

MINING WATER SYMPOSIUM  
ADAPTATIONS AND RESPONSES TO METAL STRESS

**ASSESSING THE POTENTIAL FOR RECOVERY OF  
ZOOPLANKTON FROM MINING IMPACTS**



Martha Patricia Celis-Salgado and Norman D. Yan



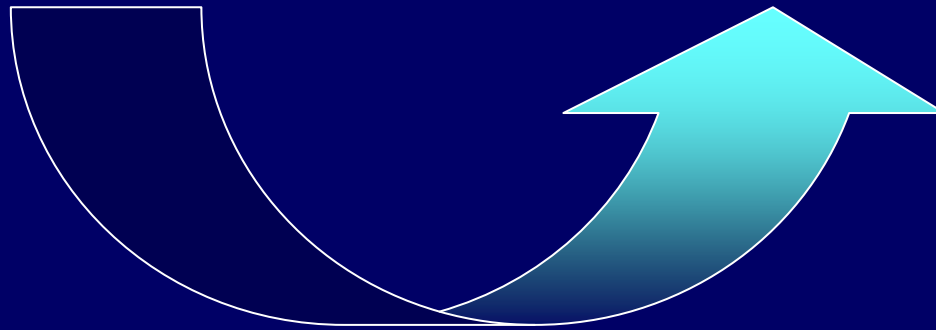
Natural Sciences and Engineering  
Research Council of Canada

Conseil de recherches en sciences  
naturelles et en génie du Canada





Restoration



# OBJECTIVES

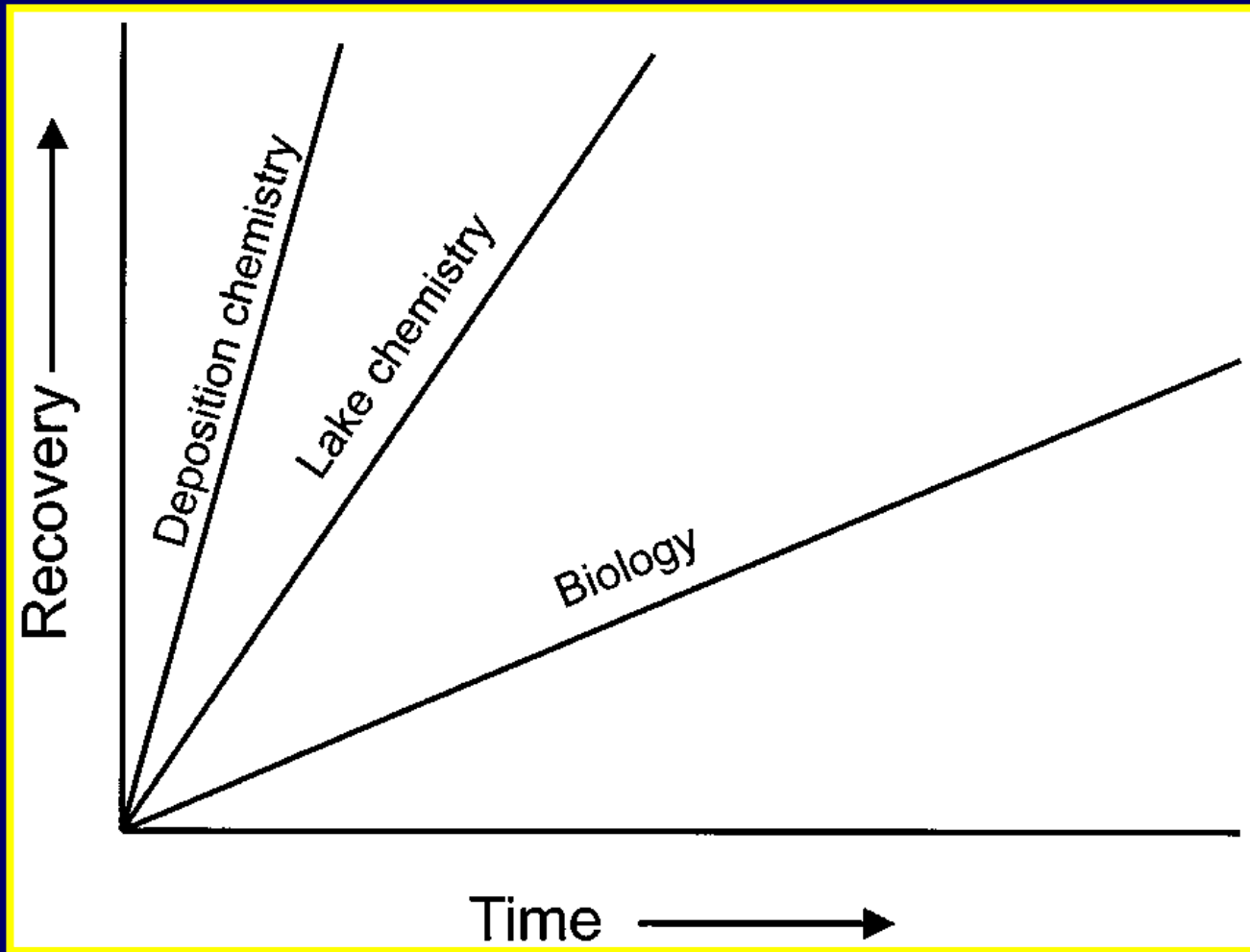
Determine if current [Cu] and [Ni] in Sudbury lakes are regulating Daphniid recovery

Levels?

Multiple stressors?



[Cu] laboratory bioassays



General sequence of recovery (Keller, Gunn and Yan, 1999)

# Copper concentrations in restored lakes

Lake	1973 [Cu] $\mu\text{g/L}$	1979 [Cu] $\mu\text{g/L}$	2005 [Cu] $\mu\text{g/L}$
Hannah N	1090	25	15.8
Middle N	496	25	15.4
Clearwater	98	49	7.4



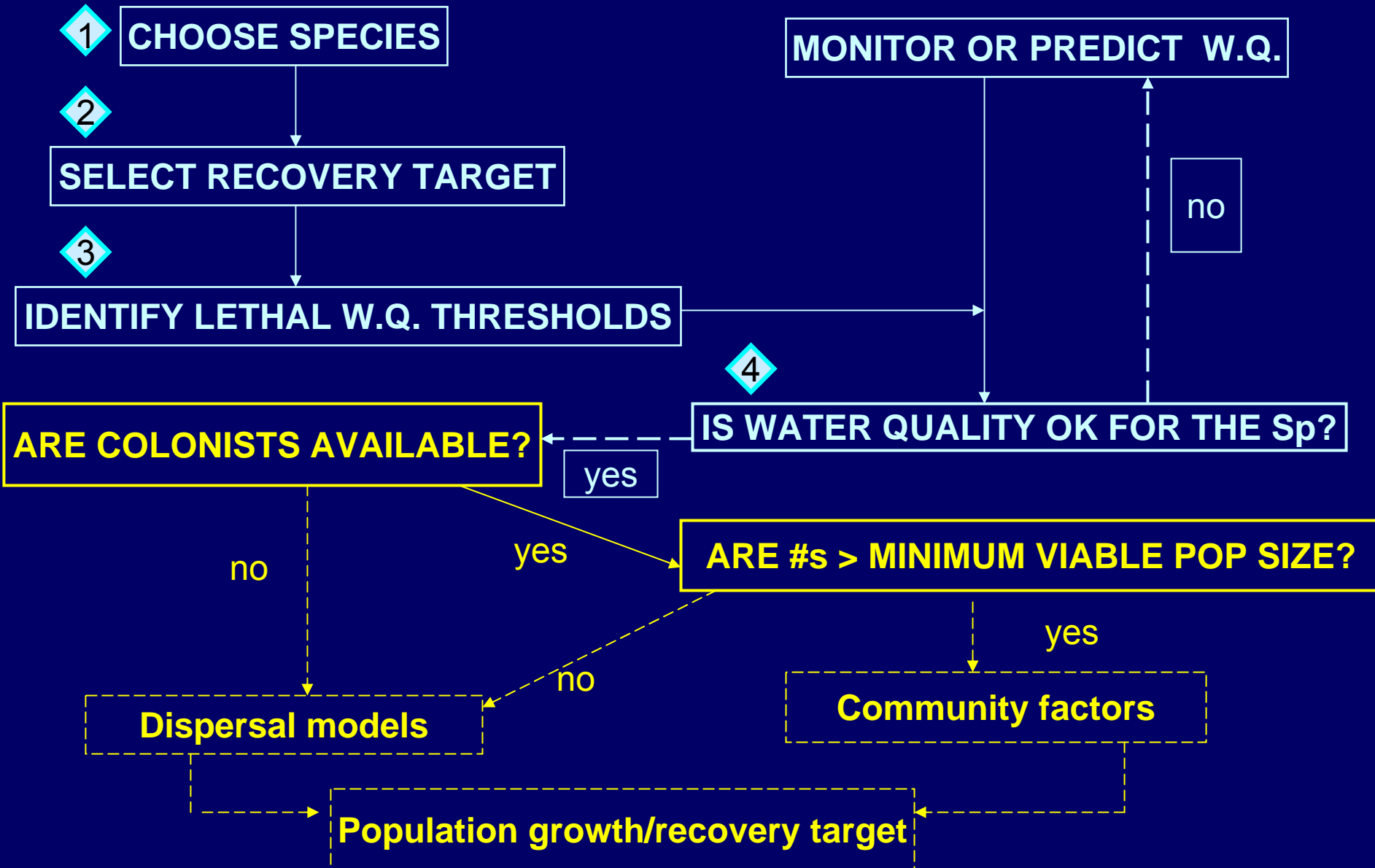
LIMING

# Successful Recovery of zooplankton (Keller 1992; Locke 1994, Keller 1998)



Copepods but not Cladocera  
after pH 6.0 was achieved  
(Yan et al, 1996; Yan et al 2004)

First conceptual framework of the processes in the ecological recovery of a species from historical acidification (Yan et al. 2003)



1. Choose species: Reference Lakes

2. Identify lethal WQ thresholds

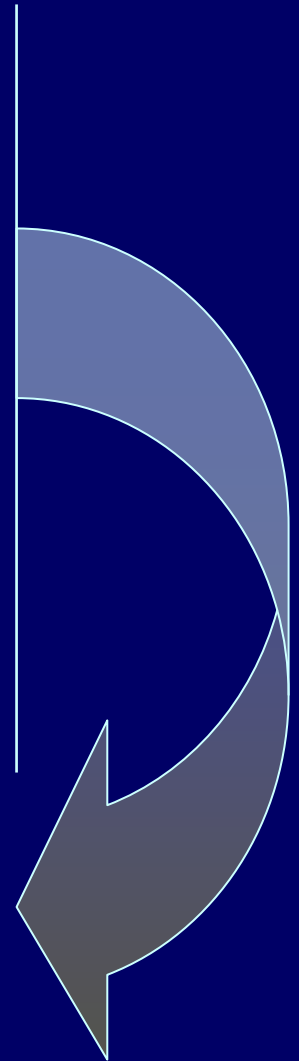
- . Lab bioassays

- . Short term acute toxicity

- . Partial life cycle

- . In situ bioassays

3. Is the Water Quality good for the Sp?





# Literature Review

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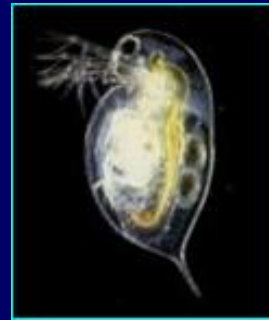
Metals?

Cu

Ni



Species of Interest?



Soft Water?

Ca

Mg

# SPECIES OF INTEREST IN REFERENCE LAKES

	A	B
	(Mean Biomass mg/m <sup>3</sup> d.w.)	
<i>Holopedium gibberum</i>	7.7-11.6	4.34
<i>D. mendotae</i>	3.3 -9.4	4.43
<i>D. pulex</i>	2.14 to 4.2	5.85
<i>D. catawba</i>	0.74	1.42
<i>D. ambigua</i>	0.11 to 0.37	0.02

## Sources:

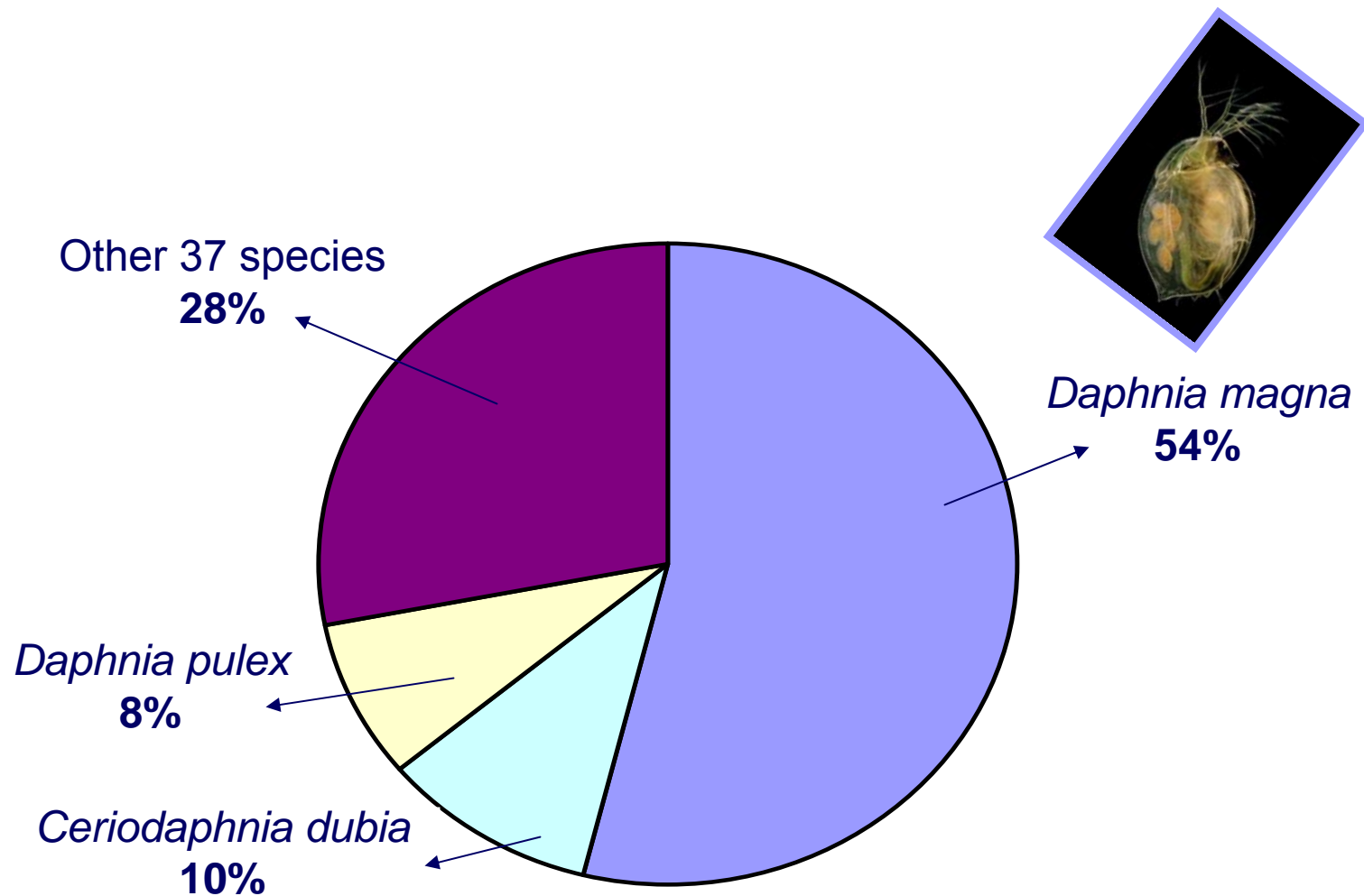
A: 259 lakes survey, 10 years (Yan, Keller, Pitblado and Mackie. 1988)

B: DESC 2000-2002 Zooplankton Data Set: Blue Chalk & Red Chalk Lakes

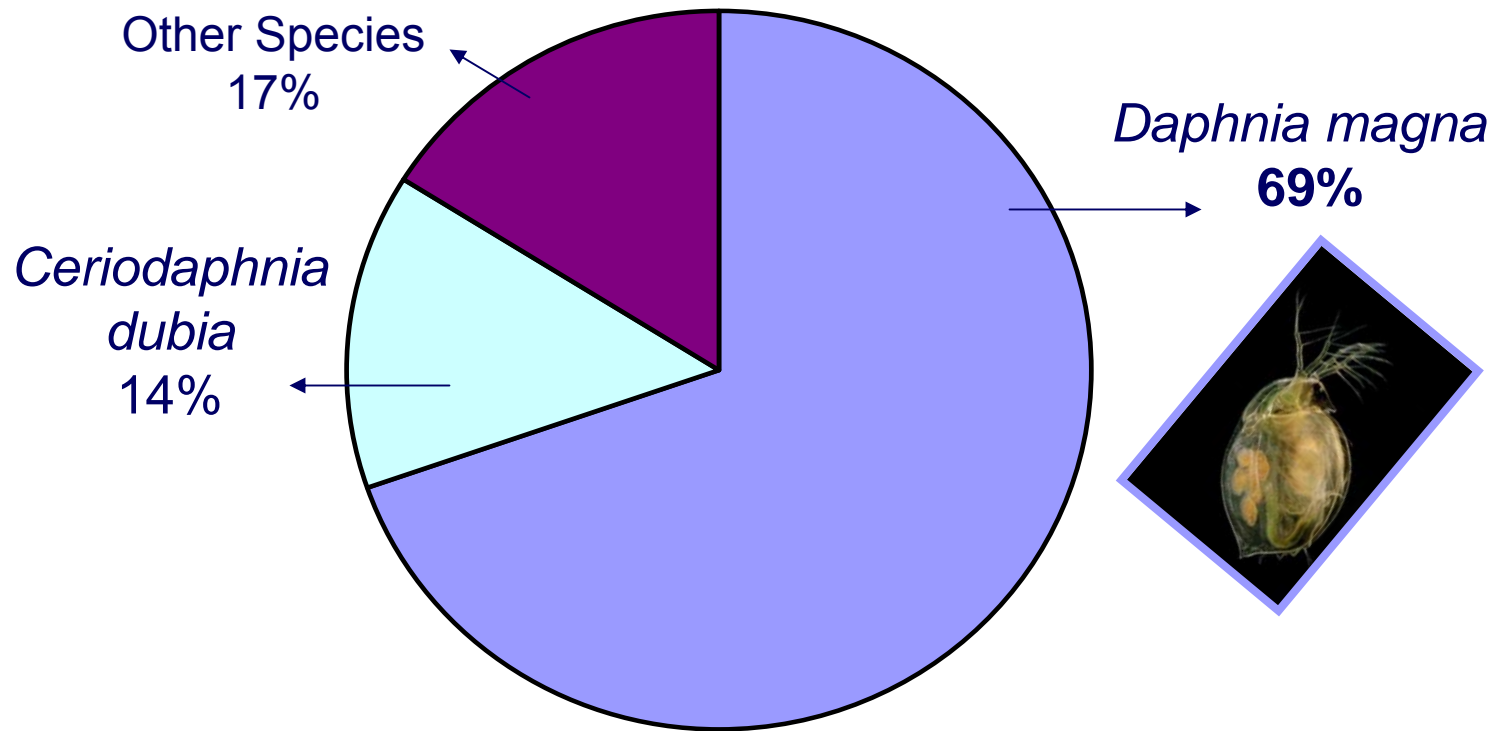
WATER QUALITY: soft, slightly acidic

# Elements tested in 641 toxicity studies with *Daphnia spp.*

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<table border="1"> <tr> <td>58</td> <td>59</td> <td>60</td> <td>61</td> <td>62</td> <td>63</td> <td>64</td> <td>65</td> <td>66</td> <td>67</td> <td>68</td> <td>69</td> <td>70</td> <td>71</td> </tr> <tr> <td>Ce Cerio</td> <td>Pr Praseodimio</td> <td>Nd Neodimio</td> <td>Pm Promecio</td> <td>Sm Samario</td> <td>Eu Europio</td> <td>Gd Gadolnio</td> <td>Tb Terbio</td> <td>Dy Disprosio</td> <td>Ho Holmio</td> <td>Er Erbio</td> <td>Tm Tulio</td> <td>Yb Iterbio</td> <td>Lu Lutacio</td> </tr> <tr> <td>90</td> <td>91</td> <td>92</td> <td>93</td> <td>94</td> <td>95</td> <td>96</td> <td>97</td> <td>98</td> <td>99</td> <td>100</td> <td>101</td> <td>102</td> <td>103</td> </tr> <tr> <td>Th Torio</td> <td>Pa Protactinio</td> <td>U Uranio</td> <td>Np Neptunio</td> <td>Pu Plutonio</td> <td>Am Americio</td> <td>Cm Curio</td> <td>Bk Berkelio</td> <td>Cf Californio</td> <td>Es Einsteinio</td> <td>Fm Fermio</td> <td>Md Mendelevio</td> <td>No Nobelio</td> <td>Lr Laurencio</td> </tr> </table>																		58	59	60	61	62	63	64	65	66	67	68	69	70	71	Ce Cerio	Pr Praseodimio	Nd Neodimio	Pm Promecio	Sm Samario	Eu Europio	Gd Gadolnio	Tb Terbio	Dy Disprosio	Ho Holmio	Er Erbio	Tm Tulio	Yb Iterbio	Lu Lutacio	90	91	92	93	94	95	96	97	98	99	100	101	102	103	Th Torio	Pa Protactinio	U Uranio	Np Neptunio	Pu Plutonio	Am Americio	Cm Curio	Bk Berkelio	Cf Californio	Es Einsteinio	Fm Fermio	Md Mendelevio	No Nobelio	Lr Laurencio
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## Percentage of Copper studies in Cladocera



## Percentage of Nickel studies in Cladocera

## Number of studies with Cu and Ni on Species of Interest

Species of <i>Daphnia</i>	Cu	Ni
<i>D. ambigua</i>	3	0
<i>D. catawba</i>	0	0
<i>D. pulex</i>	12	1
<i>D. galeata</i>	3	1 SW
Total	18	2

NO STUDIES ON CLADOCERA WITH THESE 2 METALS MIXED

Why not... *Daphnia magna*?



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Why not... the previous studies with  
the species of interest?

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# CULTURE MEDIA



## COMPARISON OF HARDNESS IN DIFFERENT CULTURE MEDIA

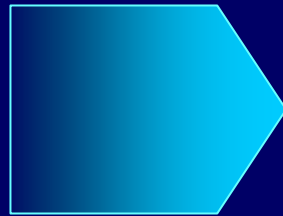
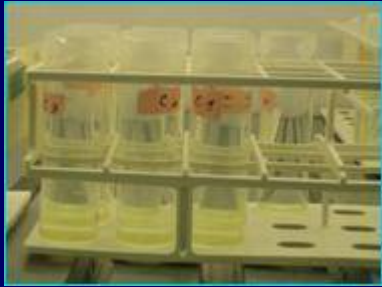
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Medium	Ca	Mg	Hardness	Classification*
ISO	80	12	250	Very Hard
Combo	10	3	40	Soft
RFW	1.75	1.75	10	Soft
FLAMES	2.5	0.75	9.40	Soft
Shield LAKES	2.5	0.75	6 to 16	Soft

\* Classification based on the US Geological Survey 2003

## Chemical composition of soft water media for standard bioassays

Major Ions mg/L	Lakes mg/L	Reconstituted Freshwater mg/L	Soft Combo mg/L	FLAMES mg/L
Ca	2.536	1.75	10.02	2.536
Cl	0.388	0.24	18.53	0.388
Mg	0.749	1.51	3.65	0.749
SO <sub>4</sub>	9.049	10.17	14.42	9.049
K	0.369	0.26	3.91	0.370
Na	1.103	3.28	31.95	1.103
Trace Elements and Vitamins	mix	none	mix	mix

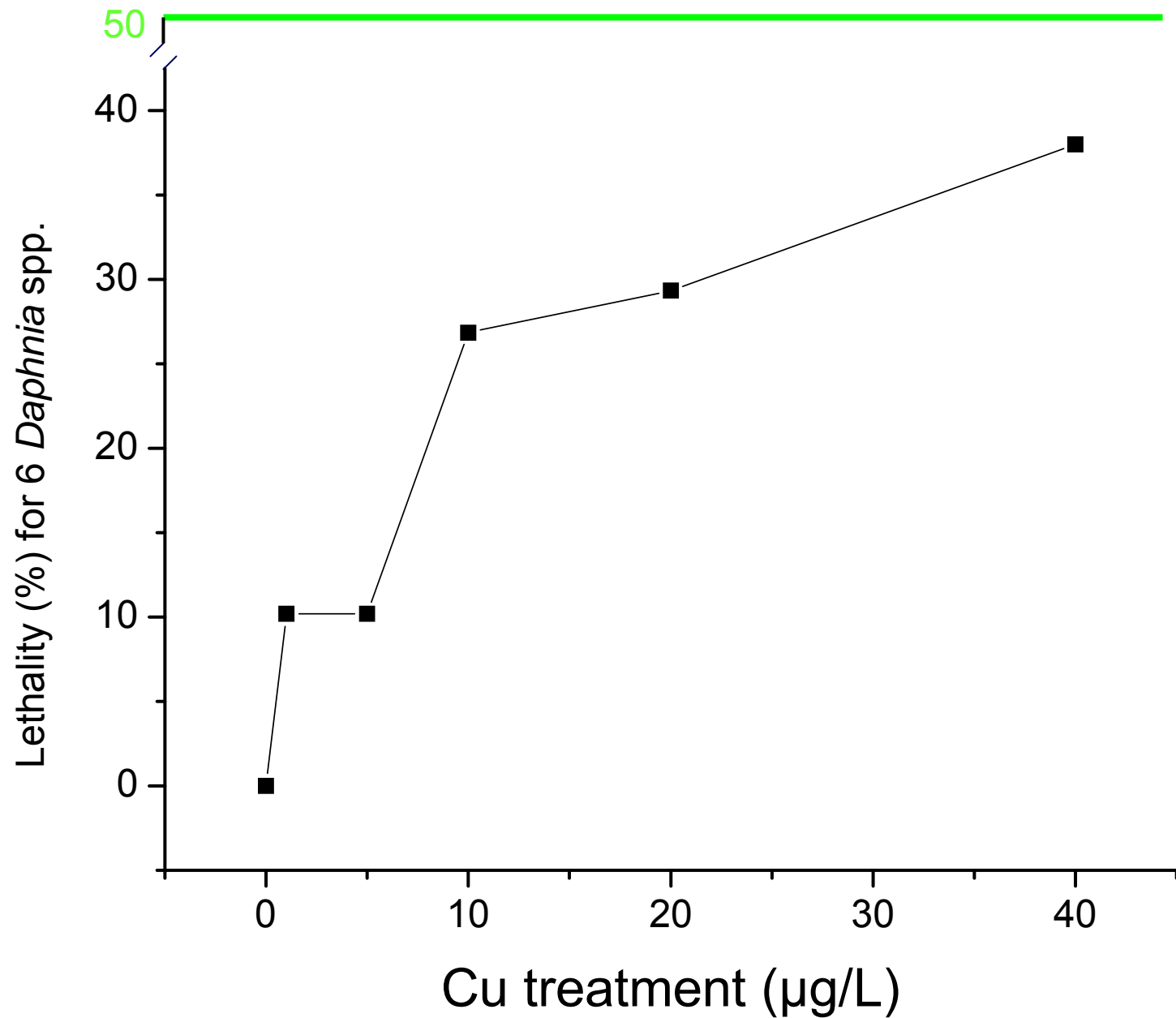


All bioassays done in culture chambers  
FLAMES Laboratory, Dorset, Ontario

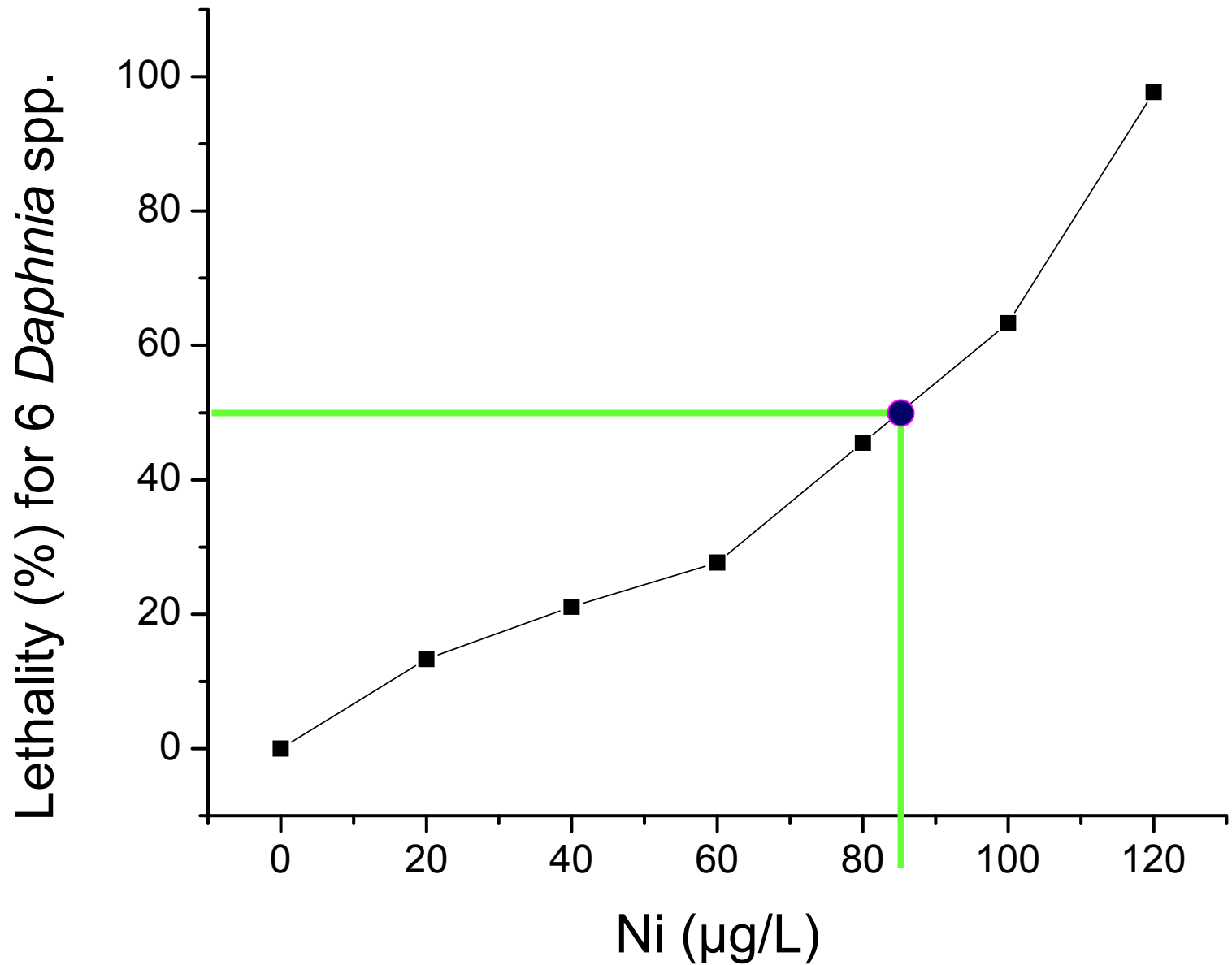
## ACUTE TOXICITY testing

### RANGE FINDING

Copper	[5]	0.28 to 40 µg/L
Nickel	[5]	0.18 to 120 µg/L



Lethality of different [Cu] to the Daphniid species in 72 hr. bioassay



Lethality of different [Ni] to the Daphniid species in 72 hr. bioassay



# 14 DAY PARTIAL LIFE CYCLE

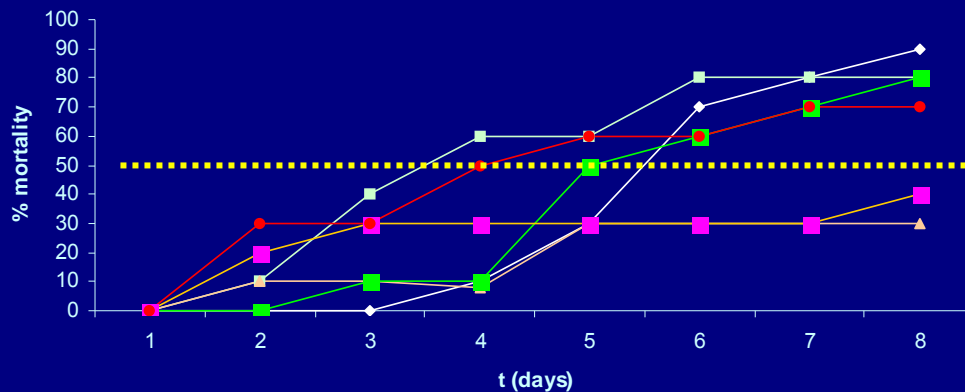
[Cu] 2.5 to 20  $\mu\text{g/L}$



0.29 - 2.5 - 5 - 10 - 15 - 20

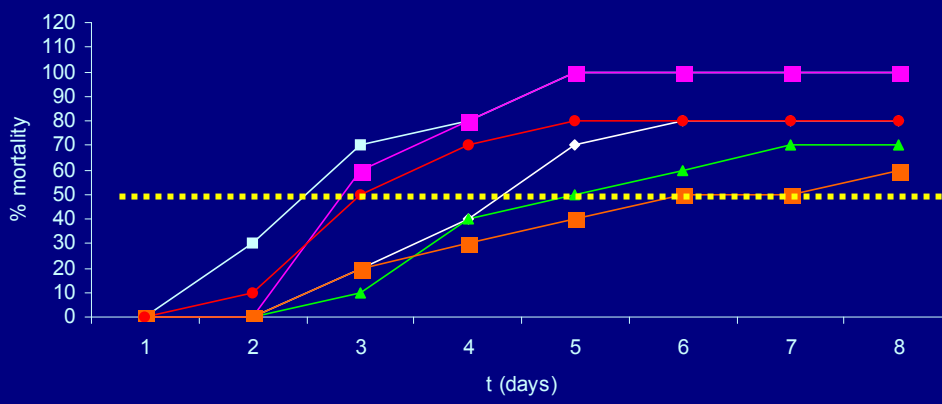




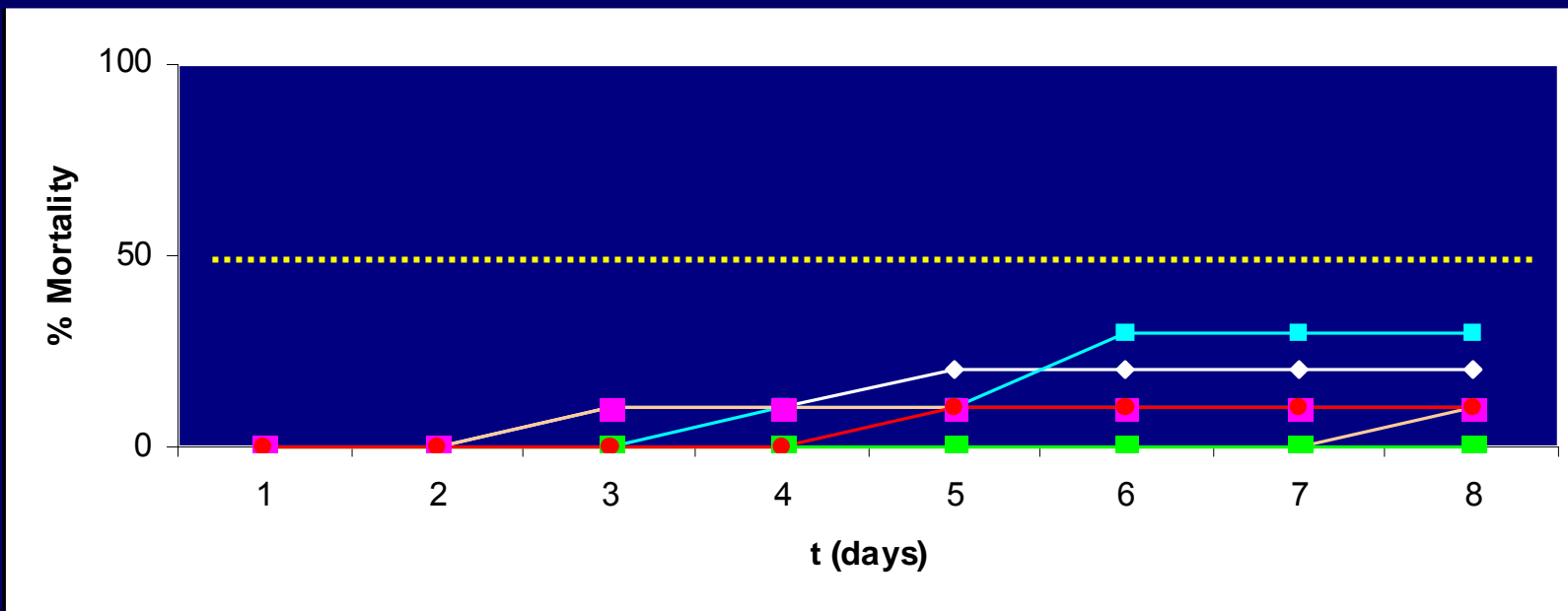


*Daphnia ambigua* mortalities in 14 days

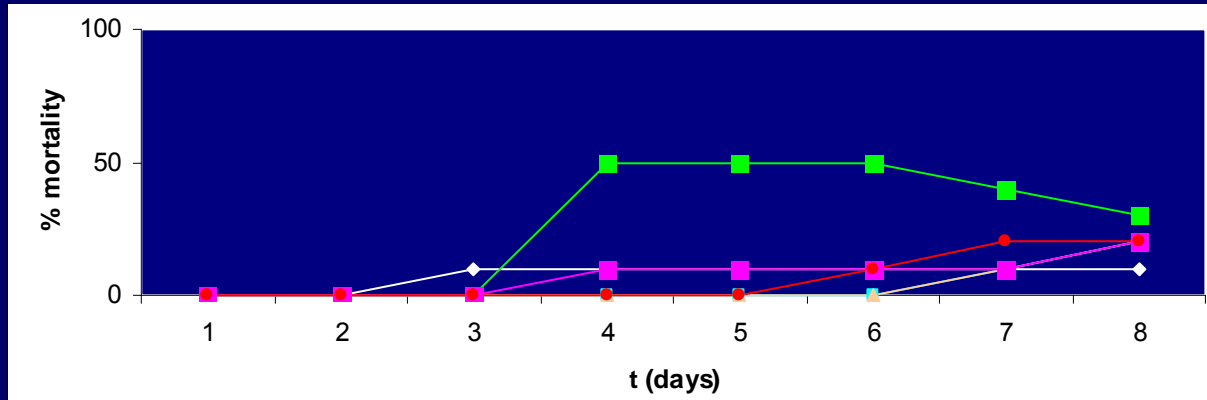
[Cu] µg/L : Control    2.5    5    10    15    20



*Daphnia catawba* mortalities in 14 days



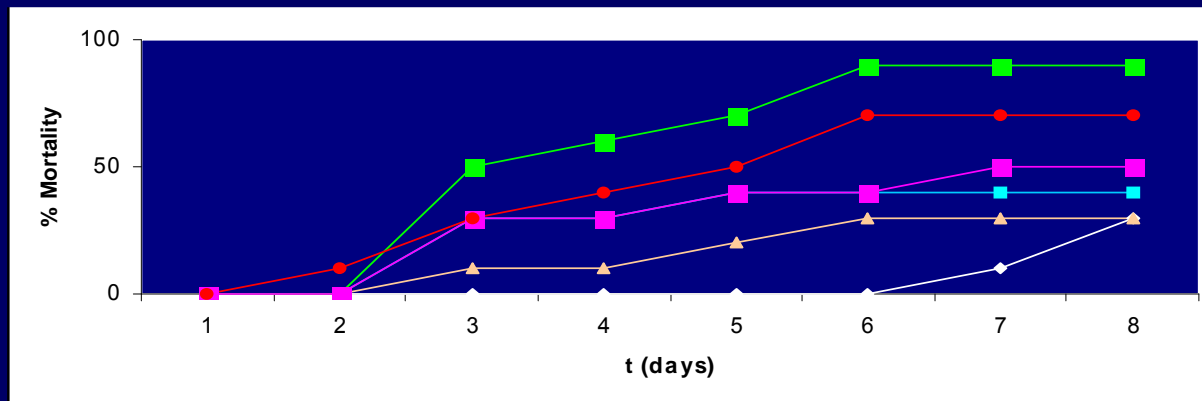
*Daphnia pulex* mortalities in 14 days  
 [Cu] µg/L : Control 2.5 5 10 15 20



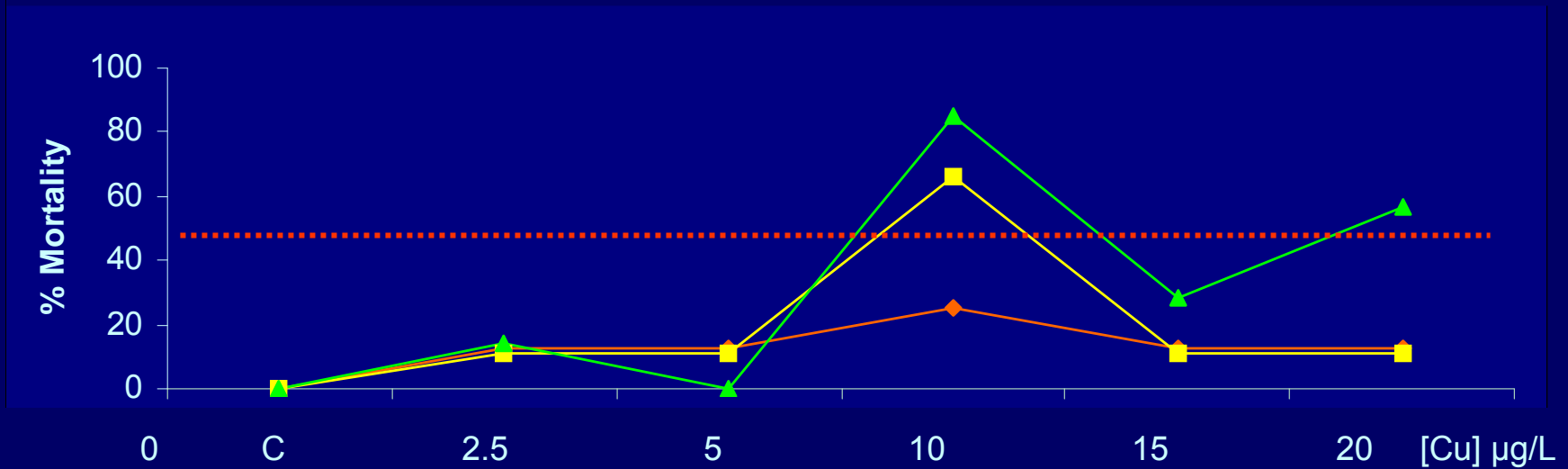
*Daphnia pulicaria* mortalities in 14 days

Control

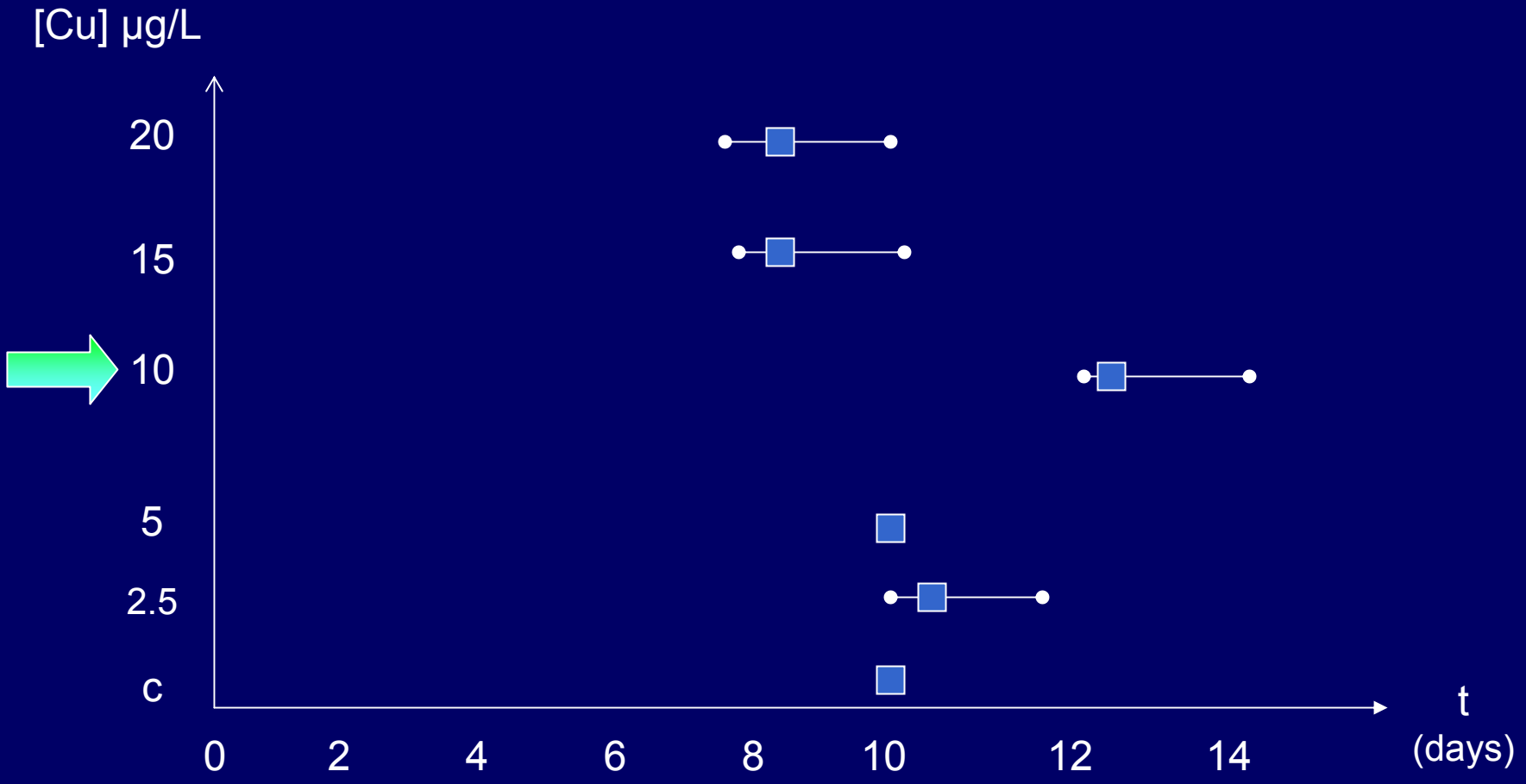
[Cu] µg/L: 2.5 5 10 15 20



*Daphnia mendotae* mortalities in 14 days

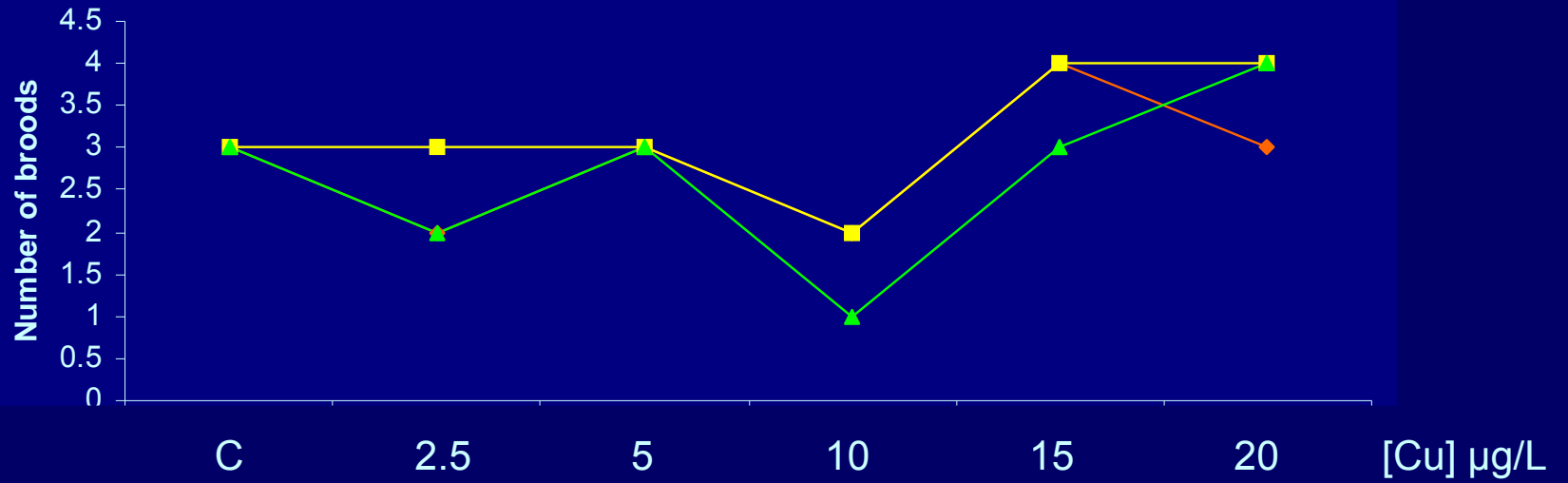


Mortality values at different copper concentrations for *Daphnia pulex*, *D. pulicaria* and *D. mendotae* corrected with Abbot's formula

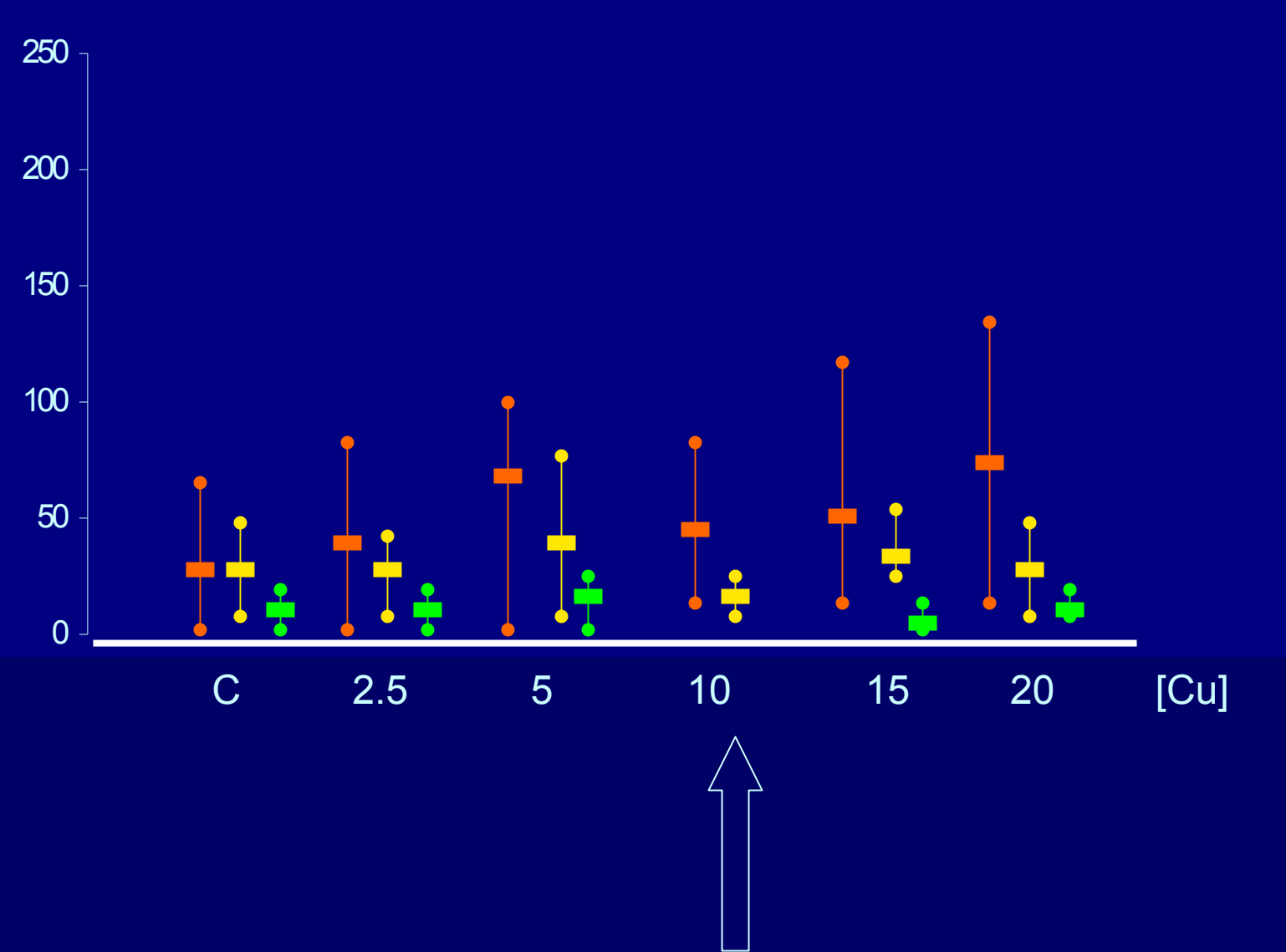


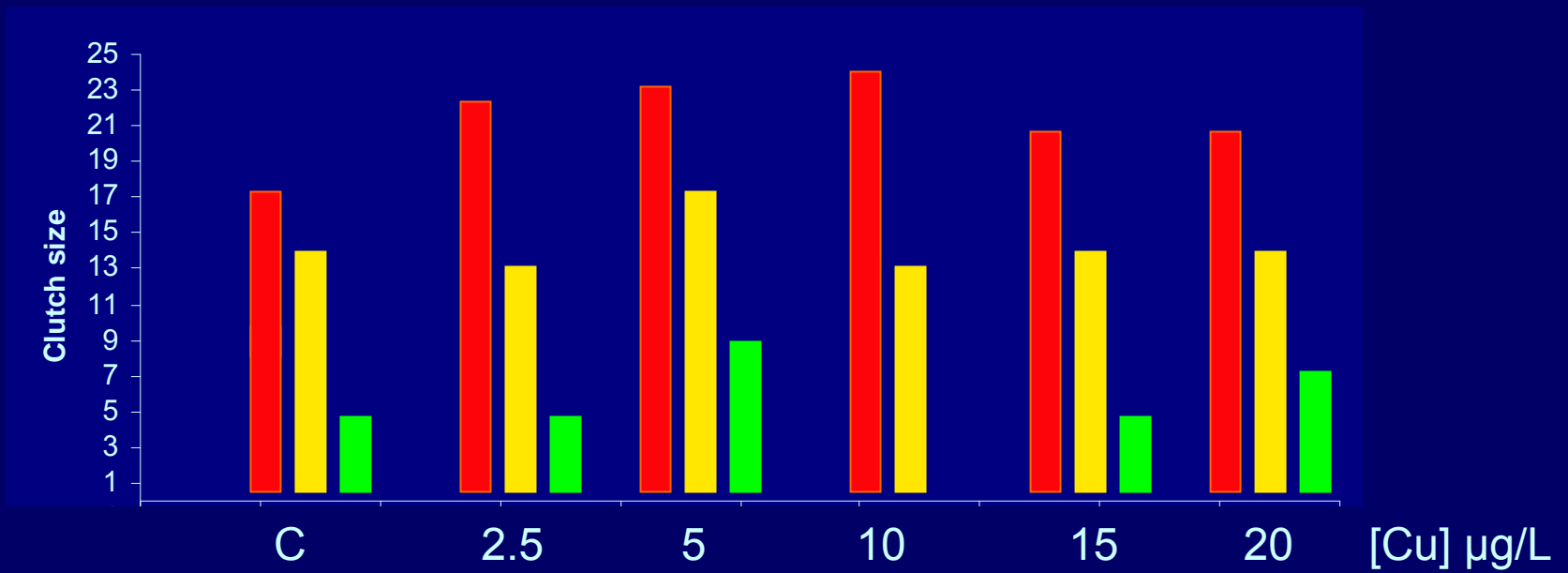
Day of primarity per [Cu] concentration for the 3 sp

Number of broods per species in 14 days



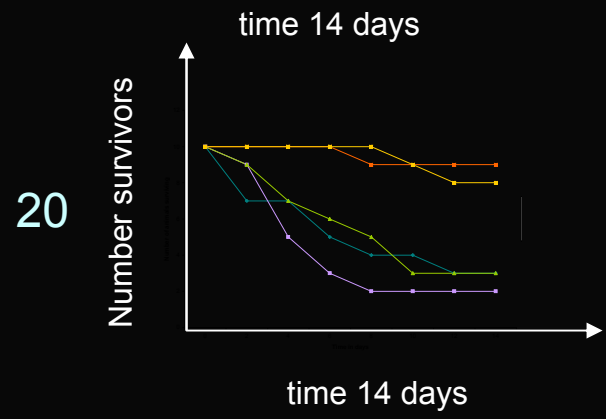
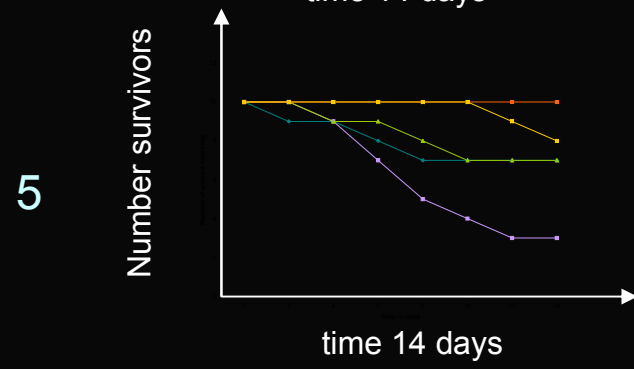
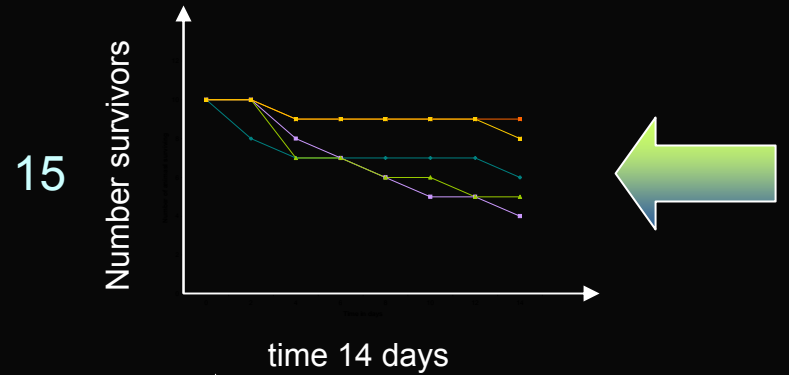
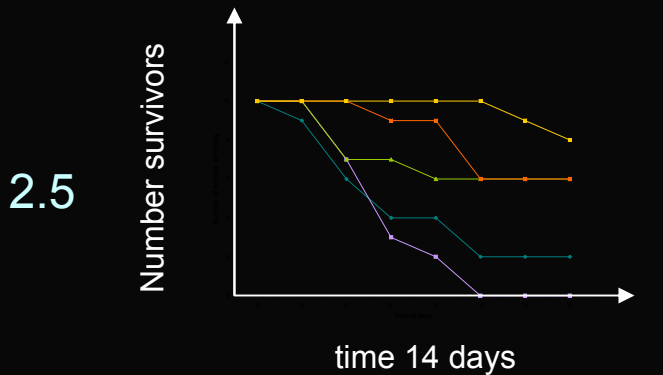
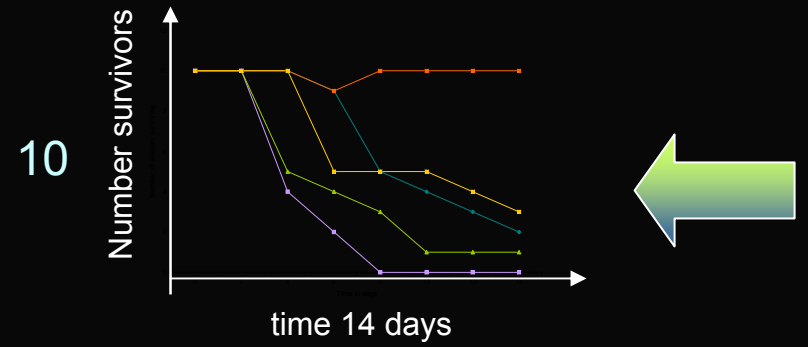
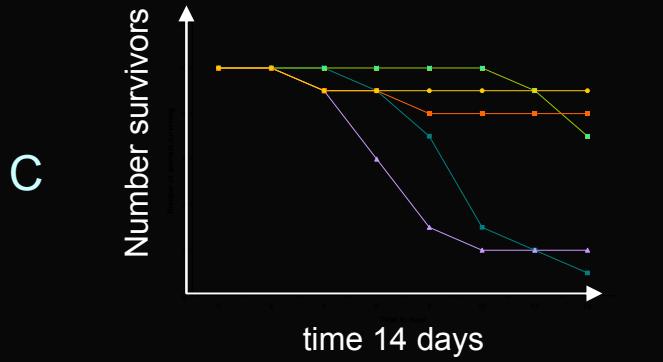
# Number of neonates produced per species per [Cu] in 14 days





Maximum clutch size per Daphniid in each copper concentration





Daphniid survival (days) in different [Cu] ( $\mu\text{g/L}$ )

## PRELIMINARY CONCLUSIONS

### FLAMES medium

#### Short term acute toxicity tests

[Cu + Ni] >>> [Cu] > [Ni]

LC 50 Cu: > 40 (µg/L)

LC 50 Ni : ~ 85 (µg/L)

LC50 mix: < 0.5 Cu + < 20 Ni (µg/L)

#### Partial life cycle toxicity tests

Non monotonic responses

Mortality values higher at 10

Delayed reproduction at 10

Number of broods diminished at 10 and increased at 15 and 20

Neonate production diminished at 10 and increased at 15 and 20

Maximal clutch size at 5 minimal at 10 for *D. mendotae*

Shifts in survival between 10 and 15

Need for refinement of culture techniques for species of Cladocera

## Next Steps

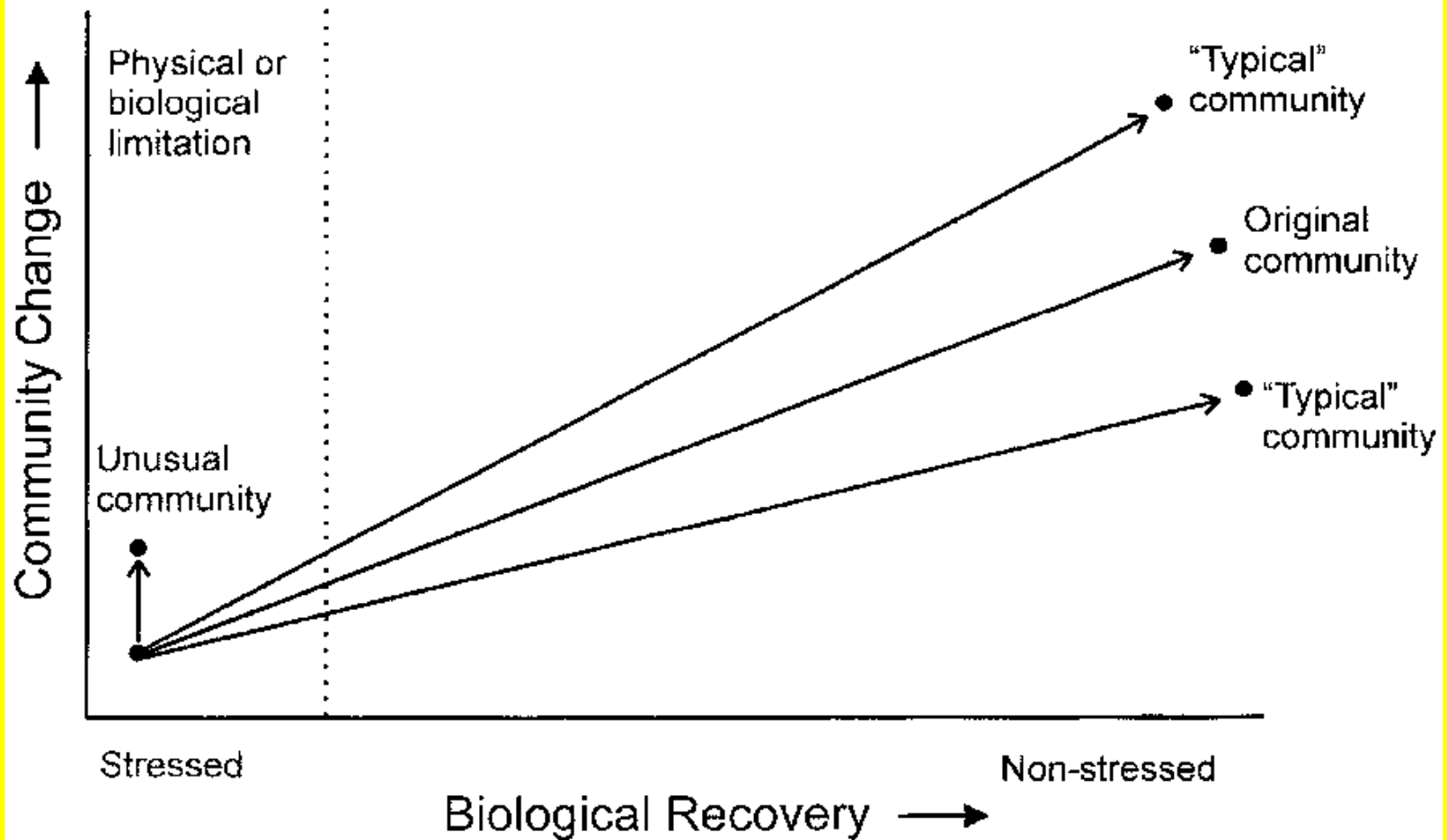
Partial life cycle bioassays with Nickel  
and mix of Cu and Ni

Speciation of metals in FLAMES medium

Analysis of data

Selection of lakes for in situ bioassays

Field bioassays



## Possible trajectories of biological recovery

(Keller, Gunn and Yan, 1999)

## Acknowledgements

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