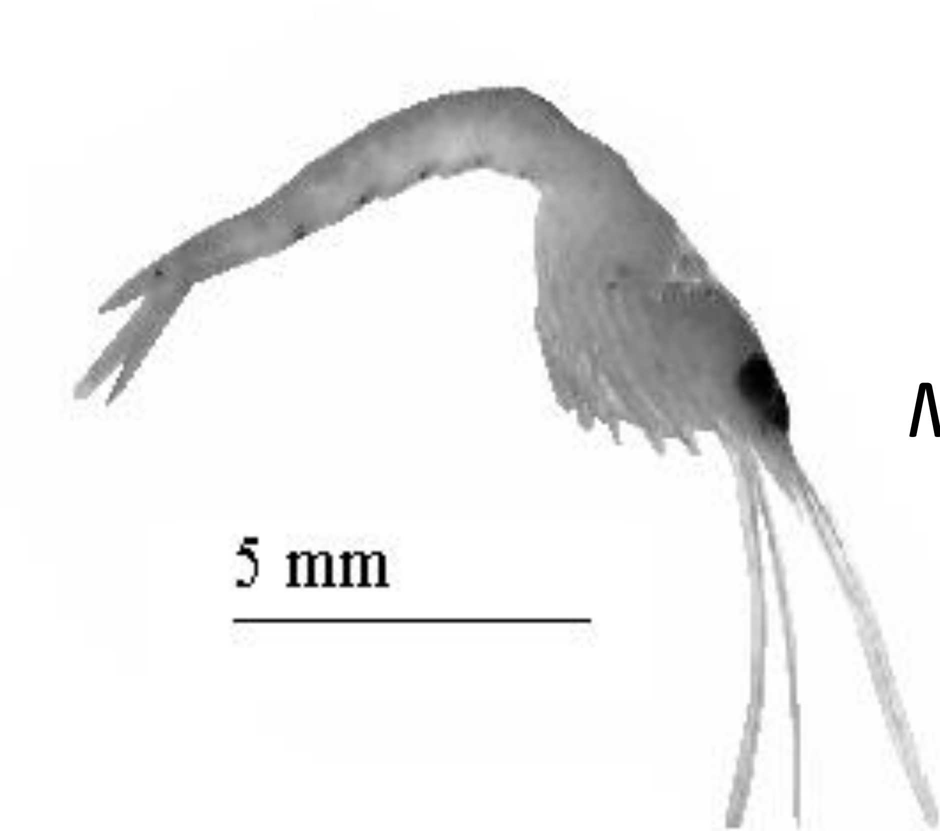
S4 - French River - D.O.(mg/L) - 2001



S4 - French River - Temp. (C) - 2001

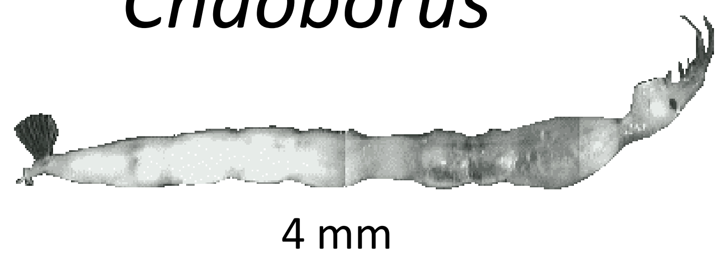


New Players



Mysis relicta

Chaoborus



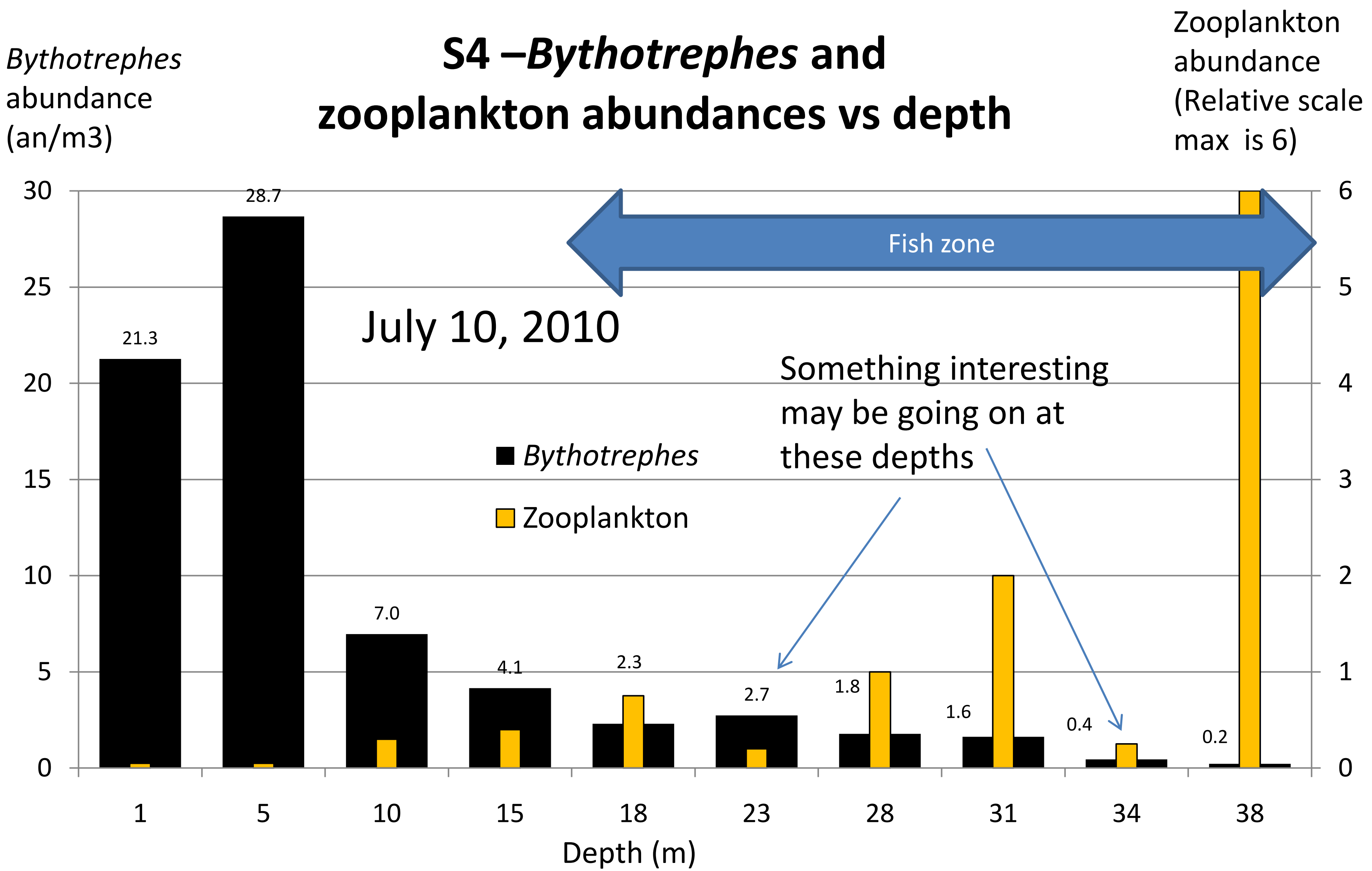
S4 – A summer cold-water-fish refuge

In the early 1930's fisheries biologist Dr. F.E.J. Fry from the University of Toronto studied the summer migration of the cisco (*Coregonus artedi*) in Lake Nipissing. His abstract describes the summer migration of lake herring to the S4 sampling site. Rainbow smelt (*Osmerus mordax)* also gather here come summer. (Richard Rowe - 2010 sampling)

" In lake Nipissing there is a general migration of the cisco population from shallow to deeper water in late spring and early summer which takes the fish participating in it below the thermocline. The fish remain in the hypolimnion for some time, scattering downwards. During late August and early September they rise from the bottom and concentrate under the thermocline. Most of them pass through the thermocline and return to shallower water before the autumn turnover.

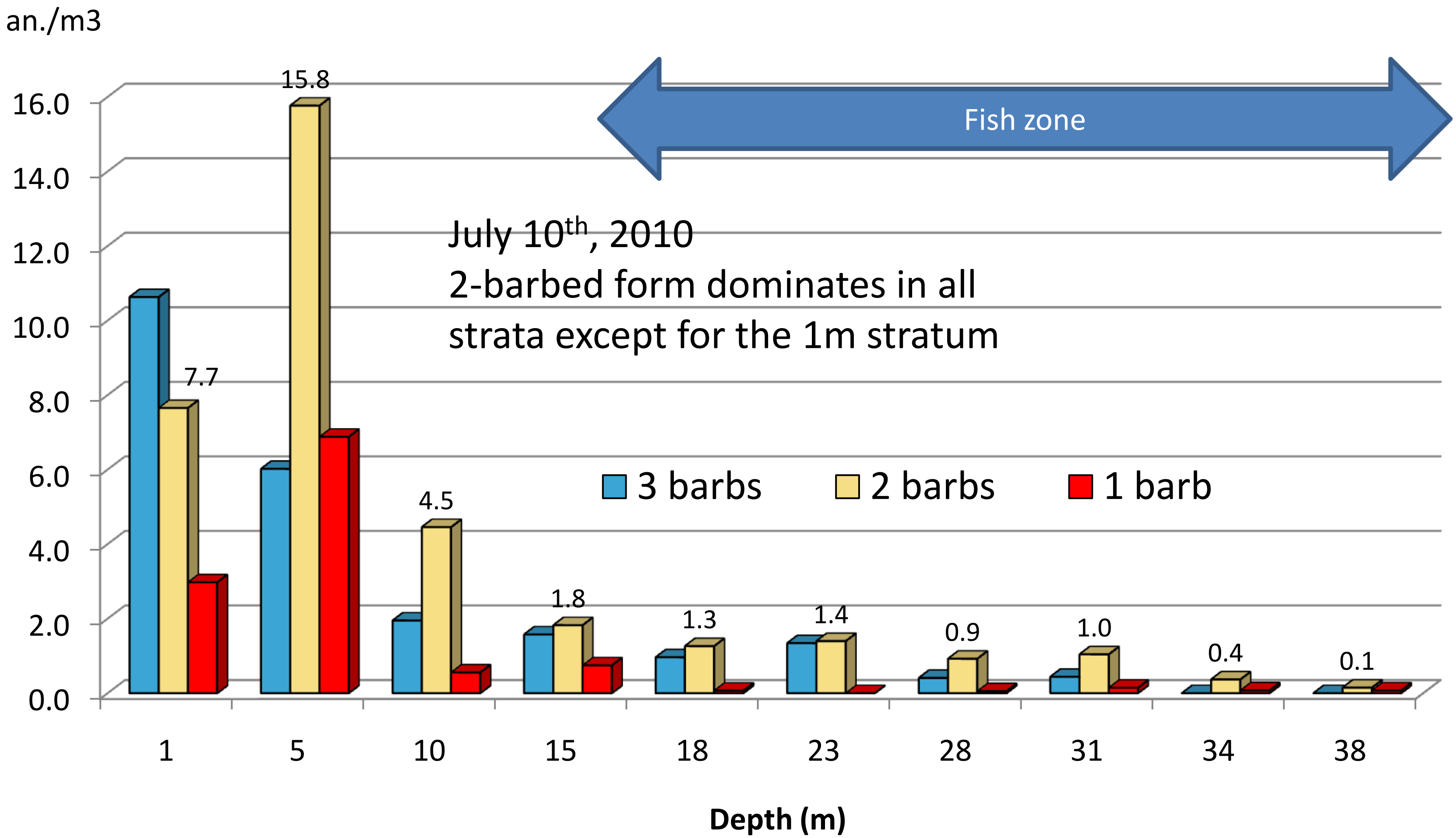
The downward movement is correlated with rising temperatures in the epilimnion until the fish have passed through the thermocline. Their continued descent is probably due to random dispersion. The subsequent ascent from the bottom is correlated with a depletion of the dissolved oxygen and an increase in carbon dioxide in solution in the bottom water. This ascent from the bottom results in concentration of the population immediately under the thermocline. The population ultimately moves upward when the balance between the opposing effects of high epilimnial temperatures above and unfavourable concentrations of dissolved gases below is destroyed by the continued cooling of the epilimnion and further stagnation in the hypolimnion."

S4 –*Bythotrephes* and zooplankton abundances vs depth

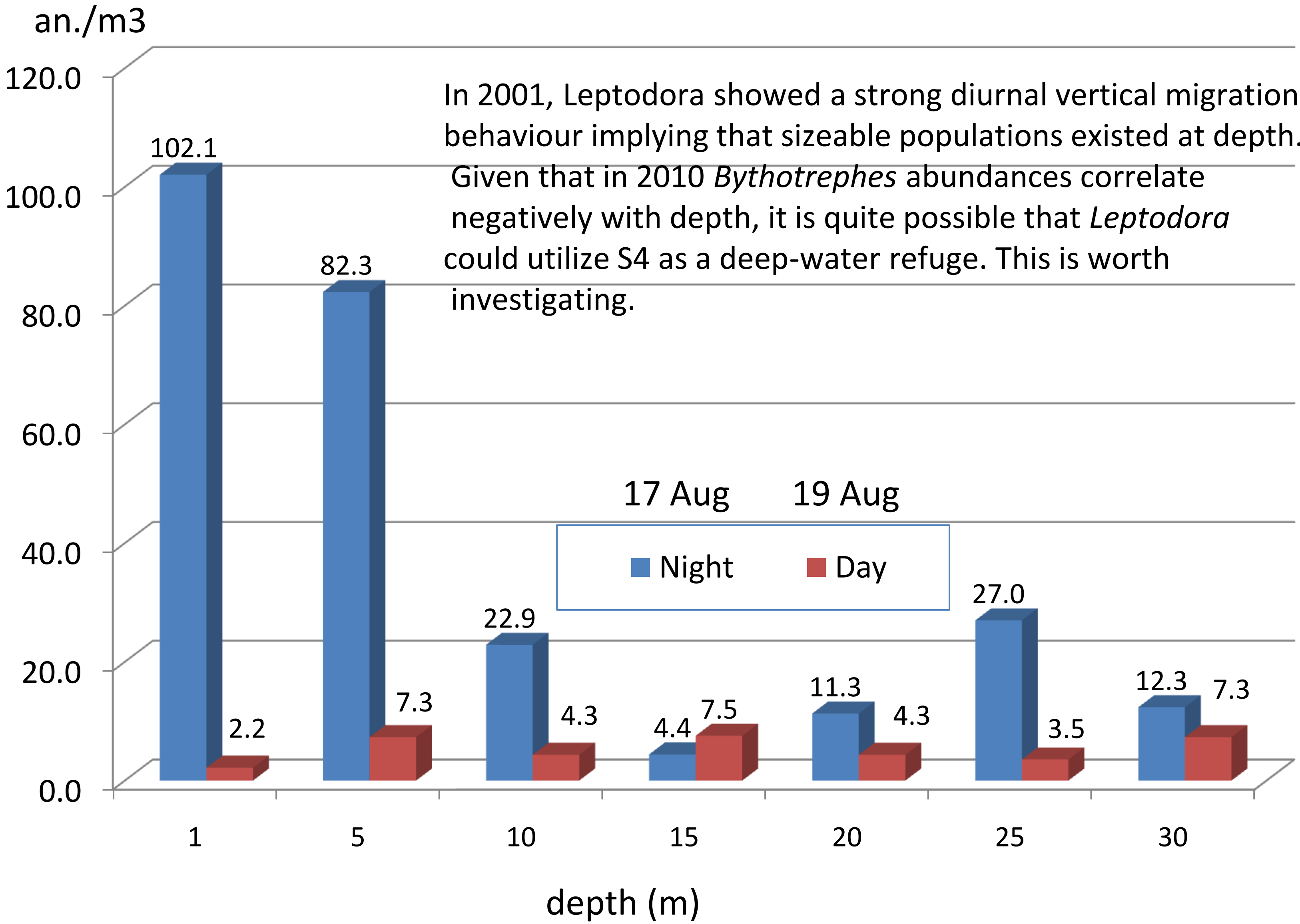


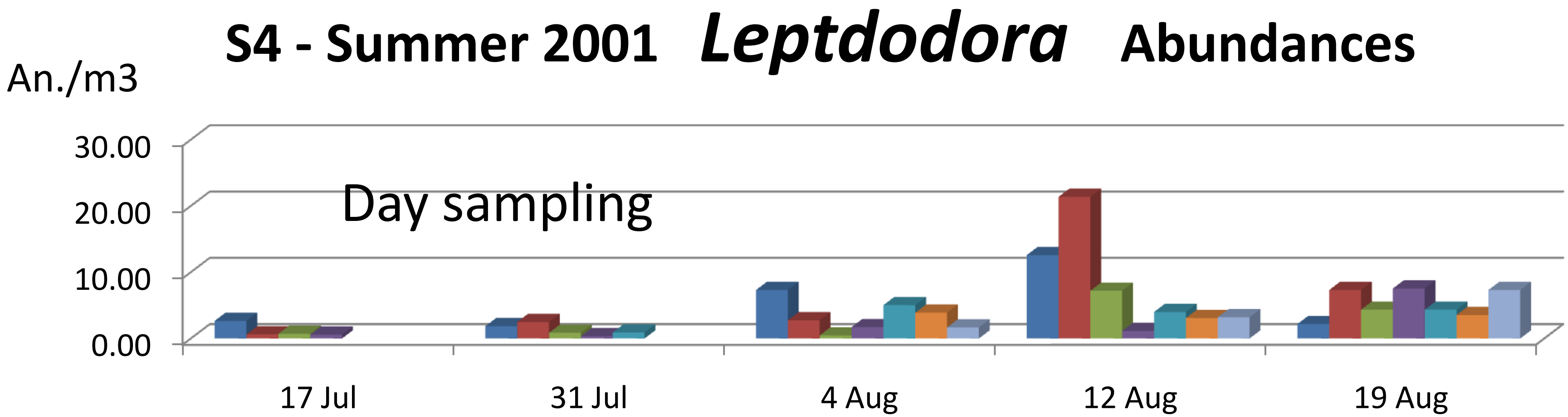
Bythotrephes abundances correlate negatively with depth

S4 - Abundances of 1, 2 and 3 barbed *Bythotrephes longimanus* vs depth

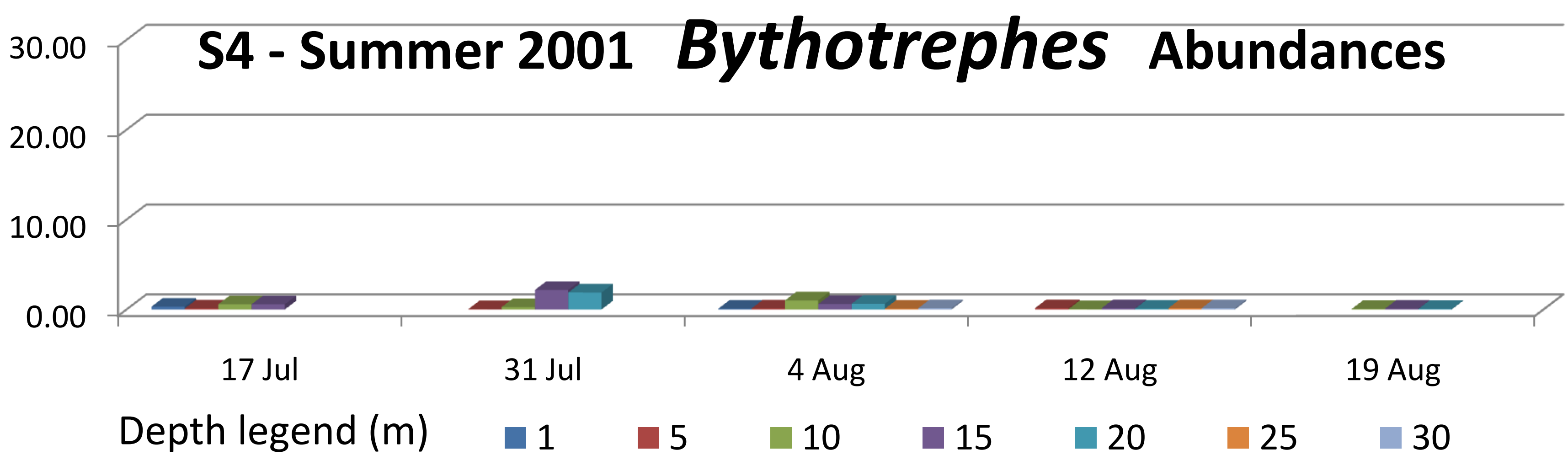


S4 - 2001 - Night / Day *Leptodora* abundances





The 2 graphs show results from 2001. In the present study, on June 10th 2010, *Leptodora* was collected in trace amounts in the 1, 5 and 15 m strata. In 20001, *Leptodora* was not abundant in early June, but abundant in August. Additional sampling, later in the summer is required to determine whether or not *Leptodora* is using S4 as a summer refuge as it was present, at depth, in 2001.



S4 – Zooplankton abundances at various depths

July 10th, 2010

	Bytho	Chaoborus	Mysis	Rank scores				
depth (m)	an/m3	an/m3	an/m3	zoo	Epi	Diap	Sen	Cyc
1	21	0	0	0.05	3	3	0	1
5	29	0	0	0.05	2	0	0	0
10	7	0	0	0.3	3	5	0	2
15	4	0	0	0.4	4	5	0	3
18	2	0.1	0	0.75	5	4	0	3
23	3	1.0	0	0.2	5	4	1	4
28	2	8.4	0	1	4	4	3	3
31	2	7.3	0	2	3	4	3	4
34	0.4	0.2	0	0.25	3	5	3	3
38	0.2	0.1	0.4	6	2	5	3	3

S4 – Zooplankton abundances at various depths . . .

July 10th, 2010

	Rank scores										
depth (m)	zoo	Daph	Bos	Diaph	Lepto	Holo	Eur	Cono	Geo	Ostr	Lat
1	0.05	2	3	1	1	0	0	0	3	0	0
5	0.05	2	2	0	2	0	0	2	1	0	0
10	0.3	2	3	0	0	0	0	2	0	2	0
15	0.4	2	2	0	1	0	0	3	0	2	0
18	0.75	3	2	0	0	0	0	3	0	2	2
23	0.2	4	5	0	0	0	1	1	1	2	2
28	1	4	4	0	0	0	3	3	0	2	3
31	2	4	4	0	0	0	3	2	0	2	2
34	0.25	4	3	0	0	0	1	2	0	1	0
38	6	4	0	0	0	0	1	2	0	0	0

Ostr – *Ostracoda,* Lat – *Latona setifera,* Eur – *Eurycercus,* - others as previous.

S4 - Copepod species distribution vs depth - colour indicates presence confirmed
(Lighter colour implies presence strongly suspected)

Depth (m)	*Epischura lacustris*	*Skistodiaptomus oregonensis*	*Leptodiaptomus minutus*	*Senecella calanoides*	*Diacyclops bicuspidatus thomasi*	*Mesocyclops edax*	*Eucyclops elegans*	*Cyclops scutifer*
1								
5								
10								
15								
18								
23								
28								
31								
34								
38								

Note: Diaptomid copepods were identified using CVI male copepodid stages.
Cyclopoid copepods were identified using adult female copepodid stages.

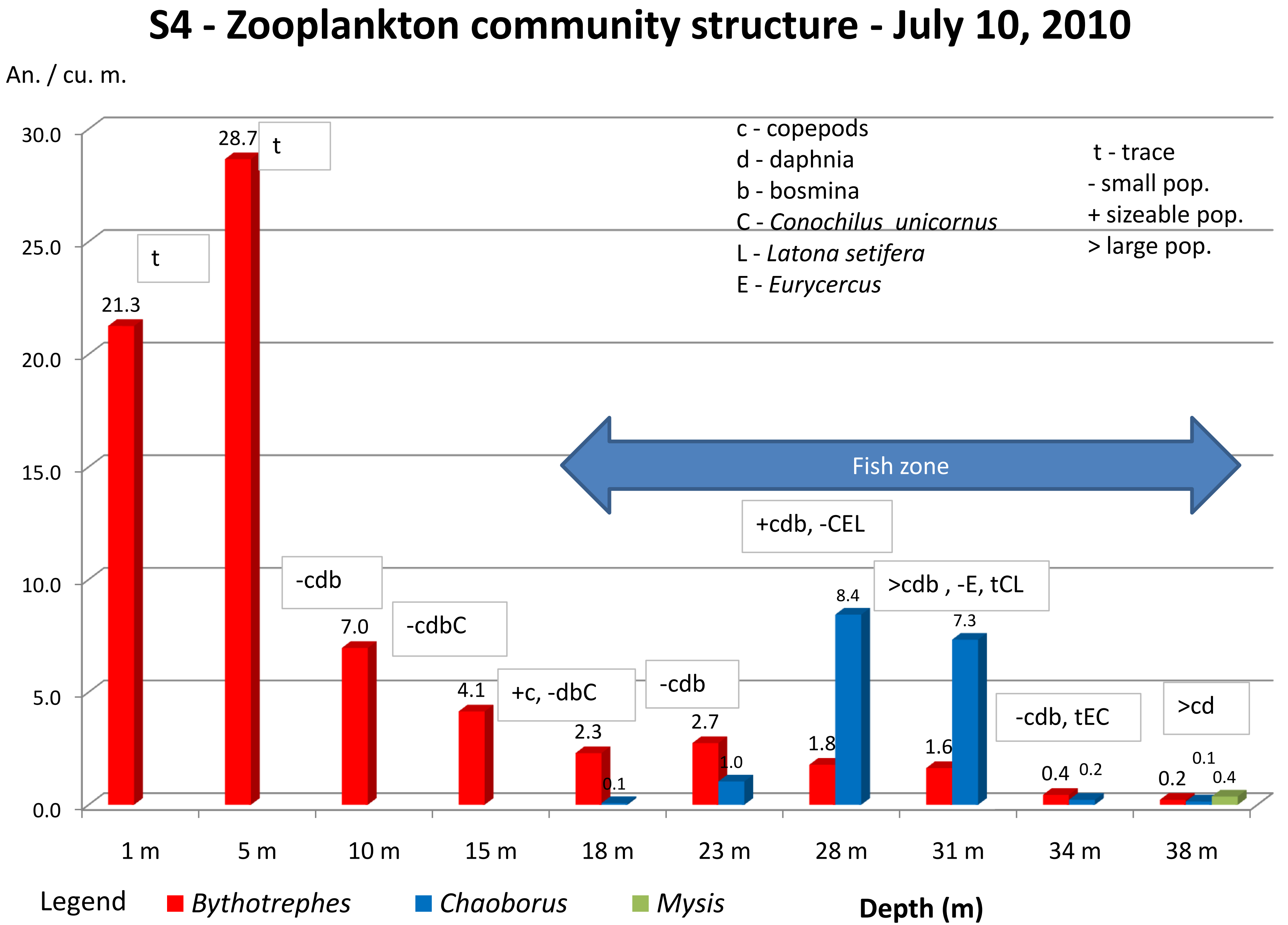
Absence in the chart simply means that the presence was not confirmed. Adult stages were perhaps not present , or sample abundances might be low leading to an absence label.

S4 – Cladocera & other taxa species distribution vs depth
Colour indicates presence confirmed at that depth

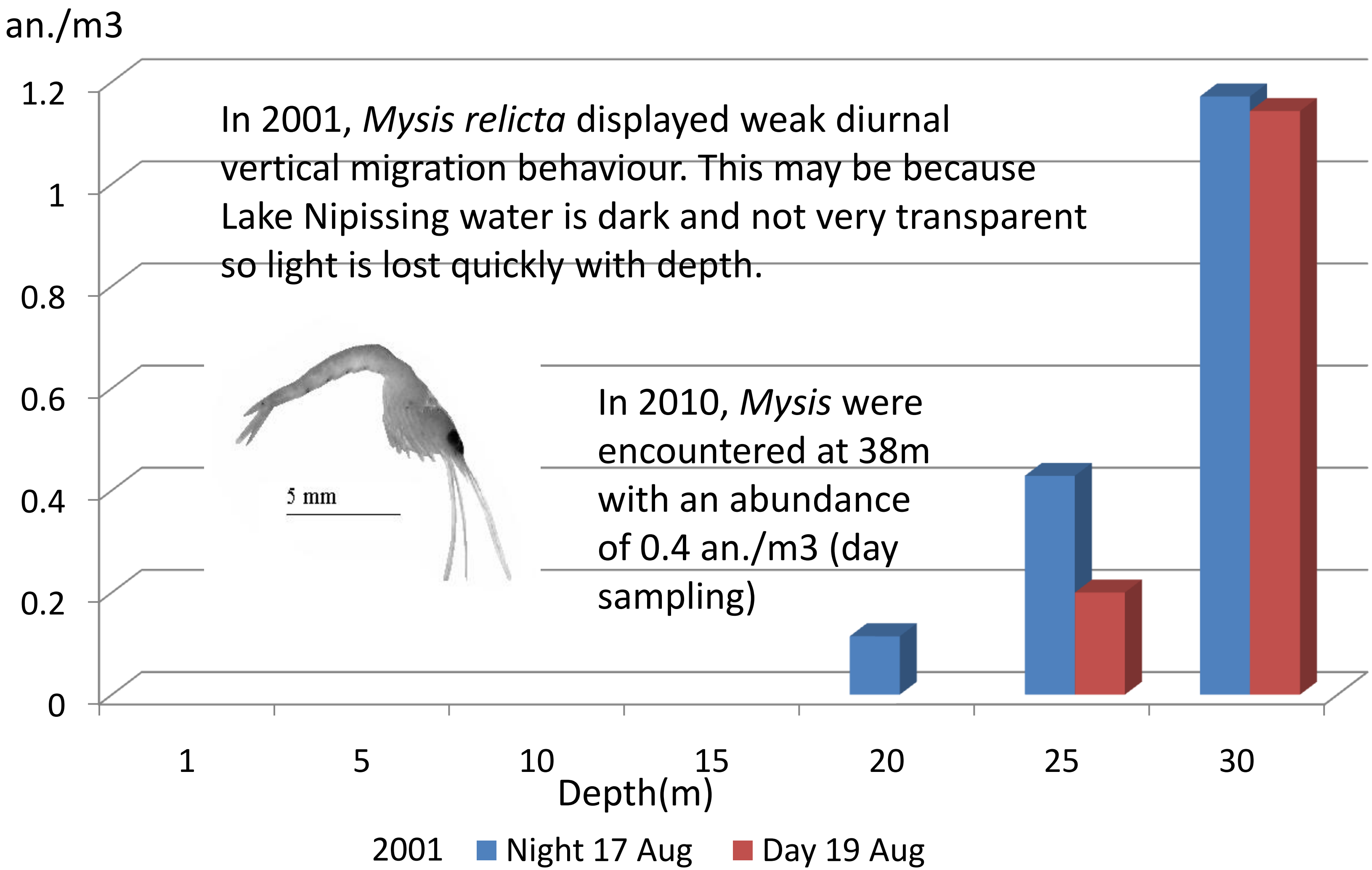
depth (m)	*Daphnia galeota mendotae*	*Daphnia pulicaria*	*Daphnia longiremis*	*Bosmian sp.*	*Diaphanasoma birgei*	*Leptodora kindtii*	*Eurycercus sp.*	*Latona setifera*	*Ostracoda sp*	*Conochilus unicornis*	*Geotrichia*
1	■		■	■	■	■					■
5	■		■	■		■				■	■
10			■	■					■	■	
15			■	■		■			■	■	
18	■		■	■				■	■	■	
23	■	■	■	■			■	■	■	■	■
28	■	■	■	■			■	■	■	■	
31	■	■	■	■			■	■	■	■	
34	■	■	■	■			■		■	■	
38		■	■				■			■	

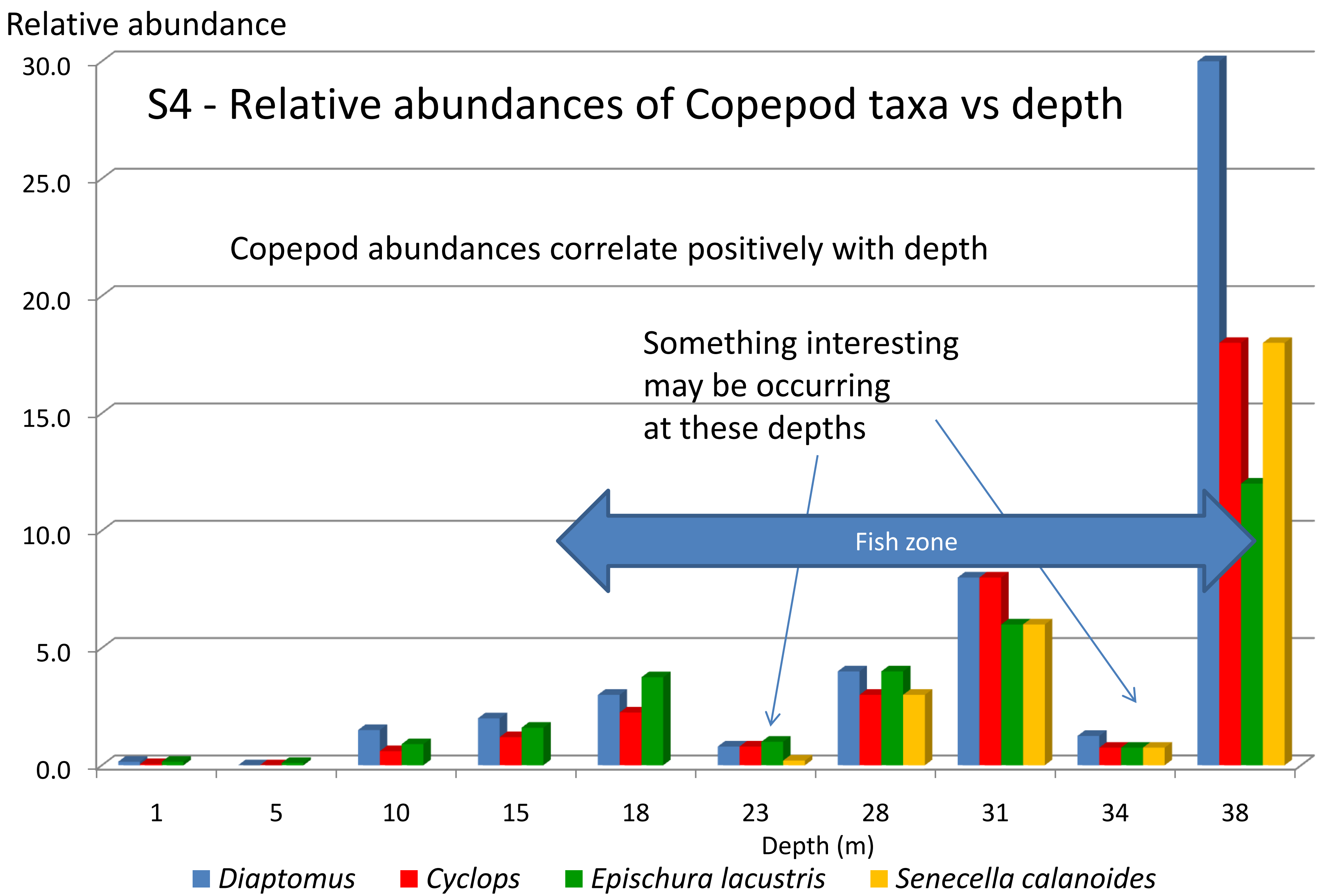
Note: Coloured square indicates that the species/taxon was collected and identified.

Species with very low abundances may be present in the stratum but may not have been collected in the 150 m haul.


S4 - Zooplankton community structure - July 10, 2010
An. / cu. m.
30.0
25.0
20.0
15.0
10.0
5.0
0.0
c - copepods
d - daphnia
b - bosmina
C - Conochilus unicornus
L - Latona setifera
E - Eurycercus
t - trace
- small pop.
+ sizeable pop.
> large pop.
Fish zone
21.3
t
28.7
t
7.0
-cdb
-cdbC
4.1
+c, -dbC
2.3
0.1
-cdb
2.7
1.0
+cdb, -CEL
1.8
8.4
>cdb , -E, tCL
1.6
7.3
0.4
0.2
-cdb, tEC
0.2
0.1
0.4
>cd
1 m
5 m
10 m
15 m
18 m
23 m
28 m
31 m
34 m
38 m
Legend
Bythotrephes
Chaoborus
Mysis
Depth (m)

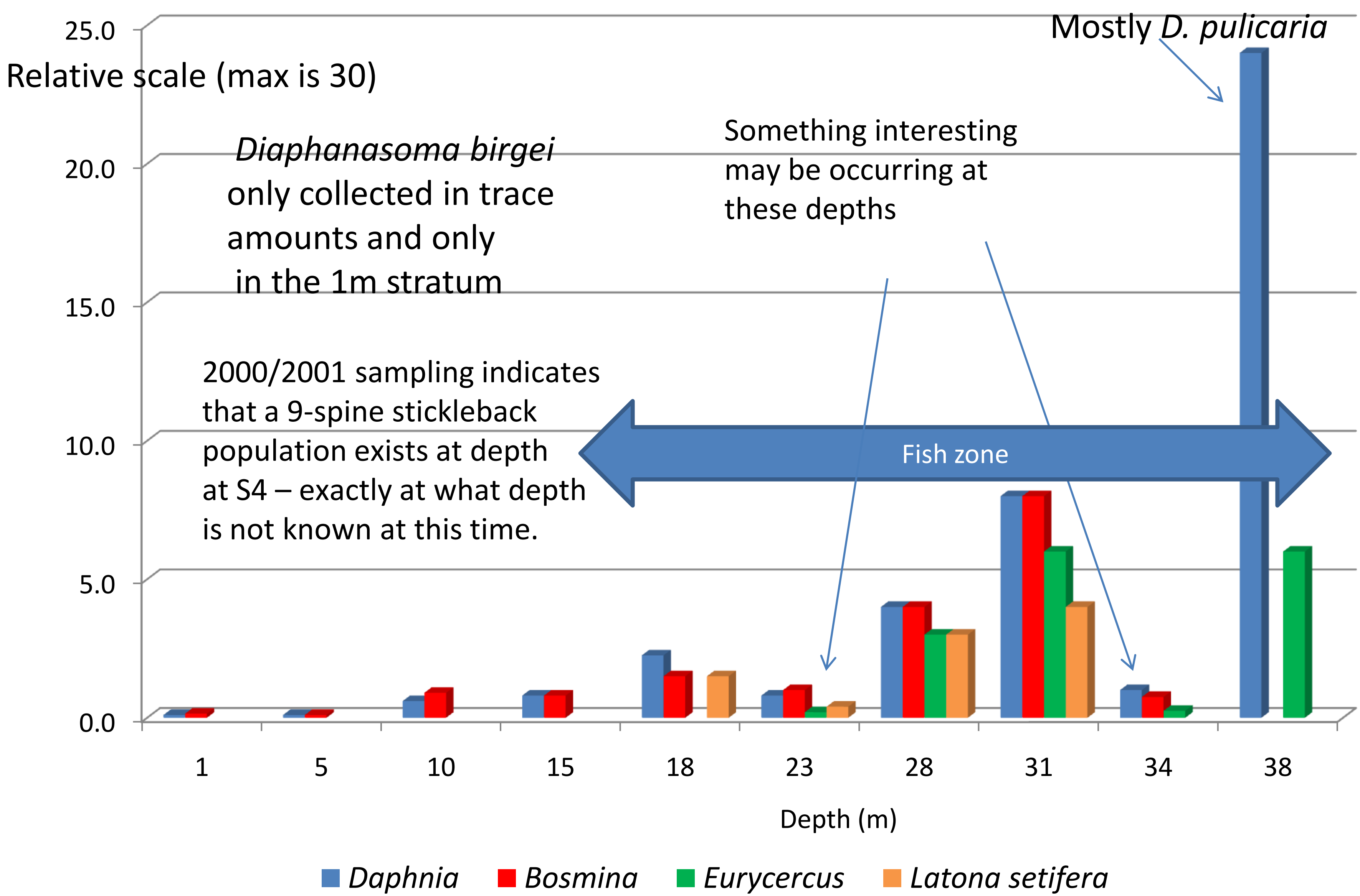
S4 - 2001 - Night / Day *Mysis relicta* abundances

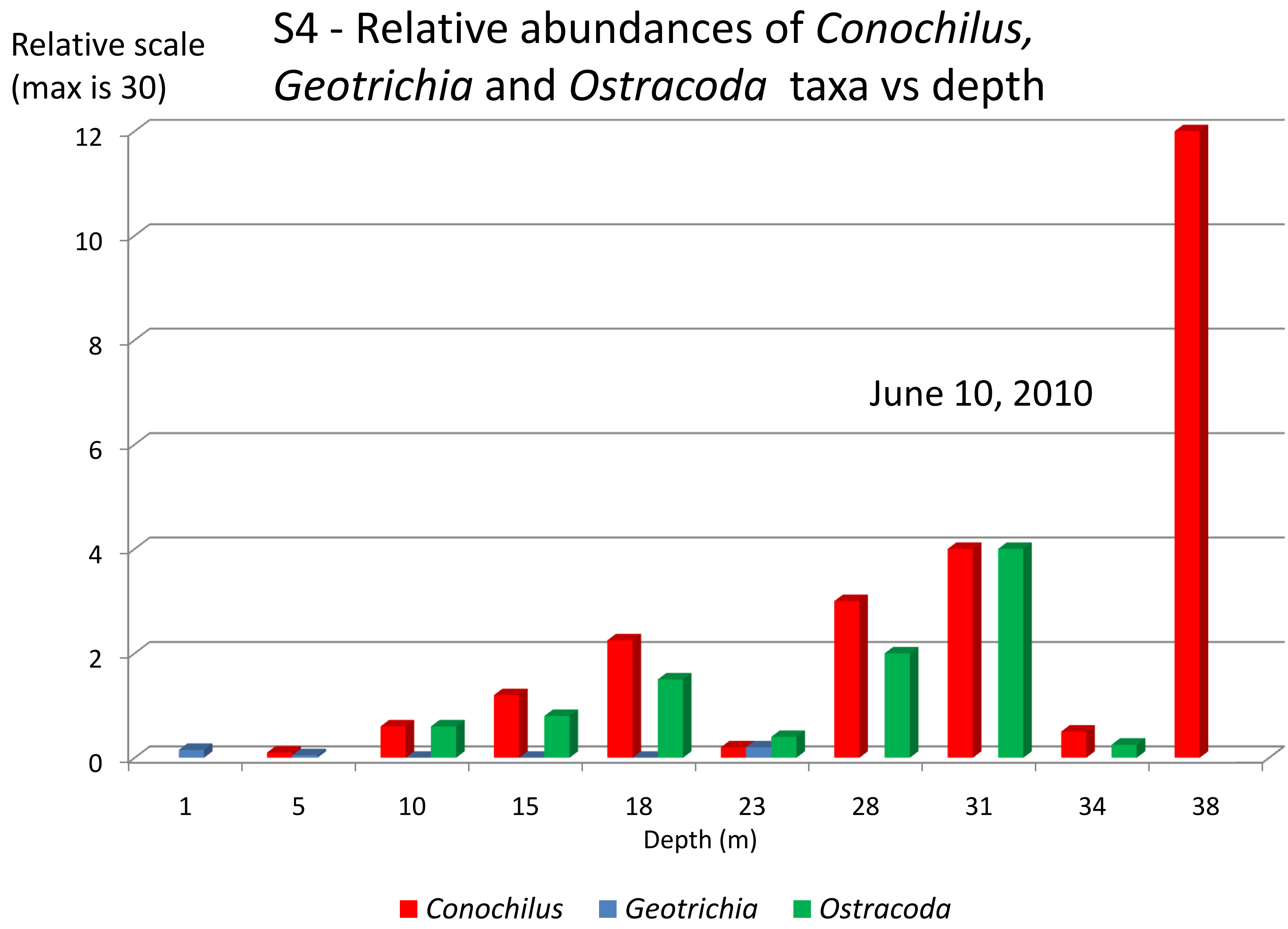




S4 - Relative abundances of Copepod taxa vs depth
Relative abundance
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Copepod abundances correlate positively with depth
Something interesting
may be occurring
at these depths
Fish zone
1
5
10
15
18
23
28
31
34
38
Depth (m)
Diaptomus
Cyclops
Epischura lacustris
Senecella calanoides

S4 - Relative abundances of selected Cladocera taxa vs depth





Relative scale
(max is 30)
S4 - Relative abundances of Conochilus,
Geotrichia and Ostracoda taxa vs depth
12
10
8
6
4
2
0
June 10, 2010
1
5
10
15
18
23
28
31
34
38
Depth (m)
Conochilus
Geotrichia
Ostracoda

Sampling station S4, 2010 summary

1. *Bythotrephes* abundances in the 1m to 10m strata are of the same order of magnitude as that reported in the other sampling stations in the lake. This is puzzling as just below these strata are to be found enormous populations of lake herring and smelt which come to seek out cooler water here to survive the summer. In Harp Lake, lake herring frequently foray into the metalimnion to feed (Young, Ellis, Yan 2009). Evidence suggests that no such mechanism is at work here as the large lake herring / smelt population would quickly crop the *Bythotrephes* population in the 1m to 10m strata. In the summer of 2010, Richart Rowe, Nipissing First Nation biologist, led a crew that set gill nets at depth in the cold-water refuge at S4 to determine the diet of both smelt and lake herring in the refuge. We participated in analyzing a portion of the stomachs collected. There was no evidence of *Bythotrephes* in the stomachs that we looked at.

   Bythotrephes abundances diminish exponentially with depth with abundances of 4 an./m3 and less from 15m downwards. This creates a large volume of water where Bythotrephes abundances are not high enough to seriously crop the zooplankton. S4 Station depth is greater than 50m. Pangle and Peacor (2009) determined that the hunting success of Bythotrephes diminishes with diminishing light availability. Given the relatively dark waters of Lake Nipissing, we feel that this is the reason that Bythotrephes abundances correlate negatively with increasing depth.

Sampling station S4, 2010 summary

1. (continued)

What is difficult to explain is the continued presence of *Bythotrephes* at depth. Bythotrephes consumption of D. mendotae was not detected under low light intensity (<1 µmol·m–2·s–1) (Pangle and Peacor 2009). We sampled to 38m where in Lake Nipissing it must be very dark, yet some *Bythotrephes* remain. At first it was suspected that these would be one-barbs, young emerging from eggs slowly making their way up the water column. However evidence points to a dominance of 2-barbs all the way down with a sprinkling of 1-barbs and 3-barbs. There shouldn't be enough light here to permit successful hunting by *Bythotrephes,* yet there they are. At that depth there is a sizeable *Bosmina* and *Daphnia pulicaria* population. Perhaps *Bythotrephes* can capture this type of prey in the absence of any light.

Sampling station S4, 2010 summary (page 2)

2. *Leptodora* was not collected in large quantity in early July in 2001. In early July 2010 it is still being collected sporadically here at S4 to 38m. Given that in 2001 it was relatively common at depth later in the summer, and demonstrated strong diurnal vertical migration behaviour, it is quite possible that even now, later in the summer, important abundances of *Leptodora* could still exist at depth at S4. This might well be its only refuge in all of Lake Nipissing, and is worthy of further investigation given the watershed-level replacement of *Leptodora* by *Bythotrephes* that is presently taking place in the Canadian Shield (Weisz / Yan 2010)

3. Not surprisingly, given that *Bythotrephes* abundances correlate negatively with depth at S4, zooplankton populations, overall, correlate positively with depth. Something bizarre is going on at d=34m and at d=23m. At first we thought that the net might have fouled given the fact that most taxa are severely reduced in abundance in these strata. However, a look at the *Bythotrephes* abundances at this level seems to indicate that the hauls were fine and that for some reason or other, we simply have much less zooplankton at these levels. More investigation is required.

Sampling station S4, 2010 summary (page 3)

4. **Copepod summary:**
   *Diaptomus (*mainly *oregonensis), Cyclops* and *Epischura lacustris* become more abundant with increasing depth. *Senecella calanoides*, a large Copepod, appears in the collections at d>= 23m. *Diacyclops bicuspidatus thomasi*, was only collected sporadically in 2010 at the other sampling stations with *Mesocyclops edax* replacing it as the most common and ubiquitous *Cyclops.* At S4 *Diacyclops bicuspidatus thomasi* remains the most common and abundant *Cyclops*, with *M. edax* only being collected sporadically, as it was in 2001 throughout all the 2001 sampling stations. At depths >= 18m, two new *Cyclops* species make their appearance, namely *Eucyclops elegans* and *Cyclops scutifer. Epischura lacustris*, more common in 2010 than in 2000/2001 in the bulk of Lake Nipissing, was collected at S4 at all depths. *Skistodiaptomus oregonensis* remains the most common Diaptomid, with a spattering of *Leptodiaptomus minutus.* This has not changed from 2001 observations. Immature copepodid forms correlate positively with increasing depth. This makes it hard to find CVI copepodid forms at depth for species identification.

Sampling station S4, 2010 summary (page 4)

5. Cladocera summary:

Contrary to what was observed in the other sampling stations, *Daphnia galeata mendotae* is neither the most common nor the most abundant *Daphnia* at S4. *Daphnia longiremis,* collected very sporadically at the other sampling stations, was collected at S4 at all depths. *Daphnia pulicaria,* either not collected or collected sporadically in small amounts at S5, is very abundant in the 38m stratum and an important component of the *Daphnia* mix at depths >= 23m. *Daphnia retrocurva,* the most abundant and ubiquitous *Daphnia* in 2001, was not collected at S4. This may imply that the bottom sediments at S4 are unsuitable habitat for *D. retrocurva* resting eggs, and that the populations of *D. retrocurva* that were found here in 2001, were hatched in the nearby vicinity, but not directly at S4. Sandgren and Lehman 1990, and Branstrator and Lehman 1991, also report the loss of *D. retrocurva,* and reduced abundances of both *Daphnia pulicaria* and *Leptodora* in Lake Michigan after the invasion of *Bythotrephes* .

Sampling station S4, 2010 summary (page 5)

5. Cladocera summary (continued)

Bosmina is an important food source for smaller fish. At S8, by mid-June 2010, it was relegated to trace amounts and only collected sporadically for the rest of the summer. Here at S4, *Bosmina* was collected from the 1m stratum all the way down to the 34 m stratum. Its abundance correlated positively with depth, with abundances becoming appreciable in the 31m stratum. After that abundances declined with increasing depth, disappearing from the 38 m collection. *Bosmina longirostris* was the most common form. *Eubosmina* is also present, as evidenced by some individuals not having a mucro.

Eurycercus was collected at all depths for d>=23m, and became quite common in the collections for d>=28m. *Latona setifera* was collected from 18 to 31m.

Sampling station S4, 2010 summary (page 6)

6. *Chaoborus,* the midge fly larva is a voracious predator and makes an appearance for depths d>= 18m. It is most abundant in the 28 and 31m strata. It too suffers a great abundance loss at the 34m level, and is therefore not responsible for what is going on at the 34m level. Despite its appetite for zooplankton, it does not seem able to crop the other zooplankton species appreciably in the 28m and 31m strata.

7. There exists a population of 9-spined sticklebacks at depth at S4 (Filion 2002). The exact depth at which this population is active is unknown at this time.

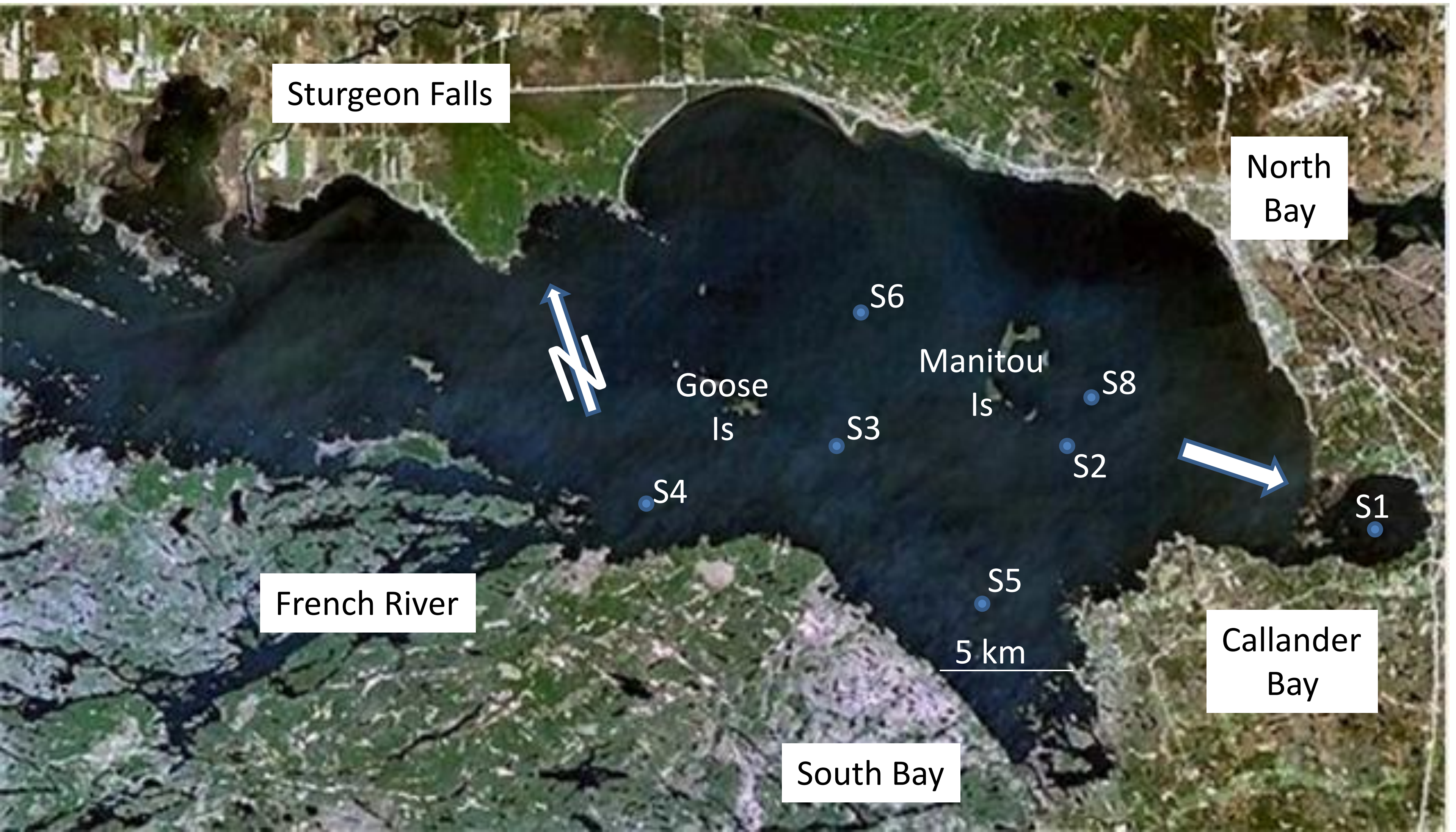
8. On July 10, 2010 *Mysis relicta*, the freshwater shrimp, was encountered at S4 starting at 38m. In 2001 it was collected during overnight sampling starting at depths of 20m and greater, and in the daytime at depths of 25 m and greater. The difference in collection depths my depend on the dates of collection. In 2001, *Mysis* was collected on the 17th and 19th of August, whereas in 2010, collections were made on July 10th. Results from 2001 show that in Lake Nipissing *Mysis* demonstrate little diurnal vertical migration behaviour.

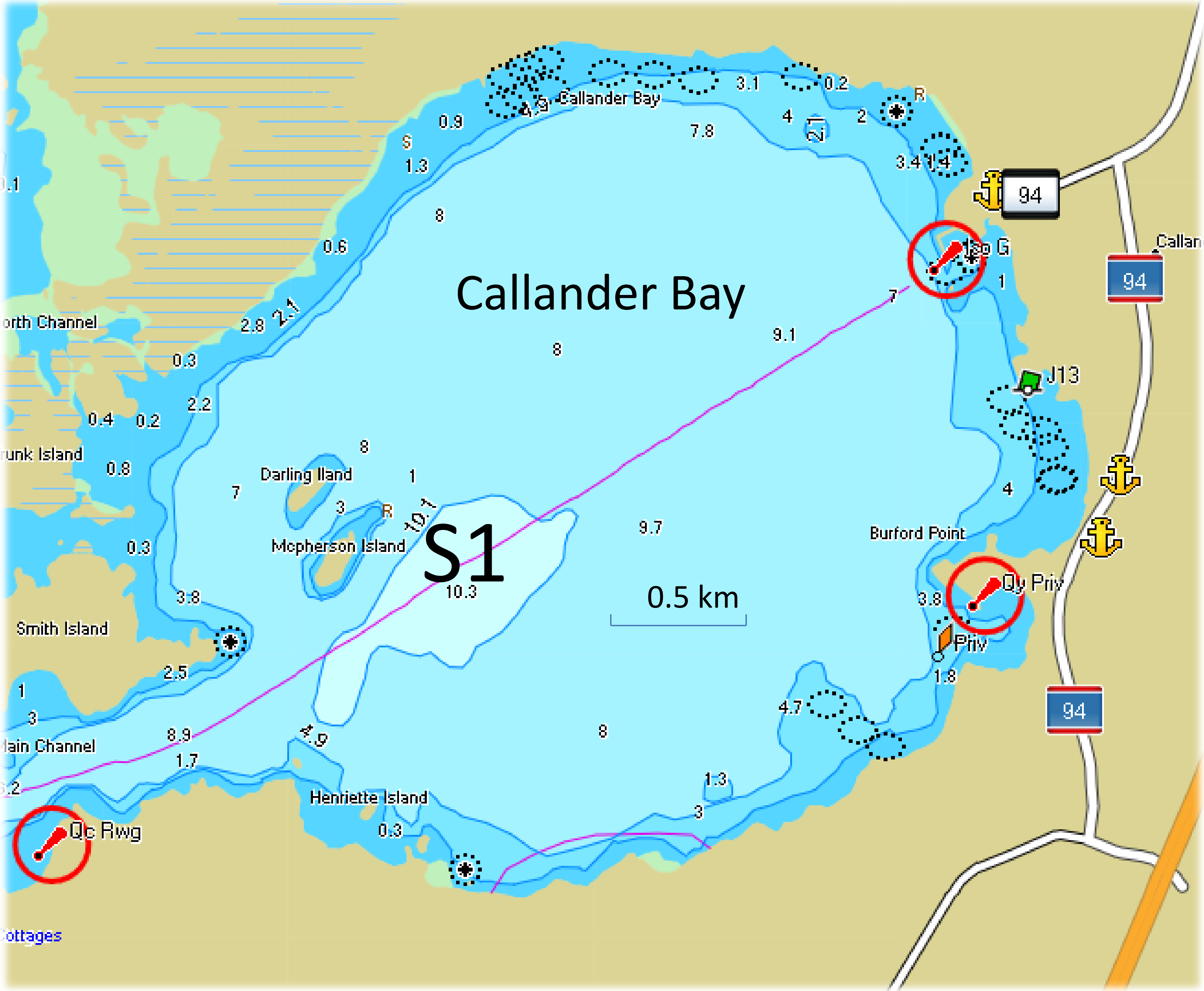
Sampling station S4, 2010 summary (page 7)

9. *Geotrichia* was collected at this site in trace quantities in the 1, 5 and 23m strata. It is probably present in very low abundances in most strata. *Conochilus* was collected in all strata other than the 1m stratum (where it probably also occurs in low quantities). Interestingly, it correlates positively with depth at S4. Ostracoda were collected from 10m to 34m inclusively. The abundance of ostracoda is low and correlates positively with increasing depth.

We are slowly deciphering the zooplankton community structure at S4. Given the enormous quantity of fish that also use this cold-water refuge, the same level of detail is required with respect to the fish if we are to start to understand the important food web dynamics that take place in this unique, and critical area of Lake Nipissing. “Who lives where?” must be looked at. “Who eats whom and does it involve vertical migrations in which to feed?” must be investigated. “Do fish living outside the cold-water refuge come to the refuge for an easy meal” is an important question. Anecdotal evidence suggests that large walleye and possibly pike do come to the refuge to feed on the large population of lake herring and rainbow smelt that occupy the refuge come summer.

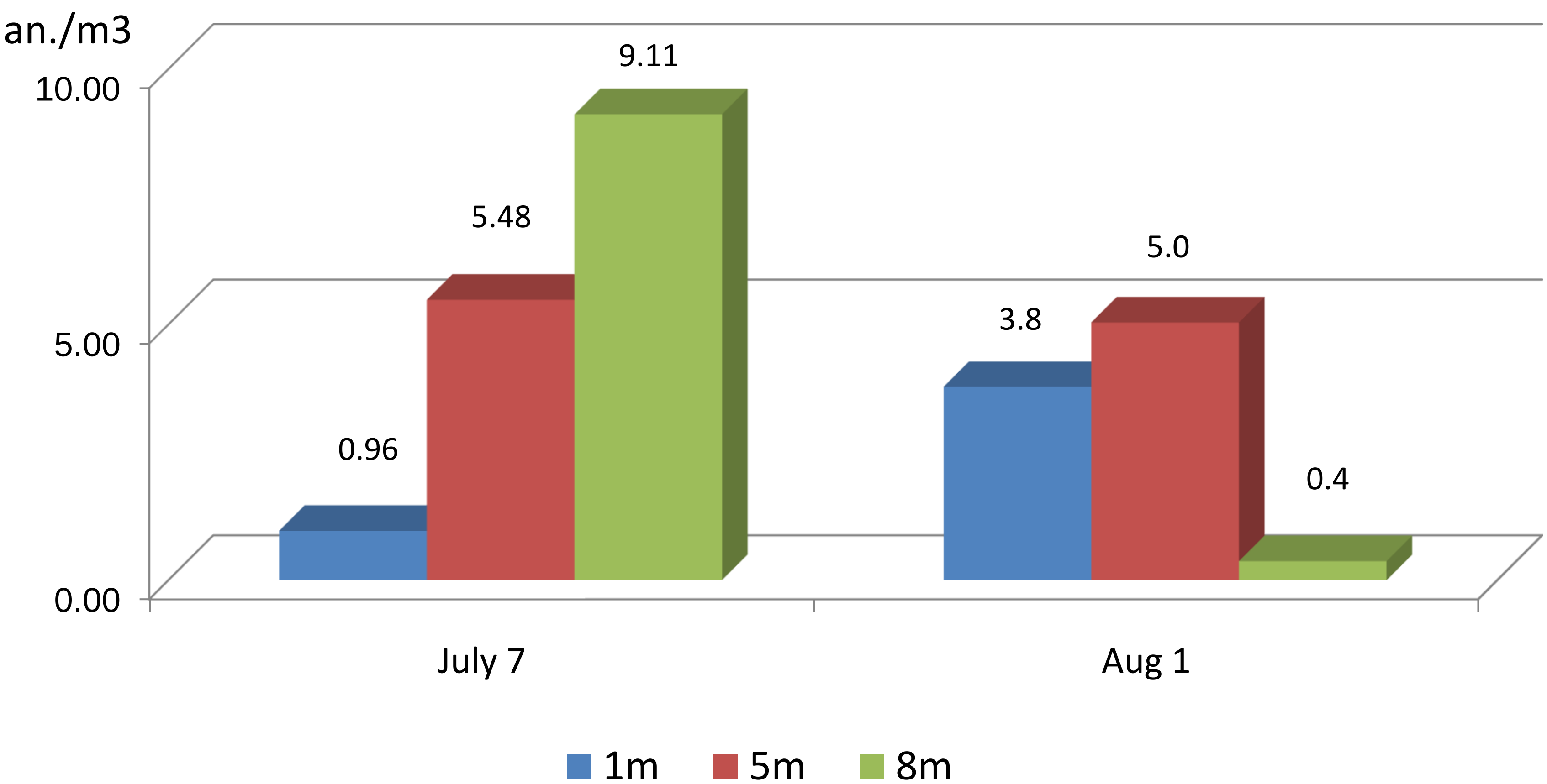
S1 - Zooplankton community structure
Callander Bay

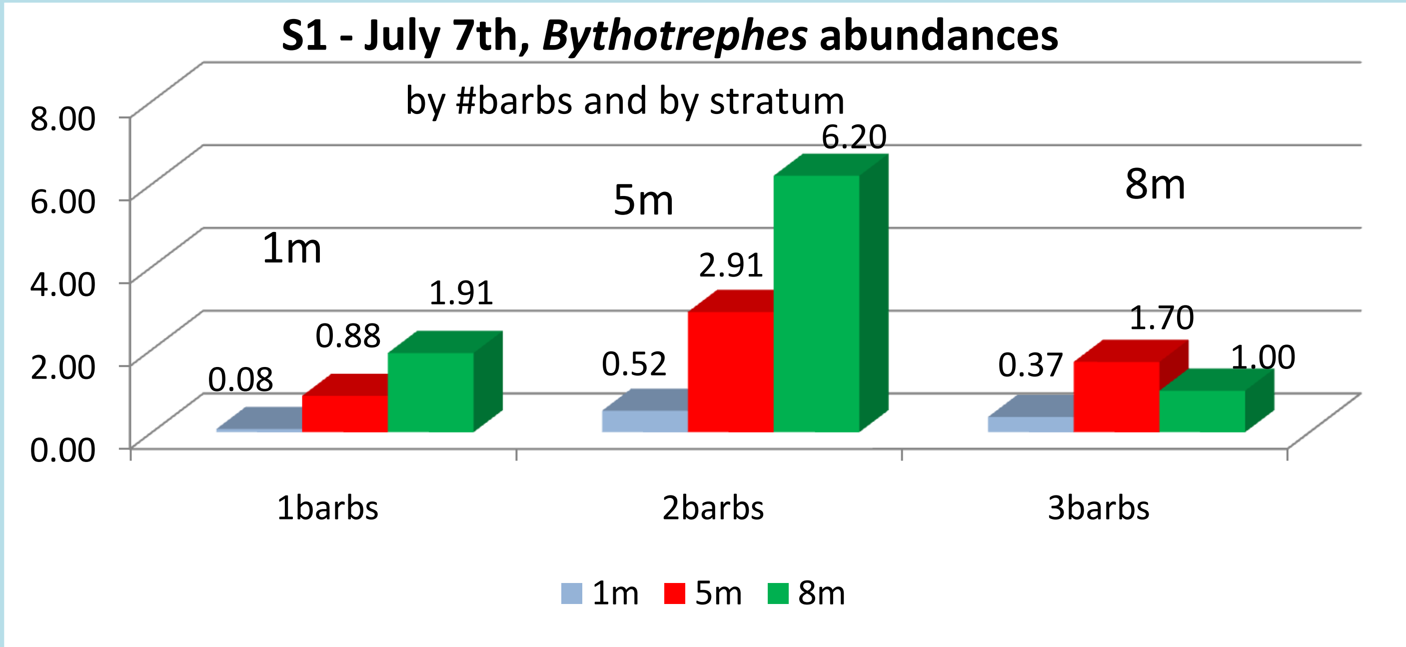


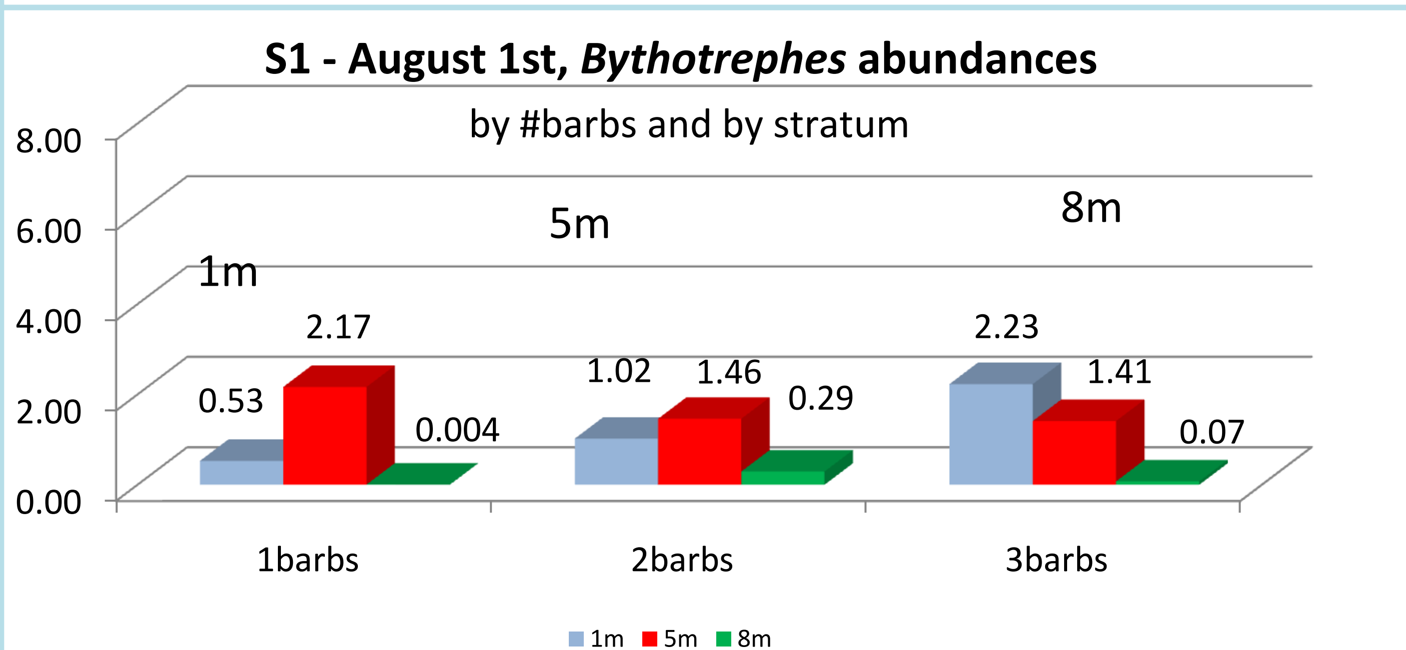

Callander Bay
S1
0.5 km
Callander Bay
North Channel
Trunk Island
Darling lland
Mcpherson Island
Smith Island
Main Channel
Henriette Island
Burford Point
J13
Qy Priv
Priv
Qc Rwg
94
Cottages

S1 - Callander Bay

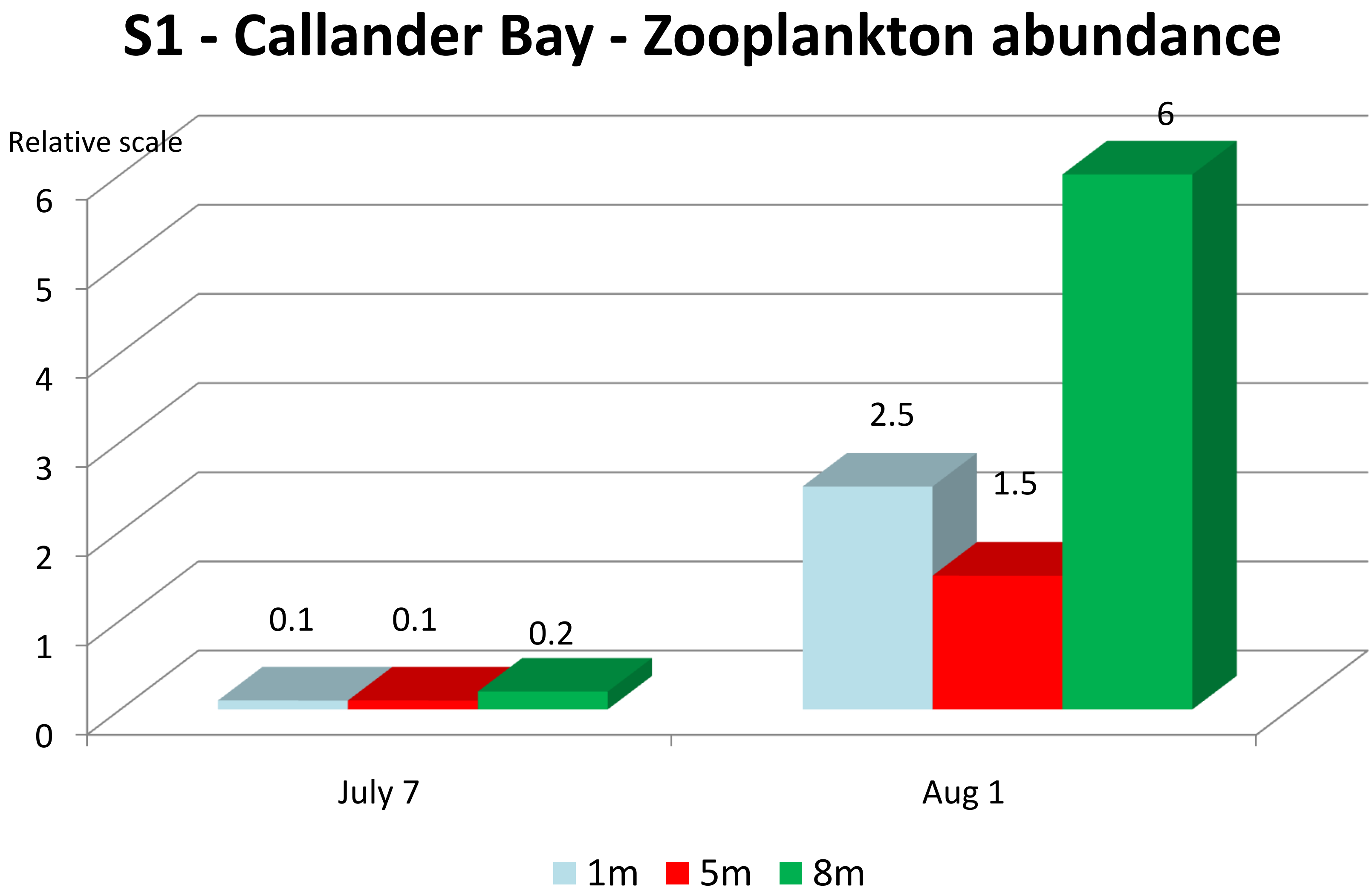
Bythotrephes abundance by date & by stratum




S1 - July 7th, *Bythotrephes* abundances
by #barbs and by stratum
8.00
6.00
4.00
2.00
0.00
1m
5m
8m
0.08
0.88
1.91
0.52
2.91
6.20
0.37
1.70
1.00
1barbs
2barbs
3barbs
1m 5m 8m


S1 - August 1st, *Bythotrephes* abundances
by #barbs and by stratum
8.00
6.00
4.00
2.00
0.00
1m
5m
8m
0.53
2.17
0.004
1.02
1.46
0.29
2.23
1.41
0.07
1barbs
2barbs
3barbs
1m 5m 8m


SI Jul 7
1m
SI Jul 7 5m
SI Jul 7
8 m
WHIRL-PAK
CAL Bay
SI 1m Aug 1
SI Cal Bay
Aug 1 5m
SI Aug 1 2010
8 m


S1 - Callander Bay - Zooplankton abundance
Relative scale
6
5
4
3
2
1
0
0.1
0.1
0.2
2.5
1.5
6
July 7
Aug 1
1m
5m
8m

S1 -2010 – Zooplankton community specifics – Callander Bay

Date	D (m)	zoo	Epi	Diap	Orego	Cyc	DBT	Medax	Cono	Geo
July 7	1	0.1	1	1	-	0	-	-	1	1
July 7	5	0.1	3	3	*	0	-	-	0	2
July 7	8	0.2	3	3	*	2	-	*	1	0
Aug 1	1	2.5	1	5	*	5	-	*	4	4
Aug 1	5	1.5	2	5	*	5	-	*	5	3
Aug 1	8	6	1	1	*	4	-	*	0	0
Date	D (m)	zoo	Daph	DGM	Dret	Bos	Lepto	Diaph	Holo	Ostr
July 7	1	0.1	3	*	-	1	4	0	0	4
July 7	5	0.1	3	*	1 only	0	4	0	1	3
July 7	8	0.2	2	*	-	0	3	0	0	2
Aug 1	1	2.5	2	*	-	0	0	1	0	1
Aug 1	5	1.5	3	*	-	0	0	1	0	1
Aug 1	8	6	5	*	-	0	0	0	0	0

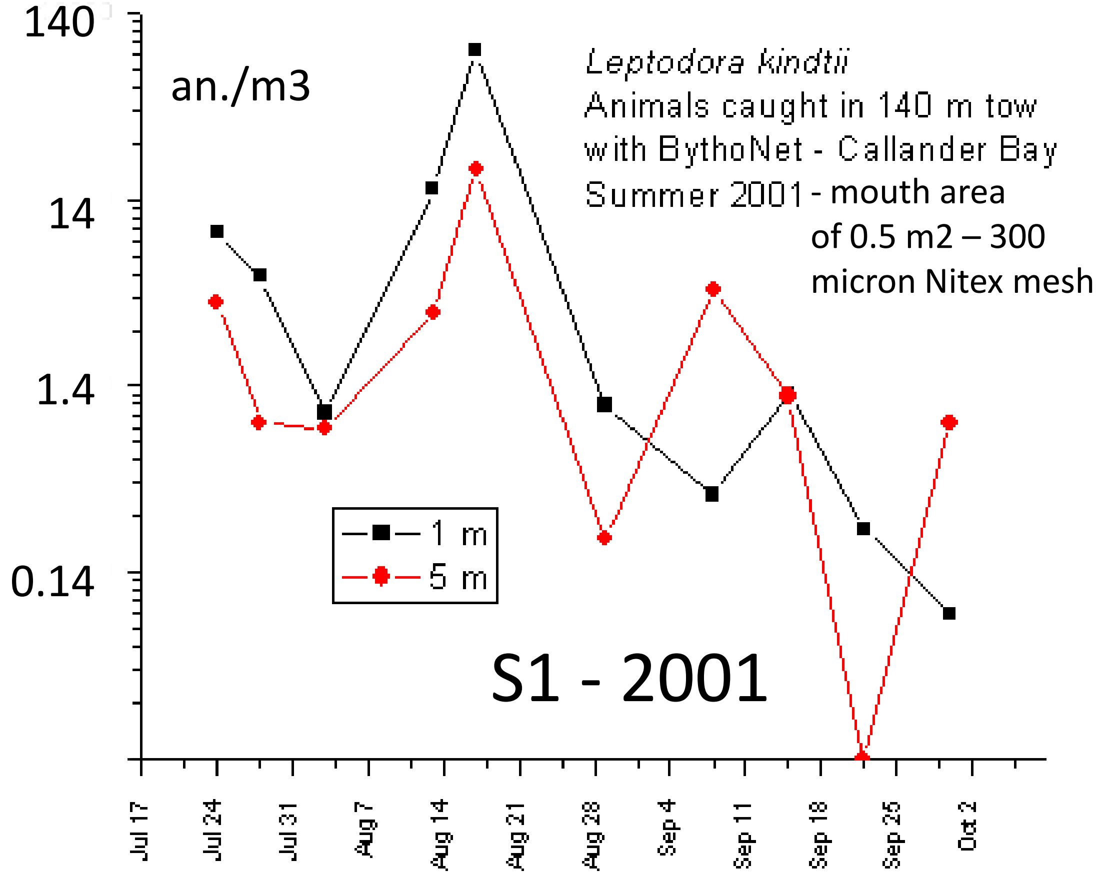
Epi – *Epischura lacustris*
Diap – *Diaptomus*
Orego – *Skistodiaptomus oregonensis*
Cyc – *Cyclops sp.*
DBT – *Diacyclops bicuspidatus thomasi*
Medax – *Mesocyclops edax*

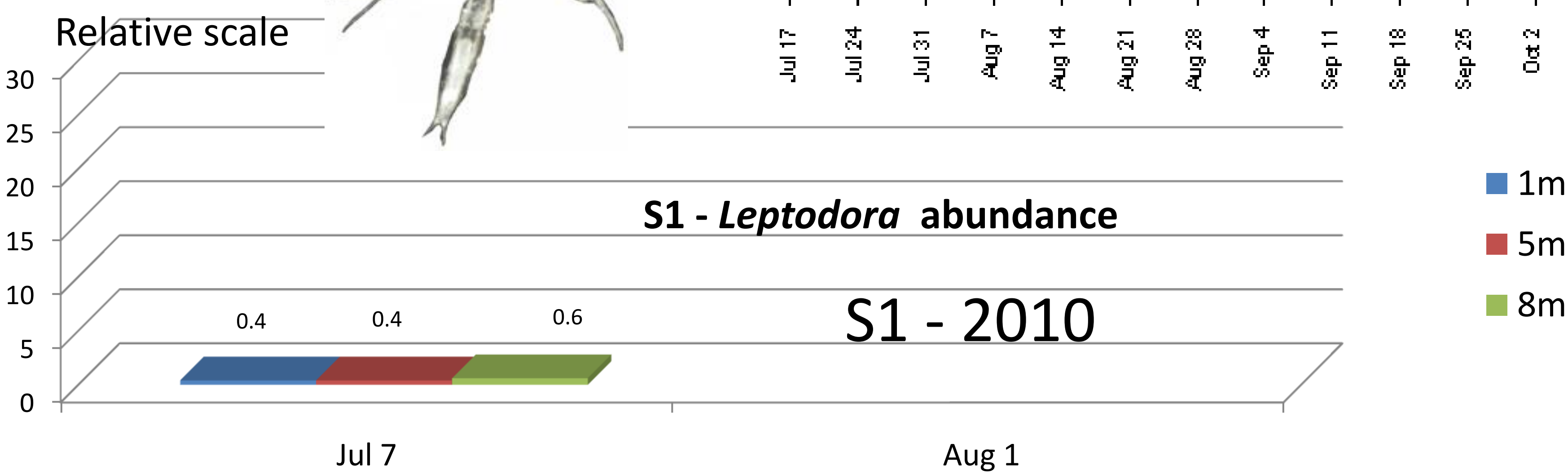
Cono – *Conochilus unicornis*
Geo – *Geotrichia*
Daph – *Daphnia sp.*
DGM – *Daphnia galeata mendotae*
Dret – *Daphnia retrocurva*
Bos – *Bosmina sp.*

Lepto – *Leptodora kindtii*
Diaph – *Diaphanasoma birgei*
Holo – *Holopedium gibberum*
Ostr – *Ostracoda sp.*

S1- *Leptodora kindtii*

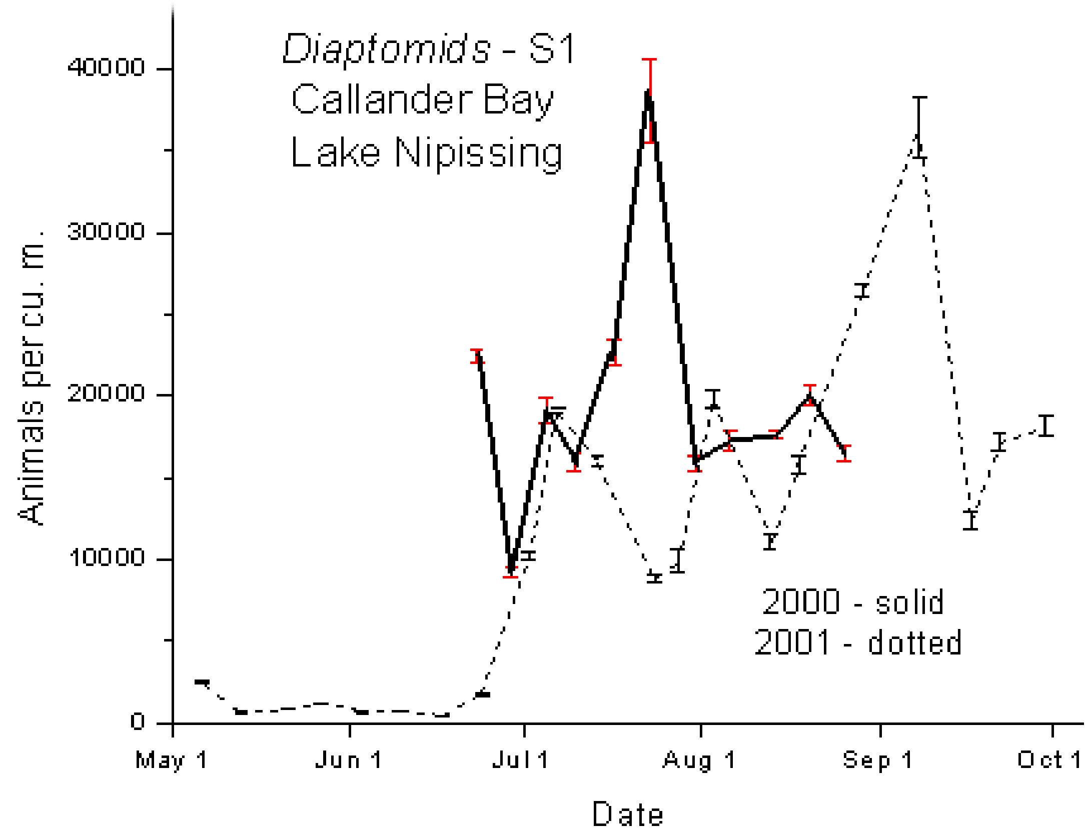
In 2000/2001 *Leptodora* was quite abundant reaching abundances of over 100 an./m3 in mid-August. In 2010, *Leptodora* is only present in trace amounts in early July, and is not collected Aug. 1st.

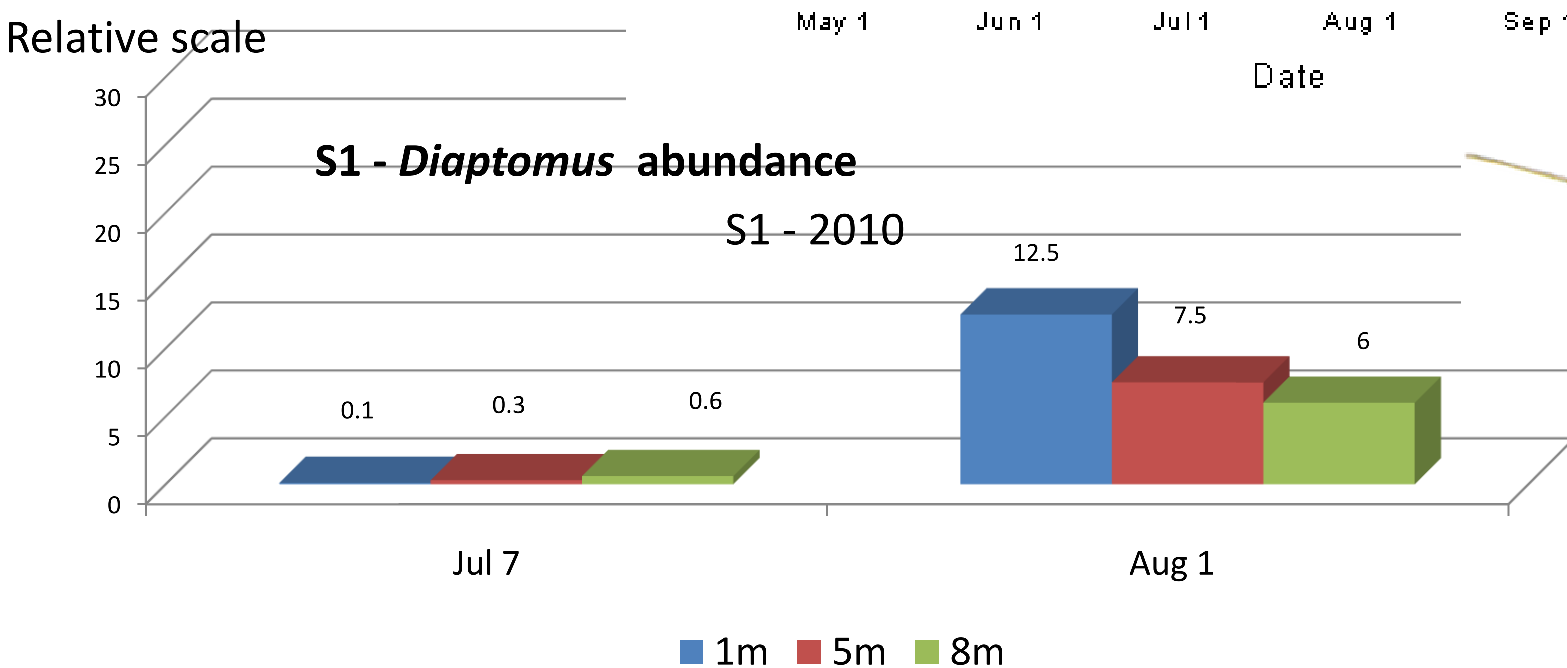




S1- *Diaptomids*

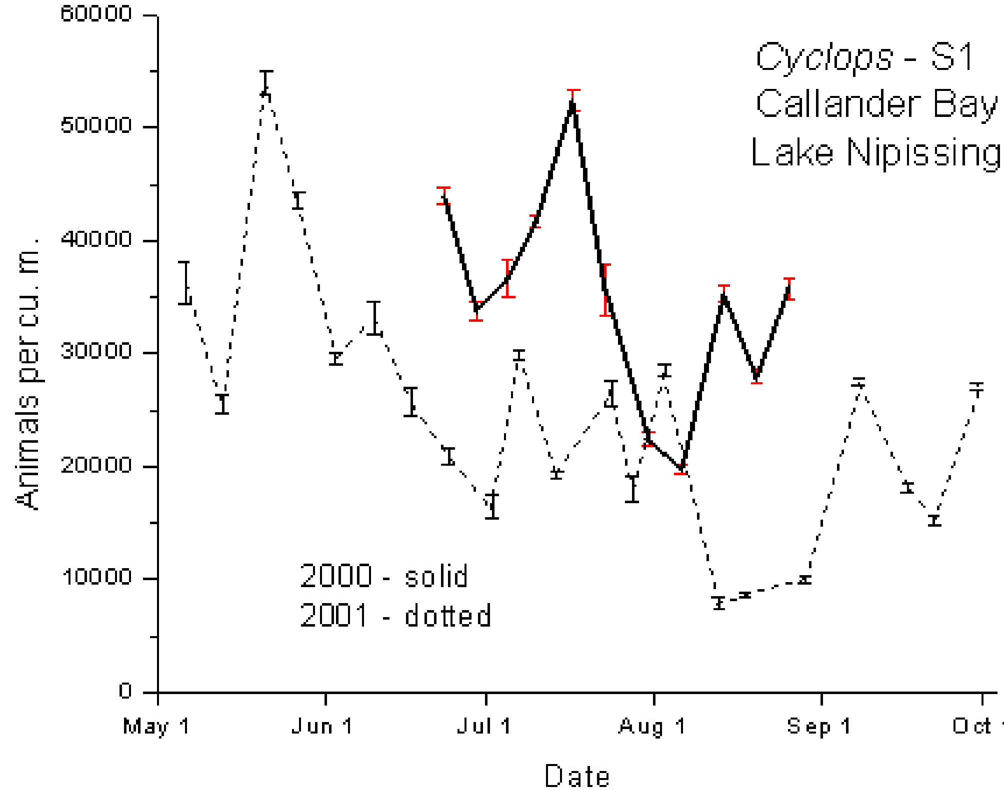
By the end of the 1st week of July *Bythotrephes* had driven *Diaptomids* at S1 to trace amounts. Historicaly abundances at this time were in the 15000 an./m3 range. By the 1st of August the *Diaptomids* are recovering somewhat.



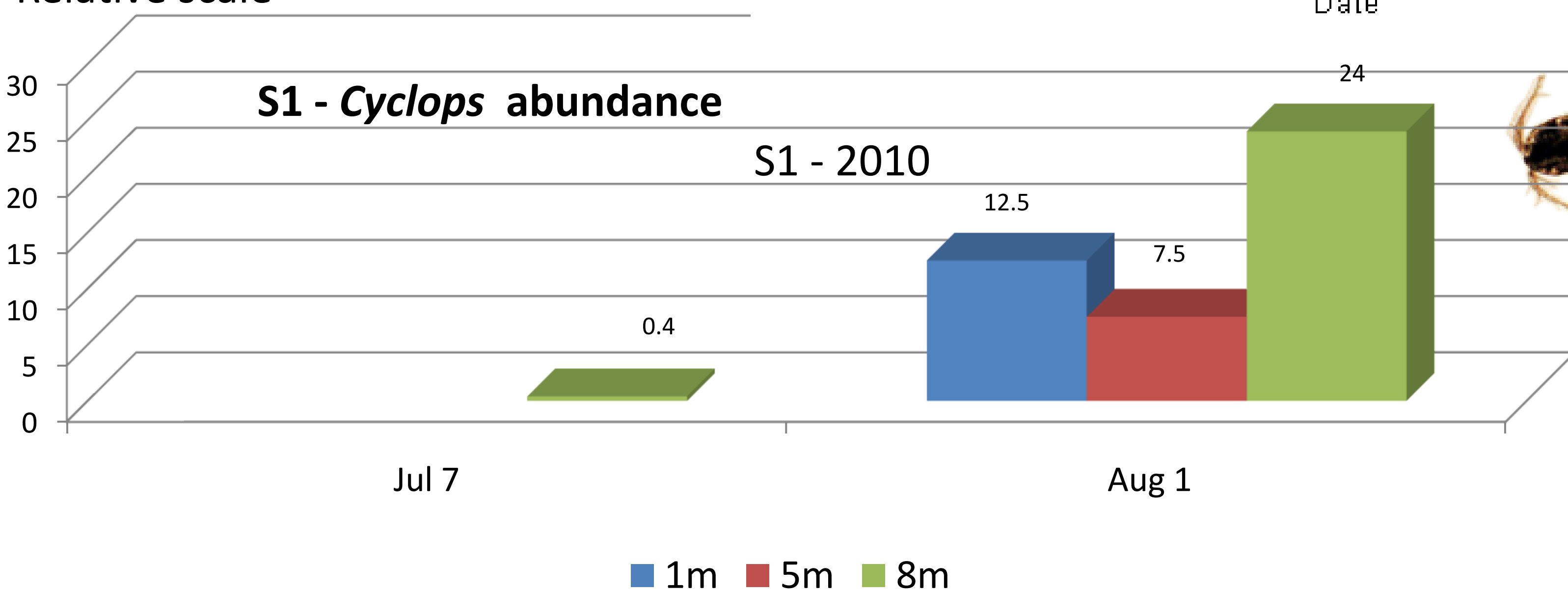


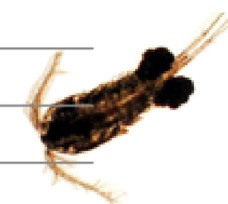
S1- *Cyclops*

By the end of the 1st week of July *Bythotrephes* had driven *Cyclops* at S1 to trace amounts. Historically abundances at this time were in the 20000 to 40000 an./m3 range. By the 1st of August the *Cyclops* are recovering somewhat.



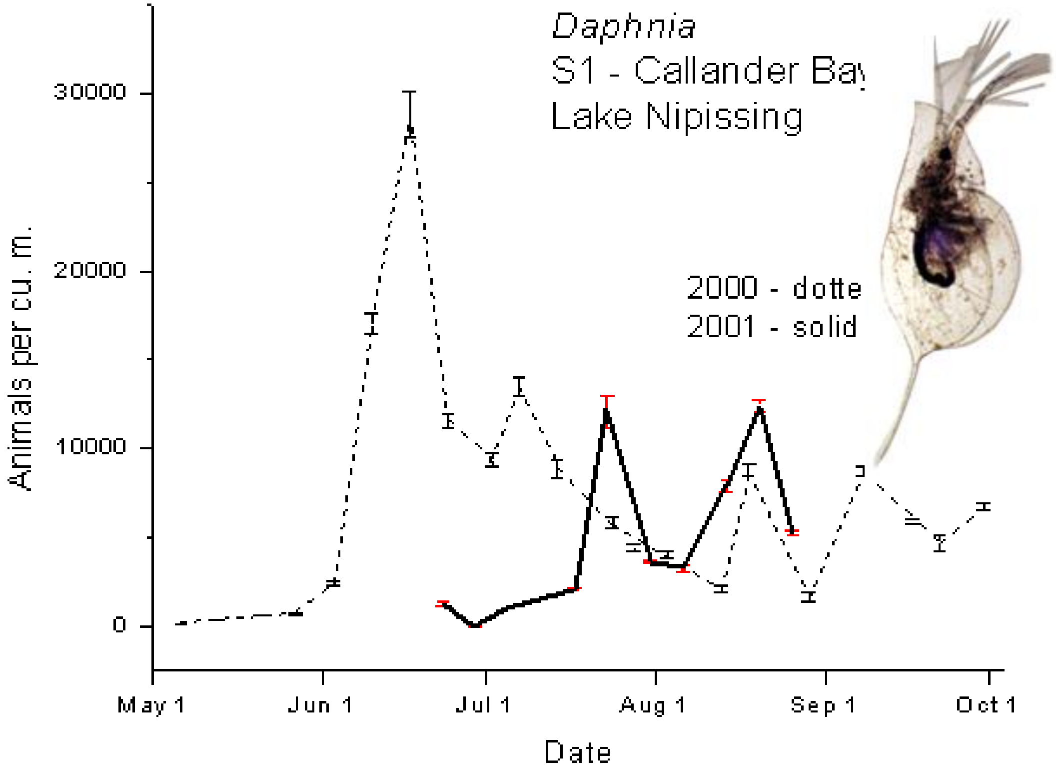
Relative scale



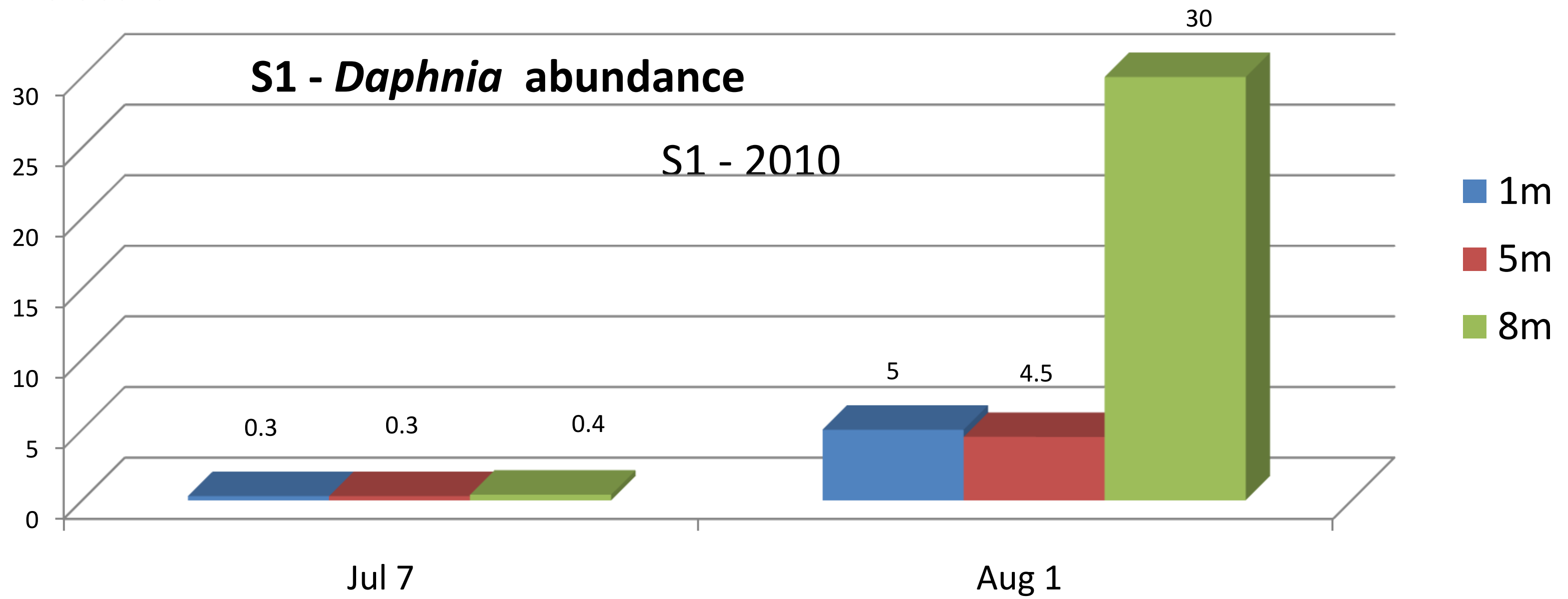


S1- *Daphnia*

By the end of the 1st week of July *Bythotrephes* had driven *Daphnia* at S1 to trace amounts. Historically abundances at this time were variable but typically in the 5000 an./m3 range. In 2010, by the 1st of August *Daphnia* were very abundant at depth. In 2001 only *D. retrocurva* was collected at S1. In 2010 only one *D. retrocurva* individual was collected, the rest being *Daphnia galeata mendotae.*

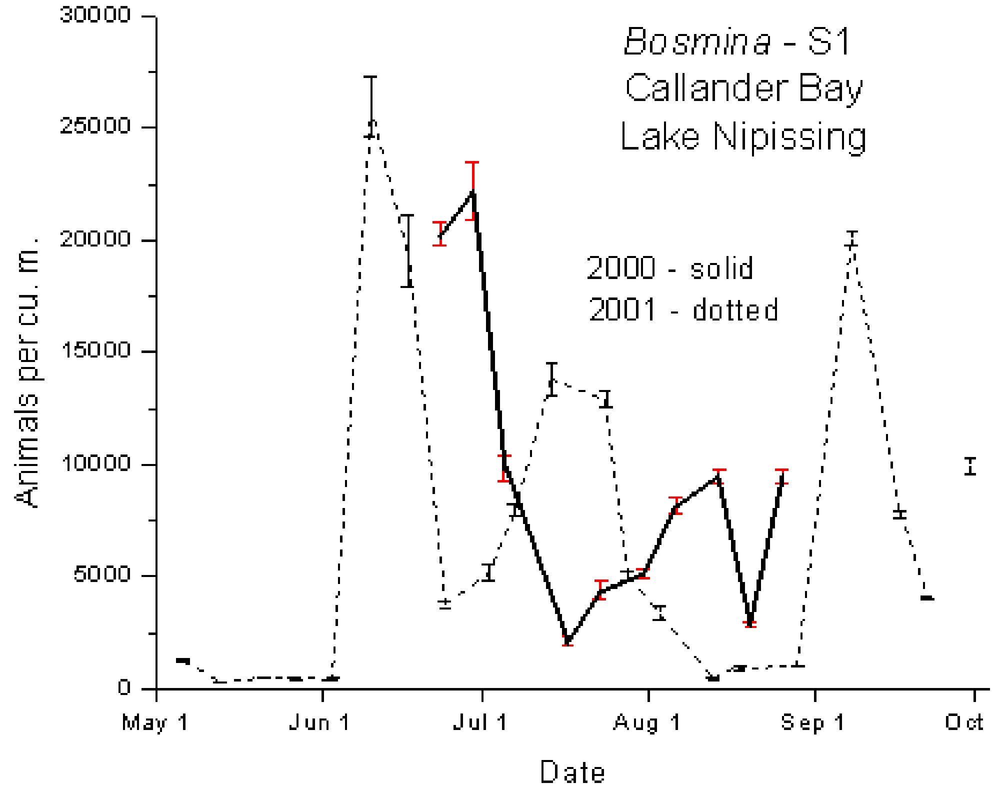


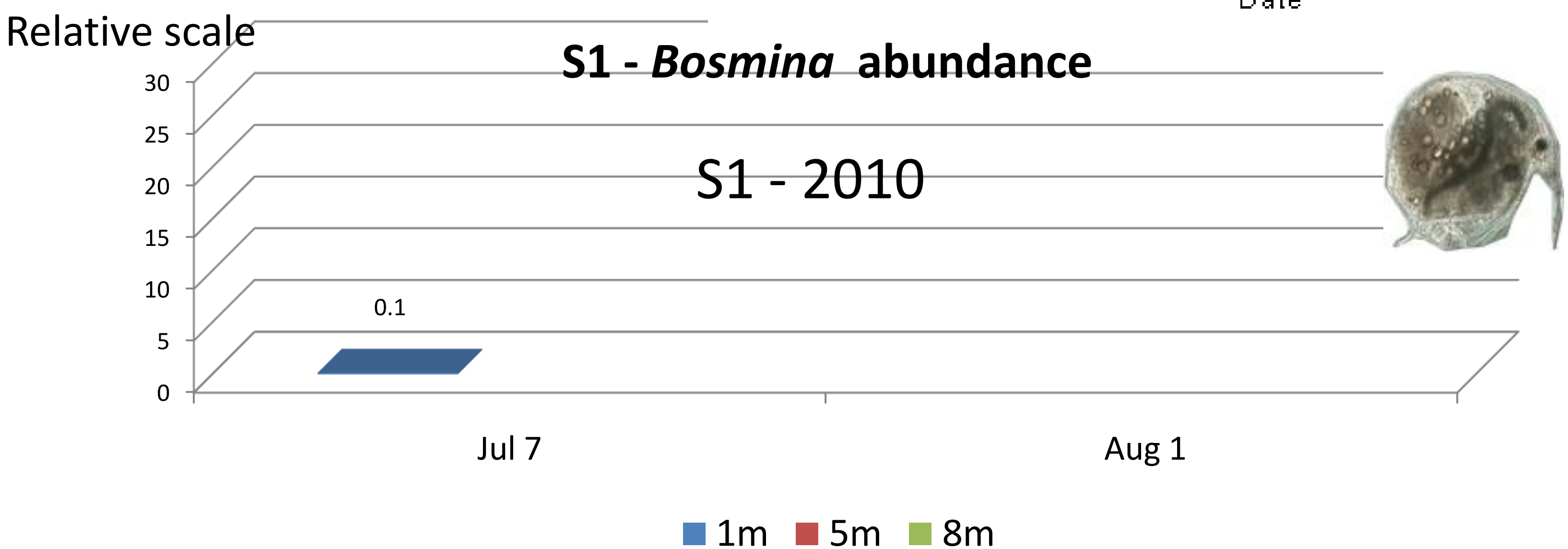
Relative scale



S1- *Bosmina sp.*

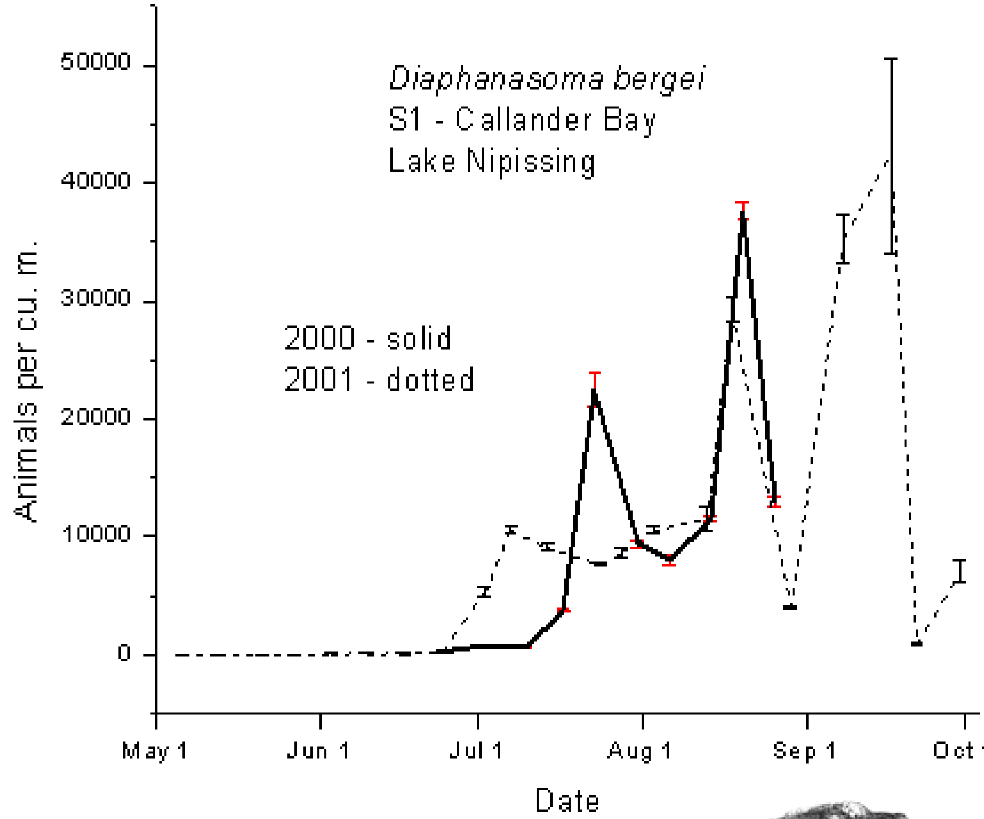
By the end of the first week of July 2010, *Bythotrephes* had pretty well eliminated the *Bosmina sp.* from Callander Bay. They remain absent from the collections on Aug. 1st. In 2000/2001 their average abundances come July were in the 5000 to 20000 an./m3 range. The 'U' shaped curve from 2001 may imply that *Bosmina* may serve as a food source for juvenile and larval fish who move on to other prey as they reach a larger size.

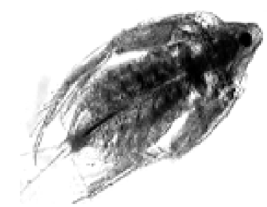




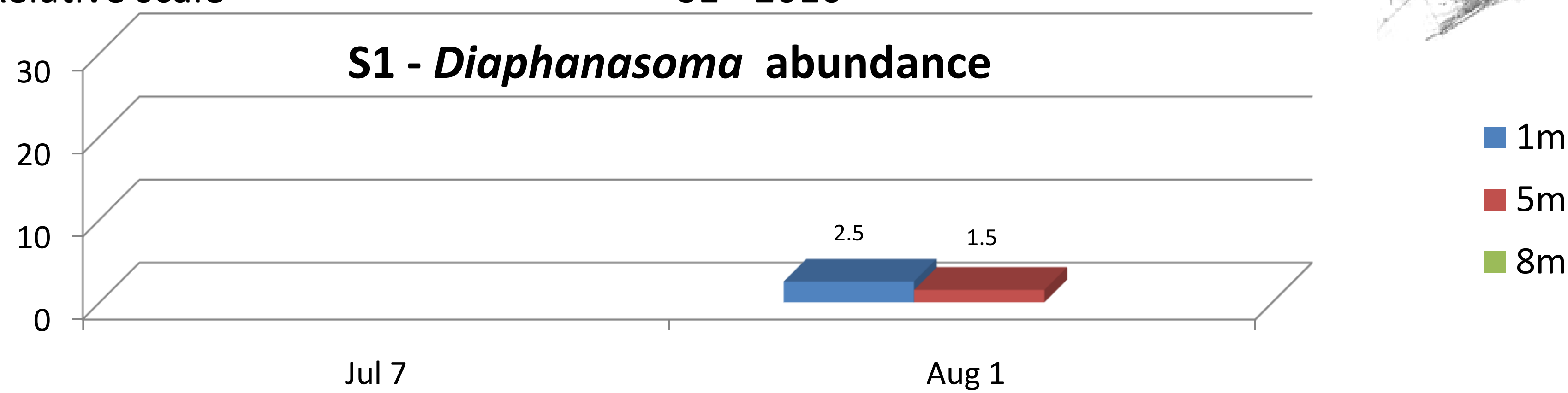
S1- *Diaphanasoma birgei*

Historically *Diaphanasoma* at S1 was a highly variable species, sometimes attaining abundances as high as 40000 an./m3, only to almost disappear from the collections the week after. Collections in 2000/01 were made using vertical hauls. This may imply horizontal patchiness. Populations were usually small at the beginning of July, but then increased to an average of 10000 an./m3 come the first of August. In 2010, *Diaphanasoma* was not collected on July 7th, 2010 and showed little sign of becoming abundant on the 1st of August. It was absent from the collections at the 8m stratum. *Bythotrephes* may be keeping this species at low abundance levels at S1.



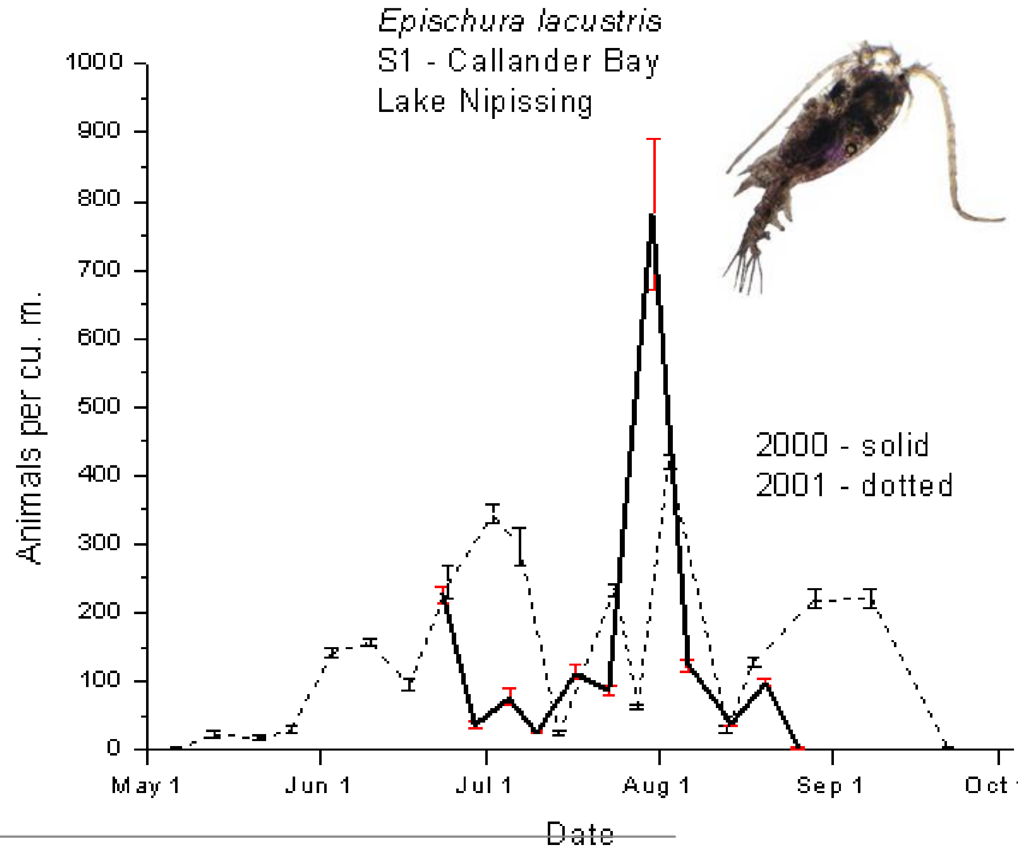


Relative scale S1 - 2010

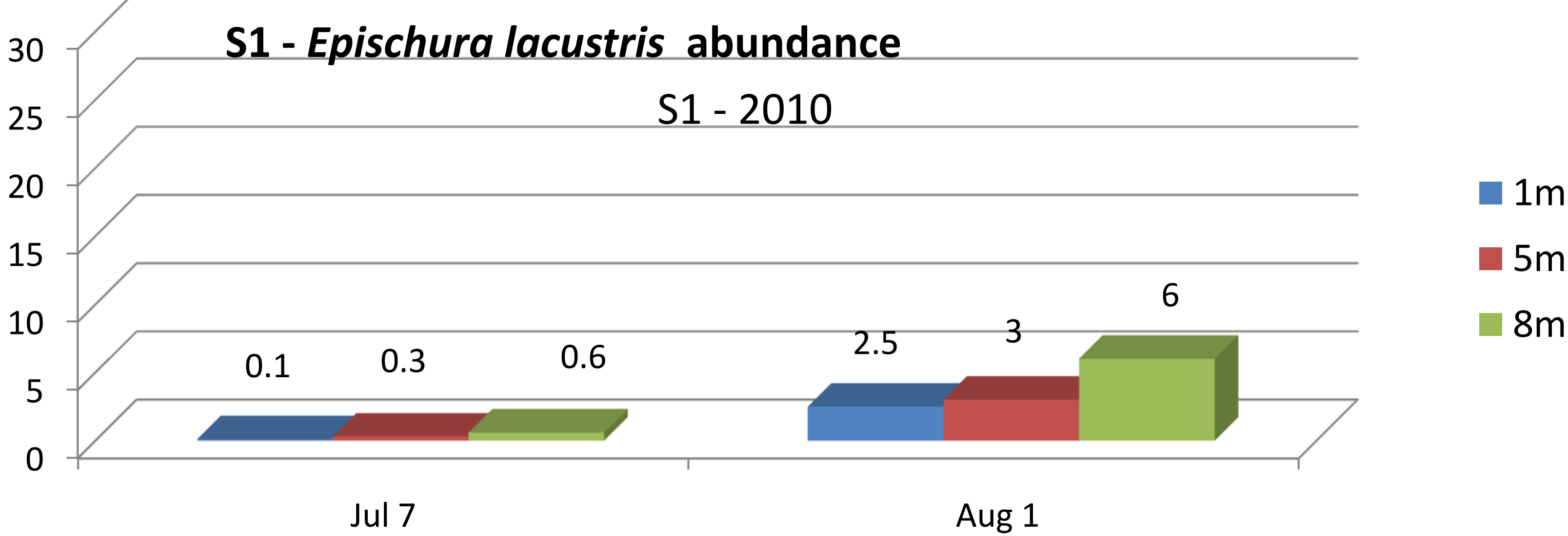


S1- *Epischura lacustris*

In 2000/2001 *Epischura* was never very abundant. It had a tendency to increase in abundance towards the 1st of August. The same trend is seen in 2010. Being a larger Copepod it may be able to better defend itself against *Bythotrephes* than many of the other zooplankton species present at S1

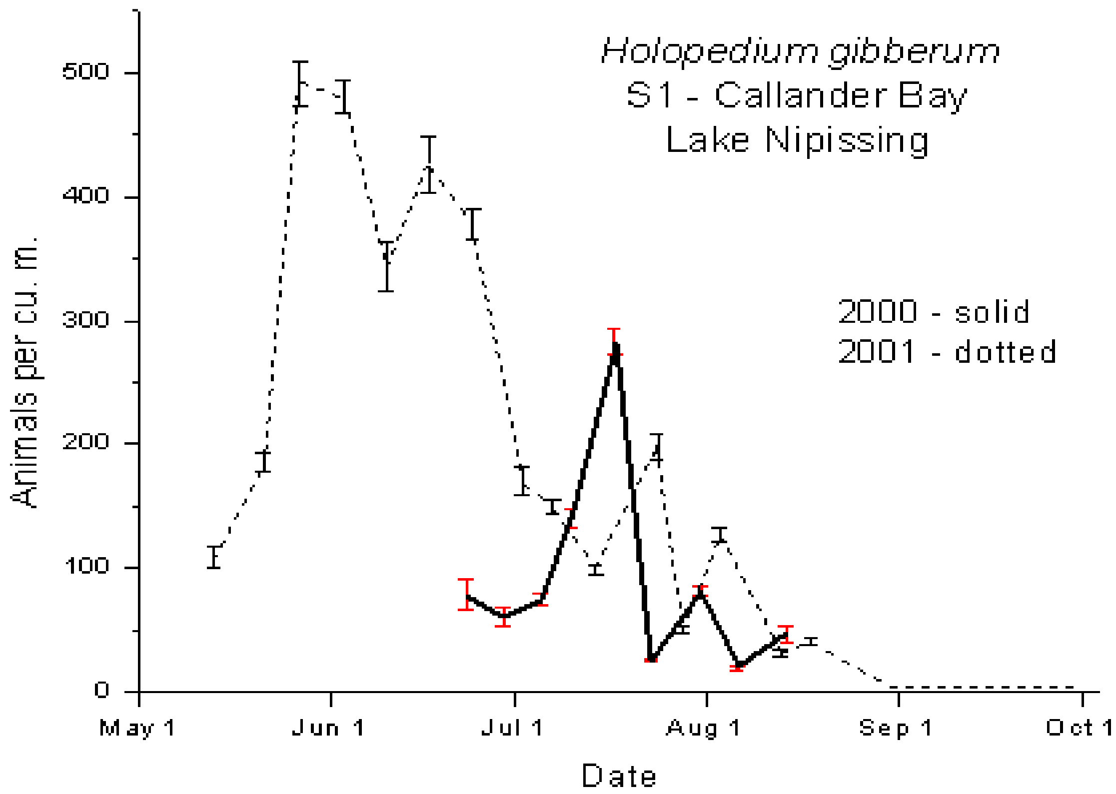


Relative scale



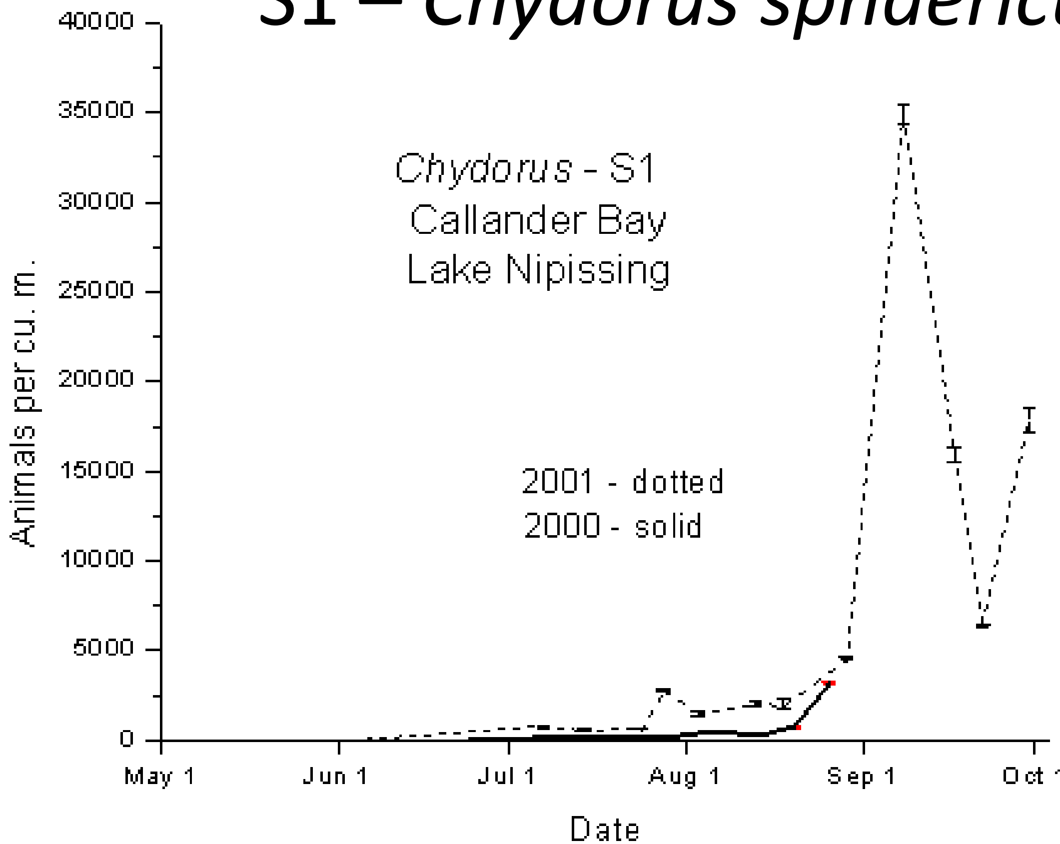
S1 – *Holopedium gibberum*

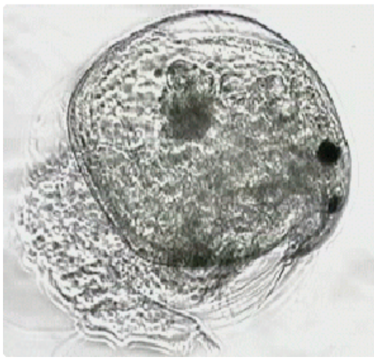
S1 was sampled July 7th and August 1st, 2010. *Holopedium gibberum* was only collected in trace amounts from the 5m stratum on July 7th. Historically, *Holopedium* had average abundances of around 100 an./m3 in early July and early August. It would seem that *Holopedium* disappears quicker and attains lower maximum abundances since the introduction of *Bythotrephes.*



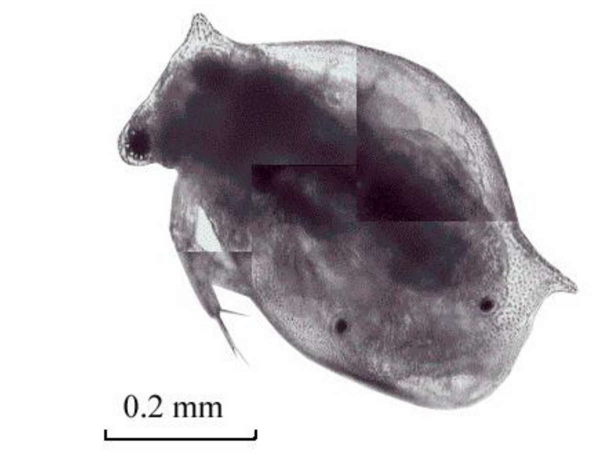
Chydorus sphaericus is about 0.2 mm in diamaeter, whereas *Bosmina* is about 0.5 mm in diameter. *Chydorus* is susceptible of being extirpated by *Bythotrephes* (Yan 1997). *Chydorus* was not collected at S1 in 2010 (June 7, August 1). However *Chydorus* is historically not plentiful here until September where it attained abundances as high as 35,000 an./m3 in 2001. It would be interesting to see whether or not *Bythotrephes* has managed to extirpate *Chydorus* from Callander Bay, by sampling for it come September.

S1 – *Chydorus sphaericus*

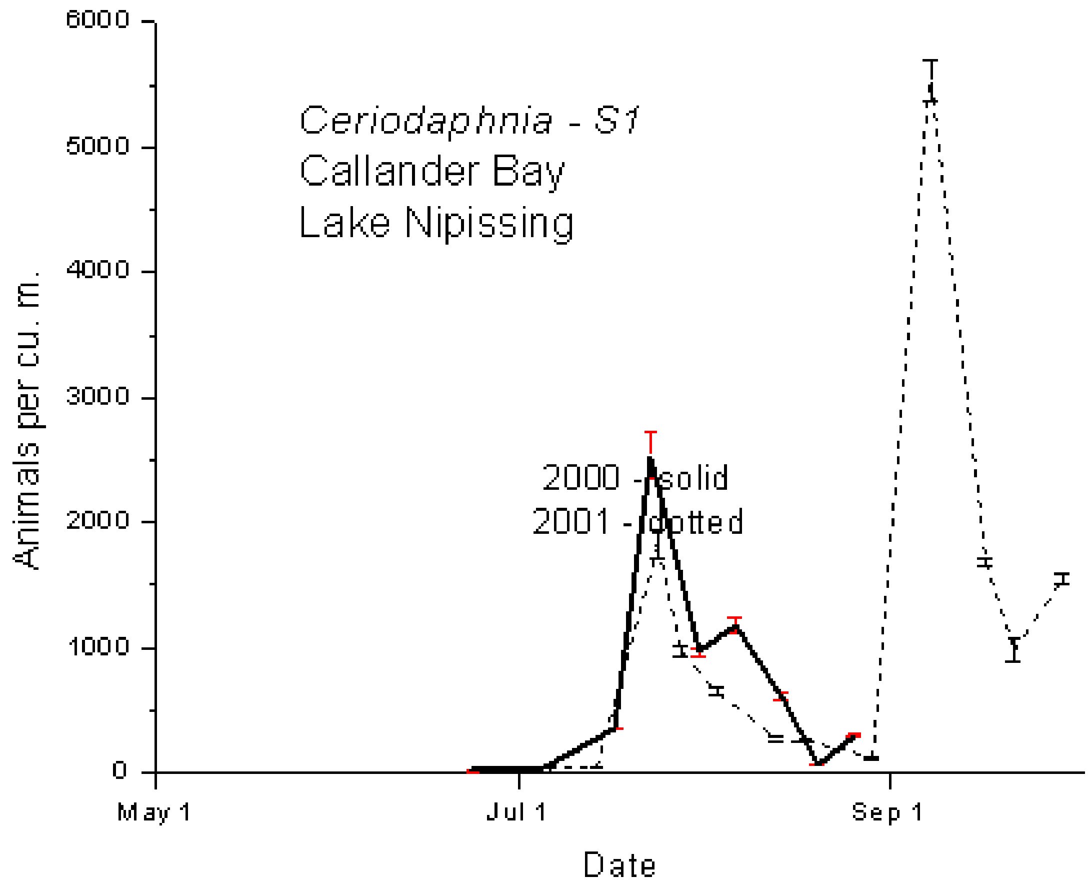




S1 – *Ceriodaphnia*

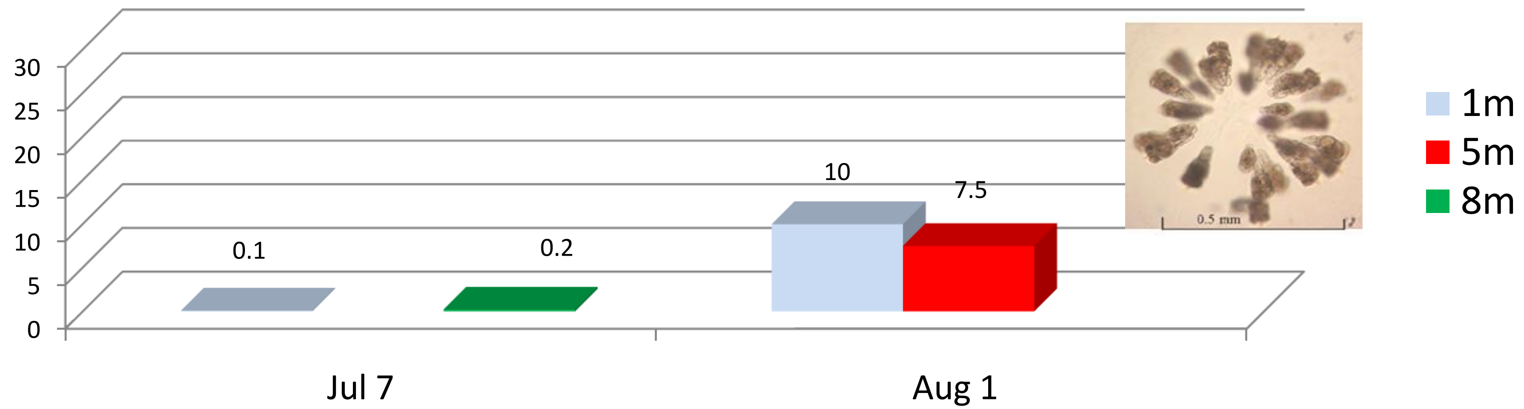


Ceriodaphnia is about the same size as *Bosmina* – a little longer but a little less wide across. It was not collected at S1 in 2010. Based on the 2000/2001 sampling it should have appeared in the August 1st collections (2010) as it was present at an average abundance of over 1000 an./m3 back in 2000 / 2001. The 150 m horizontal hauls that were performed in 2010 should have yielded over 10,000 individual *Ceriodaphnia* at those abundances. It is probable that *Bythotrephes* has extirpated this small zooplankter or driven it to very low abundances.



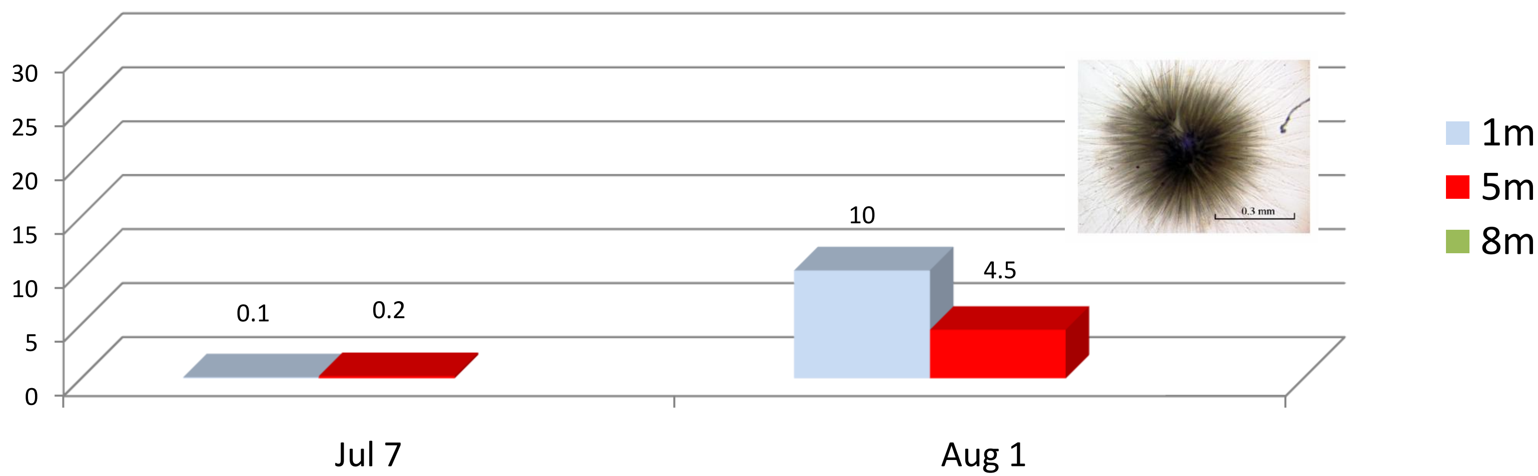
Relative scale

S1 - *Conochilus unicornis* abundance



Relative scale

S1 - *Geotrichia* abundance



Conochilus unicornis and *Geotrichia*, not collected in any important amount in 2000/01 is now becoming common to moderately abundant as summer progresses at S1.

S1 – Discussion

S1 (Callander Bay) is quite isolated, and has limited water exchange with the rest of Lake Nipissing. S1 is a historically nutrient-rich basin. Compounding the nutrient enrichment problem is the municipal lagoon which drains into this basin from the West and the Wasi river which drains farmland to the East. Despite these differences, the zooplankton community dynamics which are occurring in this basin are very similar to those taking place at S8.

It would seem that prior to the July 7th sampling of S1, *Bythotrephes* reached sufficiently high abundances to just about consume all zooplankton in this basin. This is evidenced by the extremely low abundances of all zooplankton taxa on July 7 at S1. The *Bythotrephes* abundances encountered on July 7 at S1 is in line with that encountered at the other stations after the crash of *Bythotrephes* due to running out of food resources.

S1 – Discussion (page 2)

As with S8, *Bosmina, Diaphanasoma birgei* and *Leptodora* fair poorly for the rest of the summer of 2010 subsequent to eradication or near eradication by *Bythotrephes* in June.
Chydorus shaericus and *Ceriodaphnia* were not collected and may have been extirpated or driven to very low abundances by *Bythotrephes.* Additional sampling for *Chydorus* in September is suggested to confirm the collapse of *Chydorus.*

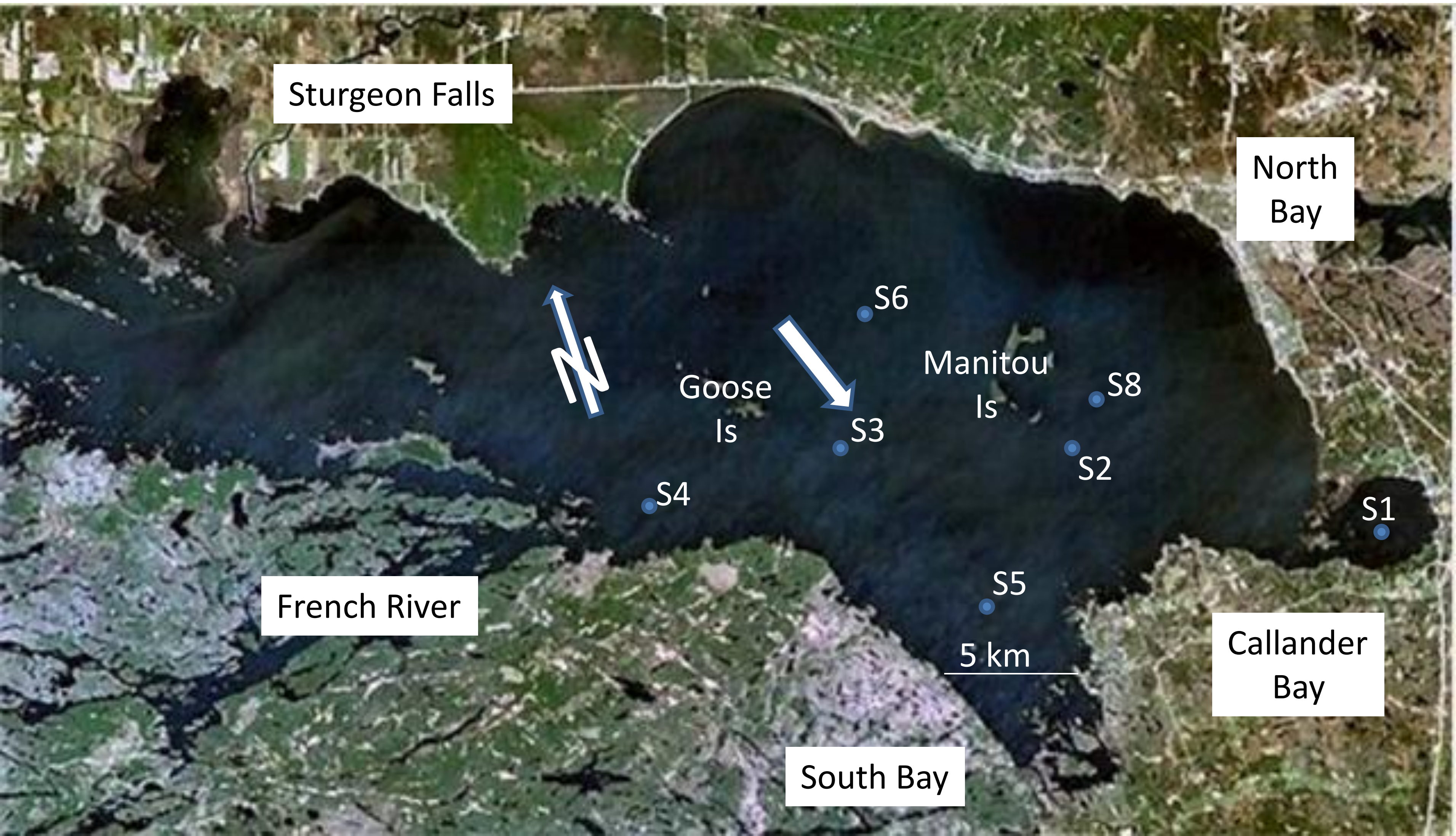
Daphnia galeata mendotae has replaced *Daphnia retrocurva* in this basin.
We encountered only one *D. retrocurva* individual in our collections, so this species is still present in extremely low abundances. Driven to trace abundances by the beginning of July, It recovers and becomes very abundant at depth (8m) come the first of August.

Holopedium gibberum is not as abundant as it was in 2000/01 and disappears from the collections earlier than it did in 2000/01. *Epischura lacustris* manages to hold its own, at low abundances and its abundance corresponds positively with the advance of summer (as it did in 2000/2001). Both these results were observed at S8.

S1 – Discussion (page 3)

The big difference at S1 is the rapidity with which some zooplankton taxa recover from the June *Bythotrephes* onslaught. *Cyclops, Diaptomus* and *Daphnia* are all abundant on August 1st at S1 – particularly at depth. Only three weeks earlier they were present only in trace amounts. This is testimony to the amazing productivity of this basin which gives it a large amount of resilience. On August 1st, there is basically a zooplankton desert in the rest of Lake Nipissing, except for a few areas at depth in the area of S4. The existence of a large zooplankton food source come August in this basin might apply selective pressure to zooplankton predators which might result in changes in behaviour such as moving in and out of Callander Bay come August for feeding purposes. This same modified behaviour might occur in the Lake Nipissing outlet area of the lake (S4 area).

S3 - Zooplankton community structure
Between Goose & Manitou Islands



S3 - Zooplankton community structure

Between Goose & Manitou Islands

Sampled once, July 9th, 2010

Bythotrephes longimanus

	Btho	%3	%2	%1	Abundance (an./m3)		
D (m)	an/m3	barbs	barbs	barbs	3barbs	2barbs	1barbs
1	2.6	14	54	32	0.4	1.4	0.8
5	7.7	26	57	17	2.0	4.4	1.3
10	1.5	20	60	20	0.3	0.9	0.3
14	2.9	15	44	41	0.4	1.3	1.2

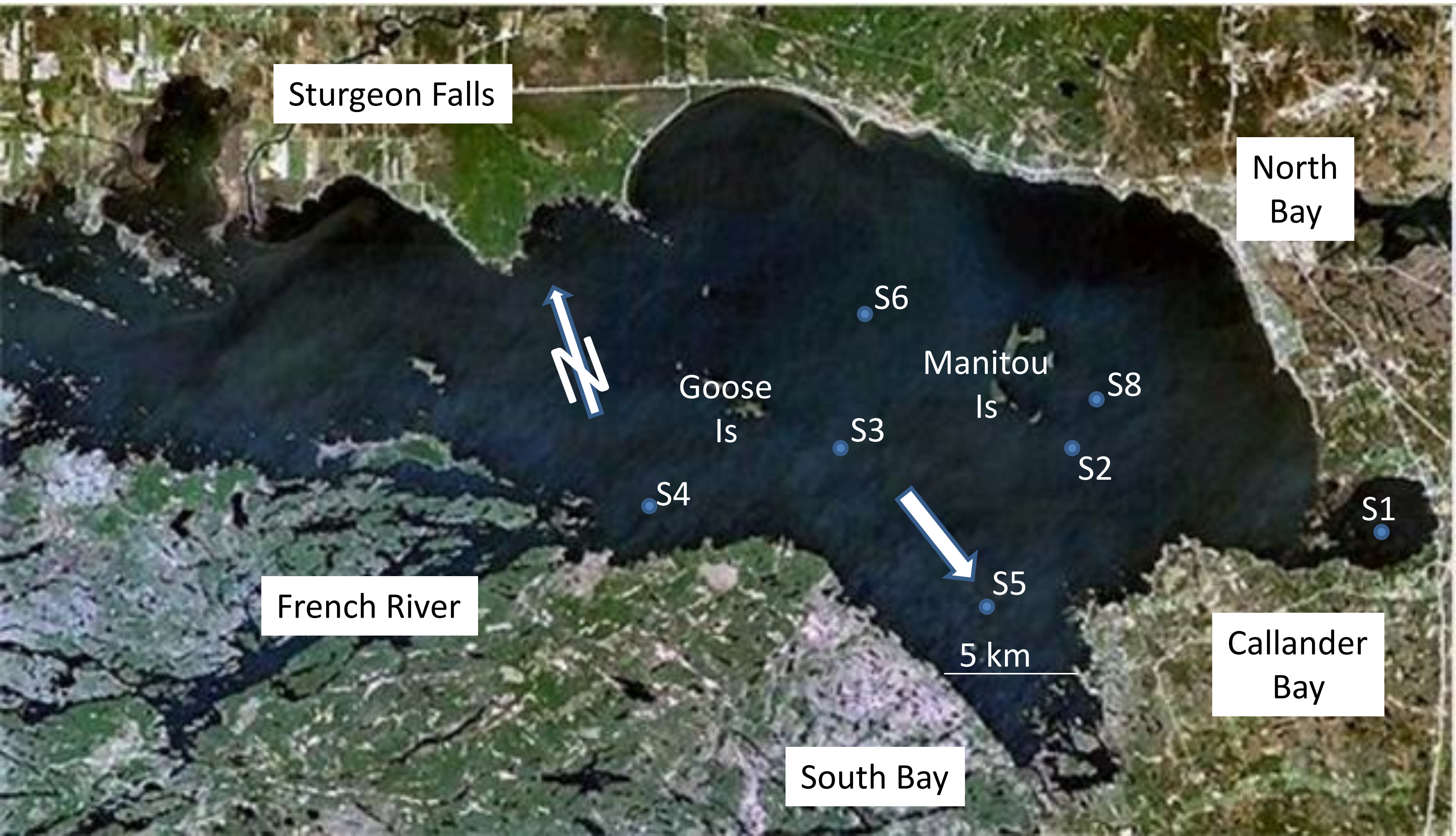
Rank scores and Presence/absence

D (m)	zoo	Epi	Diap	Orego	Cyc	DBT	Medax	Daph	DGM	Bos	Holo	Geo
1	0.05	2	0	-	0	-	-	0	-	0	0	1
5	0.05	1	1	x	0	-	-	1	x	1	1	0
10	0.05	1	0	-	0	-	-	0	-	0	0	0
14	0.6	5	5	x	2	x	x	1	x	0	0	0

Relative abundance (scale maximum is 30)

D(m)	*Epischura lacustris*	*Diaptomus*	*Cyclops*	*Daphnia*	*Bosmina*	*Holopedium gibberum*	*Geotrichia*
1	0.1	0	0	0	0	0	0.05
5	0.05	0.05	0	0.05	0.05	0.05	0
10	0.05	0	0	0	0	0	0
14	3	3	1.2	0.6	0	0	0

S5 - Zooplankton community structure
South Bay



S5 - Zooplankton community structure

Bythotrephes statistics

	Bytho	%3	%2	%1	Abundance (an./m3)		
D (m)	an/m3	barbs	barbs	barbs	3barbs	2barbs	1barbs
1	26	22	45	33	6	12	9
5	36	9	38	53	3	14	19
10	7	33	42	25	2	3	2

Sampled once
July 11, 2010

Mostly Copepod - Rank scores

D (m)	zoo	Epi	Diap	Orego	Lmin	Cyc	Medax	DBT	Cono	Geo
1	0.1	2	3	x	-	1	x	-	0	3
5	0.1	3	4	x	-	1	x	-	4	1
10	0.2	3	4	x	-	2	x	x	2	0

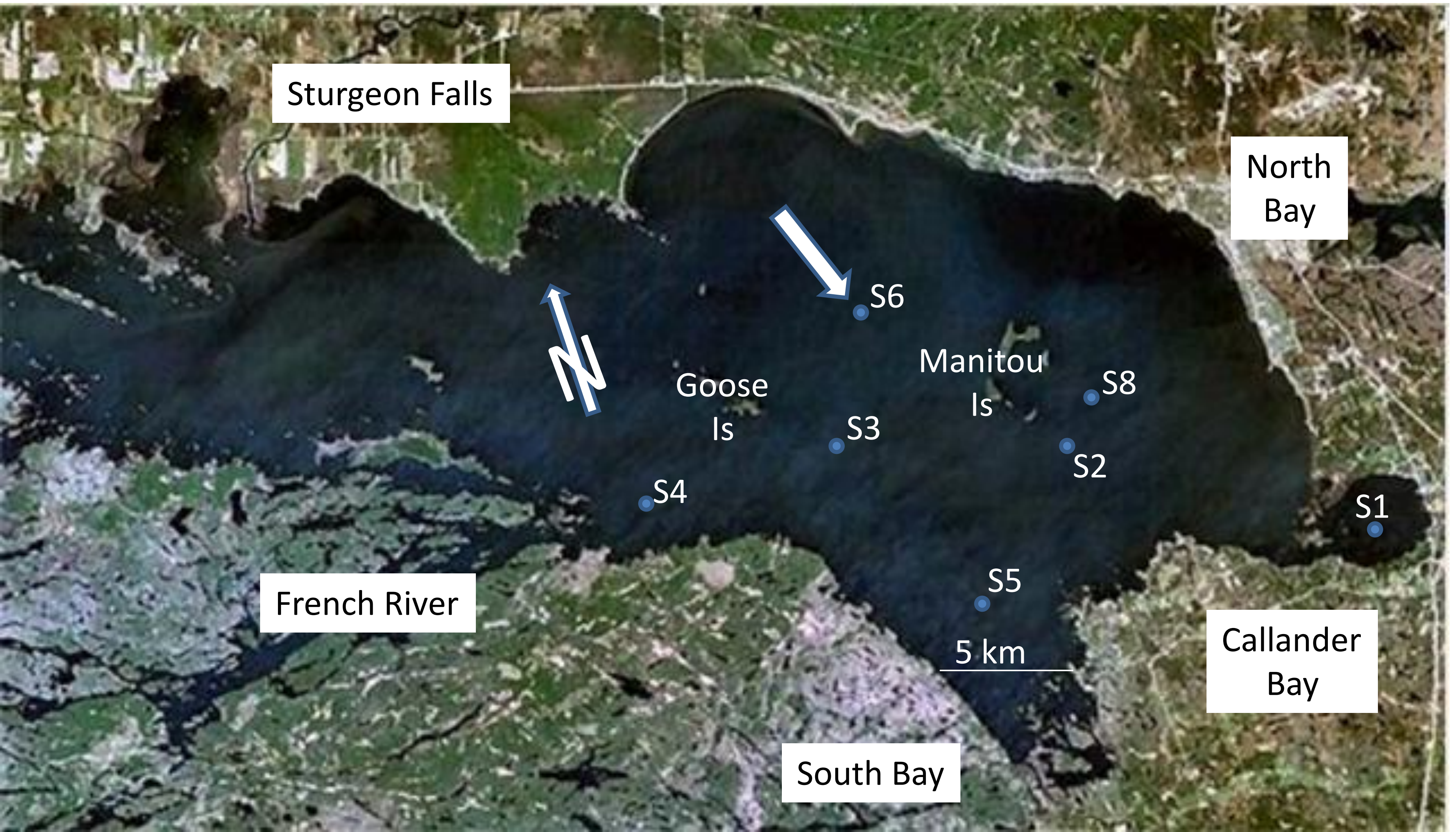
Mostly Cladocera - Rank Scores

D (m)	zoo	Daph	DGM	Dlong	Dpul	Bos	Lepto	Diaph	Cerio	Chaob
1	0.1	2	-	x	-	1	0	1	0	0
5	0.1	1	-	-	x	2	1	2	1	0
10	0.2	2	x		x	2	2	1	0	1

Relative abundances (scale maximum is 30)

D (m)	Diap	Cyc	Epi	Daph	Bos	Lepto	Diaph	Cerio	Chaob	Cono	Geo
1	0.3	0.1	0.2	0.2	0.1	0	0.1	0	0	0	0.3
5	0.4	0.1	0.3	0.1	0.2	0.1	0.2	0.1	0	0.4	0.1
10	0.8	0.4	0.6	0.4	0.4	0.4	0.2	0	0.2	0.4	0

S6 - Zooplankton community structure
NW of Manitou Islands



S6 - Zooplankton community structure
NW of Manitou Islands

	Bytho	%3	%2	%1	Abundance (an./m3)		
D (m)	an/m3	barbs	barbs	barbs	3barbs	2barbs	1barbs
1	2.6	18	46	36	0.5	1.2	0.9
5	5.3	8	60	32	0.4	3.2	1.7
7.5	4.1	22	55	23	0.9	2.3	1.0

Sampled once
July 9, 2010

Mostly Copepods – Rank scores and Presence / absence

D (m)	zoo	Epi	Diap	Orego	Cyc	DBT	Medax	Cono	Geo
1	0.05	2	2	x	1	x	-	0	1
5	0.05	2	2	x	0	-	-	0	0
7.5	0.25	4	4	x	1	x	x	1	0

Cladocera – Rank scores and Presence / absence

D (m)	zoo	Daph	DGM	Dlong	Bos	Lepto	Holo
1	0.05	1	x	-	0	1	1
5	0.05	1	x	x	0	3	0
7.5	0.25	0	-	-	1	0	1

Relative abundance (scale maximum is 30)

D (m)	Cono	Geo	Epi	Diap	Cyc	Daph	Bos	Lepto	Holo
1	0	0.05	0.1	0.1	0.05	0.05	0	0.05	0.05
5	0	0	0.1	0.1	0	0.05	0	0.15	0
7.5	0.25	0	1	1	0.25	0	0.25	0	0.25

S3, S5, S6 - Zooplankton community structure

Discussion

1. Very little zooplankton was collected at these three sites. We hypothesize that *Bythotrephes* populations had followed the dynamics of the other sites, attained high abundances, liquidated most of the zooplankton in June which set in motion its own demise. The average abundances of *Bythotrephes* is somewhat higher in South Bay (S5) and we surmise that the *Bythotrephes* is in the process of finishing its cleanup of the zooplankton, and will most likely crash to abundances more typical of the other sampling sites.

S3, S5, S6 - Zooplankton community structure

Discussion (page 2)

2. Despite the small abundances of zooplankton these sites showed some resilience re zooplankton species biodiversity. Two species of Cyclops were identified at all three sites: *Mesocyclops edax* (most common) and *Diacyclops bicuspidatus thomasi.*

   S5 and S6 showed more species diversity than S3. Trace quantities of *Ceriodaphnia* and *Chaoborus* were collected at S5. Small quantities of *Leptodora* remain at S5 and S6, but none was collected at S3. Three species of *Daphnia* were collected at S5: *Daphnia galeata mendotae* (most common), *Daphnia longiremis* and *Daphnia pulicaria*. At S6 *Daphnia galeata mendotae* and *D. longiremis* were collected. The only other area where *D. pulicaria* was collected in 2010 was at depth at S4, the deep basin outlet of Lake Nipissing. S3, while less diverse in species, still had moderate populations of *Epischura lacustris* and *Skistodiaptomus oregonensis* in the 14m stratum, again positively correlating depth to zooplankton abundance subsequent to *Bythotrephes* semi-eradication of the zooplankton.

Concluding remarks and a trip into the grey area.

This report paints a pretty bleak picture of the Lake Nipissing zooplankton community. It is incredible to think that one species of zooplankton (*Bythotrephes longimanus)* is capable of applying 'top down control' to the point of bringing the zooplankton community in Lake Nipissing to its knees as it were.

Could the liquidation of most of the zooplankton in the lake in June by *Bythotrephes,* followed by its own collapse in early July, lead to problems for one of Ontario's great walleye fisheries? Hopefully not. It is possible that Lake Nipissing's amazing productivity will be the key to its salvation as far as its fisheries are concerned. The enormous productivity of the lake is capable of nurturing huge quantities of other kinds of organisms, occupying very different niches. One important aspect of study that remains to be done on Lake Nipissing is a look at the benthos. Forced with little to eat in the water column come summer, some fish may simply rely more on the invertebrate species living in, on and near the sediments.

Historically come late June, shoreline inhabitants would have to shovel and sweep their porches to get rid of the mayflies that would accumulate. This is a manifestation of the mayfly naiad (or, colloquially, nymph) *(Ephemeroptera)* emerging out of Lake Nipissing as a flying adult. Those aquatic naiads are an alternate food source to potentially many fish species and they may be abundant throughout the lake.

Concluding remarks (page 2)

To investigate the interest in benthic organisms to young walleye and perch we captured perch and walleye in 10m of water a few kilometres South of S2 on January 25/27 2011, a time when *Bythotrephes* is unavailable and zooplankton is scarce in the water column. Results are presented below.

Stomach contents of yellow perch / walleye
Caught South of S2, Jan. 25/27, 2011 in 10 m of water
Legend: E- Ephemeroptera, G - Gastropoda, F - Fish vertebrae

Total length (cm)	Sex	Stomach Contents	Total length (cm)	Sex	Stomach Contents
17.5	F	E	17.5	M	E
18	F	G	18	M	E
19	F	G, E	18	M	E
19	F	G, E	18.5	M	E
19	F	G, E	19	M	G
20	F	EMPTY	21	M	E
20.5	F	EMPTY	23	M	G
20.5	F	EMPTY	23	M	G
21	F	G	26	M	G
21	F	G, F		Walleye	
21	F	E, F	25	Immature	G
23	F	G	26	Immature	G
23	F	G	26	Immature	Empty
23.5	F	G			
26	F	G			

The snails appeared to belong to the familae *Physidae* perhaps *Basommatophora.* They had an average diameter of 9 mm or less – typically 4 mm. Winter is a time when the Cladocera are mostly absent from the water column, and the copepods are in low abundance. In this mid-winter zooplankton desert both perch and young walleye key on benthic organisms.

The availability of this benthic food source provides energy pathways that bypass zooplankton to support Lake Nipissing's fisheries, so the collapse of the zooplankton community come summer may have limited impact on the fisheries if young fish target the benthos. More sampling may show that walleye also key on E*phemeroptera.*

In the winter perch turn to eating snails and mayfly naiads. They could do the same in the summer.

Concluding remarks (page 3)

There were very few fish vertebrae in the perch stomachs caught on January 25/27, 2011. The few vertebrae that we did find may be a result of the perch "stealing" a few minnows from anglers. This report underlines the fact that the smaller-sized Cladocera (*Bosmina, Diaphanasoma etc.)* are not available to smaller-sized fish come the end of the first week in June. This may be affecting the minnow population. A study looking at the minnow-sized species of fish in Lake Nipissing might be something to consider. In the meantime, supposing that the minnow population has collapsed to a certain degree, the perch and young walleye are still doing fine by switching to benthic organisms.

This January (2011) there exists in Lake Nipissing a strong class of walleye young-of-the-year (see photo). These were born last April. They are being angled (and probably released due to their small size) this January by anglers fishing through the ice.

Despite the lack of zooplankton this summer, the small walleye seem to have survived just fine. They were not caught by anglers in any numbers this summer. They may have been too small at that time to be recruited to the fishery in any number. The small walleye may have survived the summer by feeding on benthic organisms (mayfly naiads *(Ephemeroptera)* , snails (*Gastropoda)* etc.) and perhaps on *Bythotrephes* (as did the perch) and may now be of sufficient size to start appearing in angler catches.

Concluding remarks (page 4)

What about the larger walleye? In the summer some have switched to eating *Bythotrephes*, which implies that even after the collapse of the *Bythotrephes* population to more modest abundances, there were still enough *Bythotrephes* around to feed the walleye and the perch, again a tribute to Lake Nipissing's tremendous productivity. Walleye are large predators, with large teeth, and eyes adapted to hunting in low light conditions. It is odd to see them target prey as small as *Bythotrephes.*

This behaviour is not completely atypical. In the McConnel Lakes area, between North Bay and Temiskaming there is a naturally reproducing population of lake trout *(Salvelinus namaycush)* that, come summer, feeds almost exclusively on *Daphnia pulicaria,* despite having a large mouth and large teeth adapted over millennia to target much larger and faster-swimming prey.

Walleye are great swimmers and are known to cover large distances in Lake Nipissing.
The cold-water fish sanctuary at the outlet of Lake Nipissing may just look like food-on-the-menu come summer and there may be selective pressure on the walleye population to take greater advantage of this food source.

Concluding remarks (page 5)

The existence of this cold-water-refuge is not new. It has probably existed for hundreds if not thousands of years, so the large predators of the lake have already adapted their feeding habits to make use of this very available food source. The point is, not all walleye have had to dip into this food source. They could 'make their living' in other ways, as it were. Now they may just have to be a little more creative. Eating *Bythotrephes* directly is one solution. Eating mayfly naiads and snails is another. Targeting larger perch is yet another possibility. Oddly enough, large walleye do not seem eager to hunt larger-sized perch as typically few are found in their stomachs. Given their very large mouth and large teeth, they might just consider gulping down a few of these larger perch every once in a while. Migrating to where the food is, is yet another hunting alternative and nature is usually wonderful at filling all niches that have solutions that work.

The smelt population seems to be expanding and the lake herring population contracting (Richard Rowe – personal communication). It would appear that the lake herring are not doing well in many parts of Ontario (Rennie & Sprules 2010). During the summer both species are in the cold-water refuge, which makes them vulnerable to predation by walleye and pike. During the other three seasons they are free-swimming throughout the expanses of Lake Nipissing. They should be encountering very hungry walleye intent on making them their next meal, all over the lake. This should lead to a shrinking of the smelt population. The fact that the smelt population is actually expanding, not shrinking is puzzling. Perhaps there simply are not enough large walleye to affect the overall abundance of smelt in Lake Nipissing.

Concluding remarks (page 6)

There is no question that the entire Lake Nipissing ecosystem is under stress due to the consequences of the introduction of *Bythotrephes.* We have no idea if this is a transition state on a path to some yet undefined new equilibrium, or the new state of affairs. This is a time for caution. If more walleye are targeting the smelt and lake herring in the cold-water refuge come summer, then a greater percentage of the walleye stock may be in this area of the lake which could make them more vulnerable to fishers setting their nets in this area. This could lead to shrinking walleye fish stocks.

Ecosystems are under siege from a variety of aspects including invasive species, climate change and development pressures altering habitat and creating pollution. Despite shrinking MNR budgets, now is not the time to reduce funds allocated to monitoring. In a time of change, only monitoring can give managers the data they need to react to change and continue to manage our ecosystems for the greater good. Unfortunately what we see around us is a widespread cut to monitoring programs because they are seen as unessential or not producing immediate results. I would like to end this report by recommending just the contrary. Now is the time to expand our monitoring programs to make sure that we have the data that is and will be needed to manage our ecosystems in a time of change.

Jean-Marc Filion
February 2011

Acknowledments

I am deeply indebted to my all-volunteer crew (Kevin O'Grady, Lois Filion) that worked with me tirelessly on this project. Their only credit, other than my enduring gratitude, is one picture in this presentation. I include a picture of our Chesapeake Miga who spent countless hours swimming around the boat as we concentrated samples, coiled lines and rinsed nets. Miga added a lot of comic relief and enjoyment to the sampling activities. I thanked her with a picture.

I would like to thank Dr. Norman Yan for the opinions and impressions that he provided early on in this project based on his long history of zooplankton research and familiarity with *Bythotrephes longimanus*. I would also like to thank Richard Rowe (Nipissing First Nation biologist) for his on-going dedication to unraveling the mysteries of Lake Nipissing's biology. Most importantly I thank the Executive of the Lake Nipissing Partners in Conservation who decided that this was an important study worth funding.

Jean-Marc Filion
Project leader
February 2011

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2 mm
Bow to
the queen !