Pressures on Shallow Lakes

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Schallenberg & Sorrell, NZJMFR (in press)

Flipping Lakes – between stable ecological states

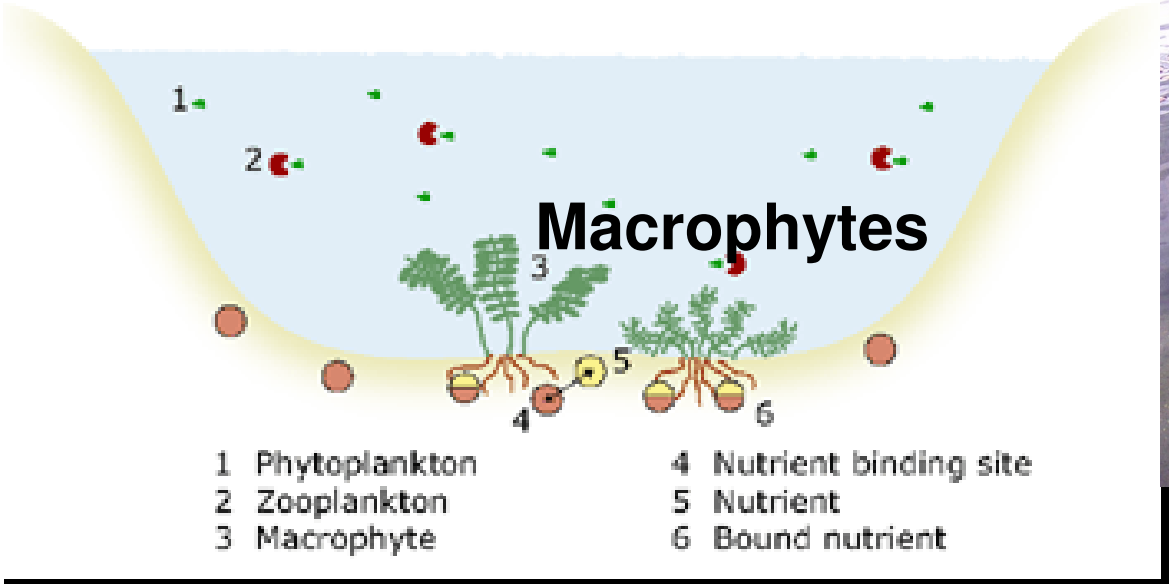
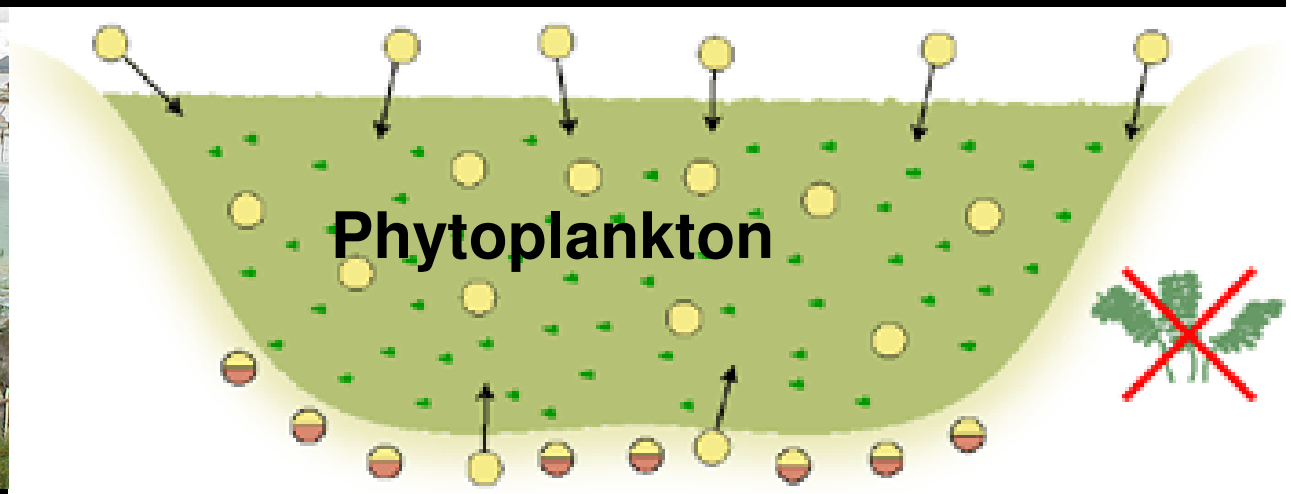
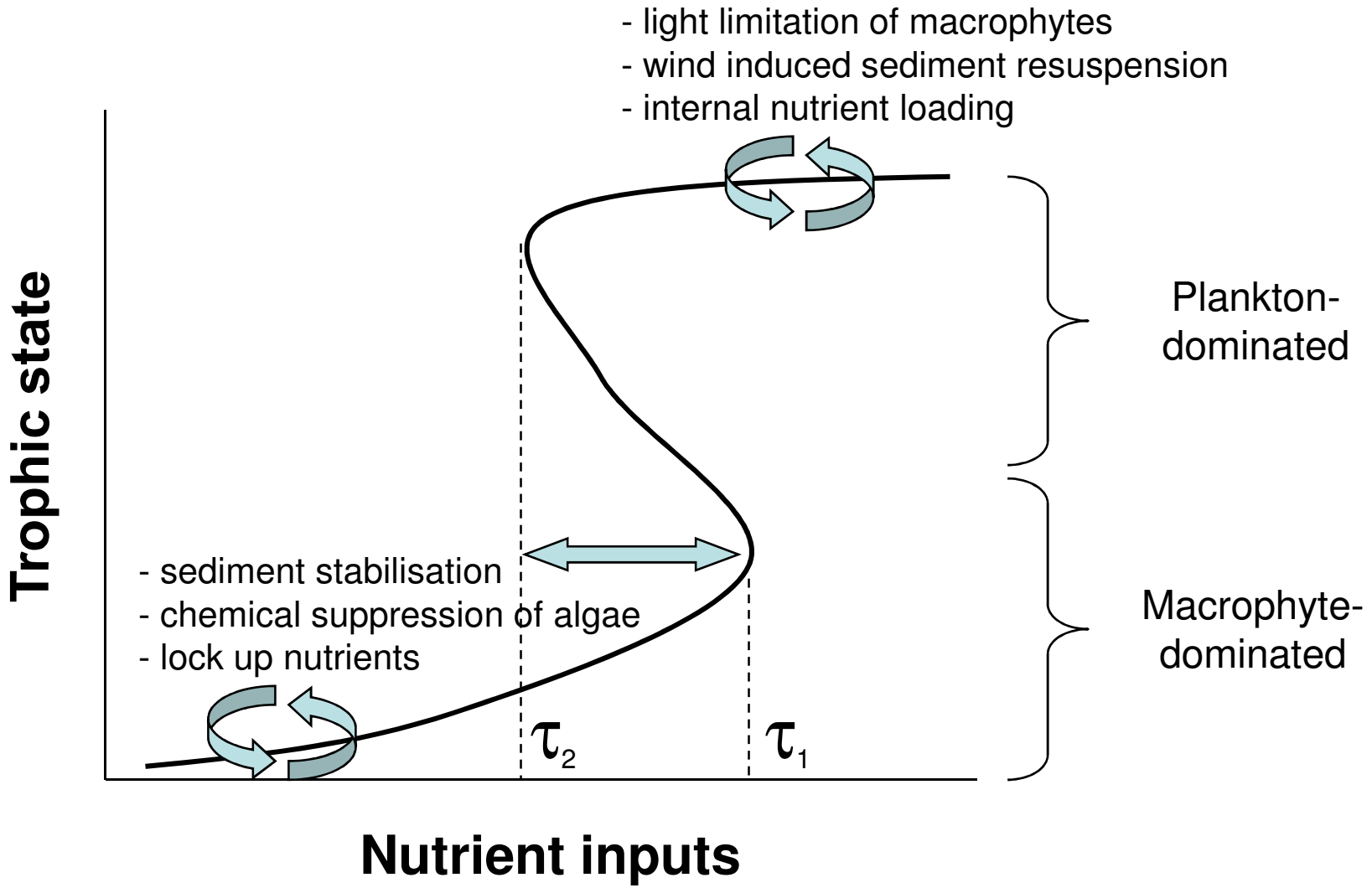


Photo: G. Zwart

Diagrams: Environment Waikato



How and Why Flipping Lakes Flip…



Pressures causing a lake to change

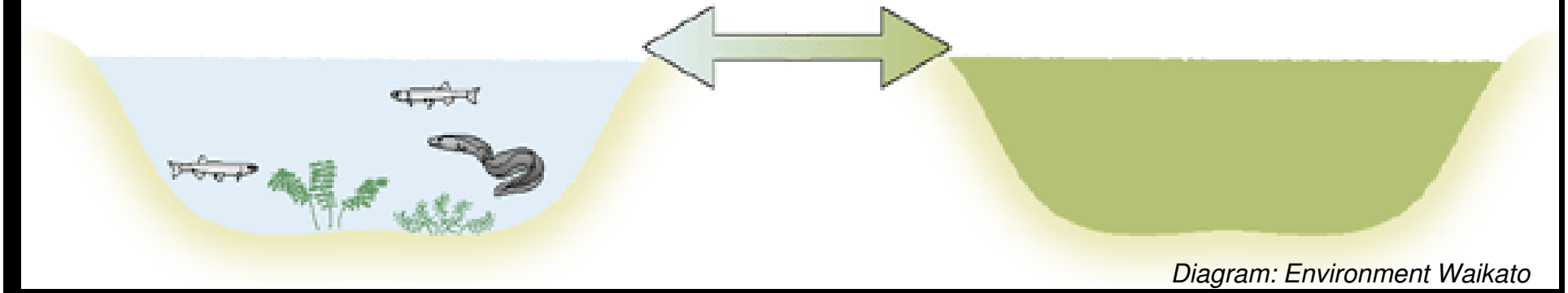


Diagram: Environment Waikato

- Sweden
- Netherlands
- Denmark
- UK
- Australia

1. Tomahawk Lagoon #2, Otago (Mitchell et al. 1988; Mitchell 1989)
2. Hawkesbury Lagoon, Otago (Wass & Mitchell 1996)
3. Lake Ellesmere / Te Waihora, Canterbury (Hughes et al. 1974; Gerbeaux 1993
4. Lake Omapere, Northland (Howard-Williams & Kelly 2003)

Pressures Related to Flipping in Shallow Lakes:

Definition of a Flipping Lake:

…shows a rapid, visible shift between:

1) a clear water state characterised by the presence of submerged macrophyte beds

and

2) a turbid state characterised by a lack of, or distinct reduction in, macrophyte biomass.

NB: seasonal variation in macrophyte cover not considered a regime shift

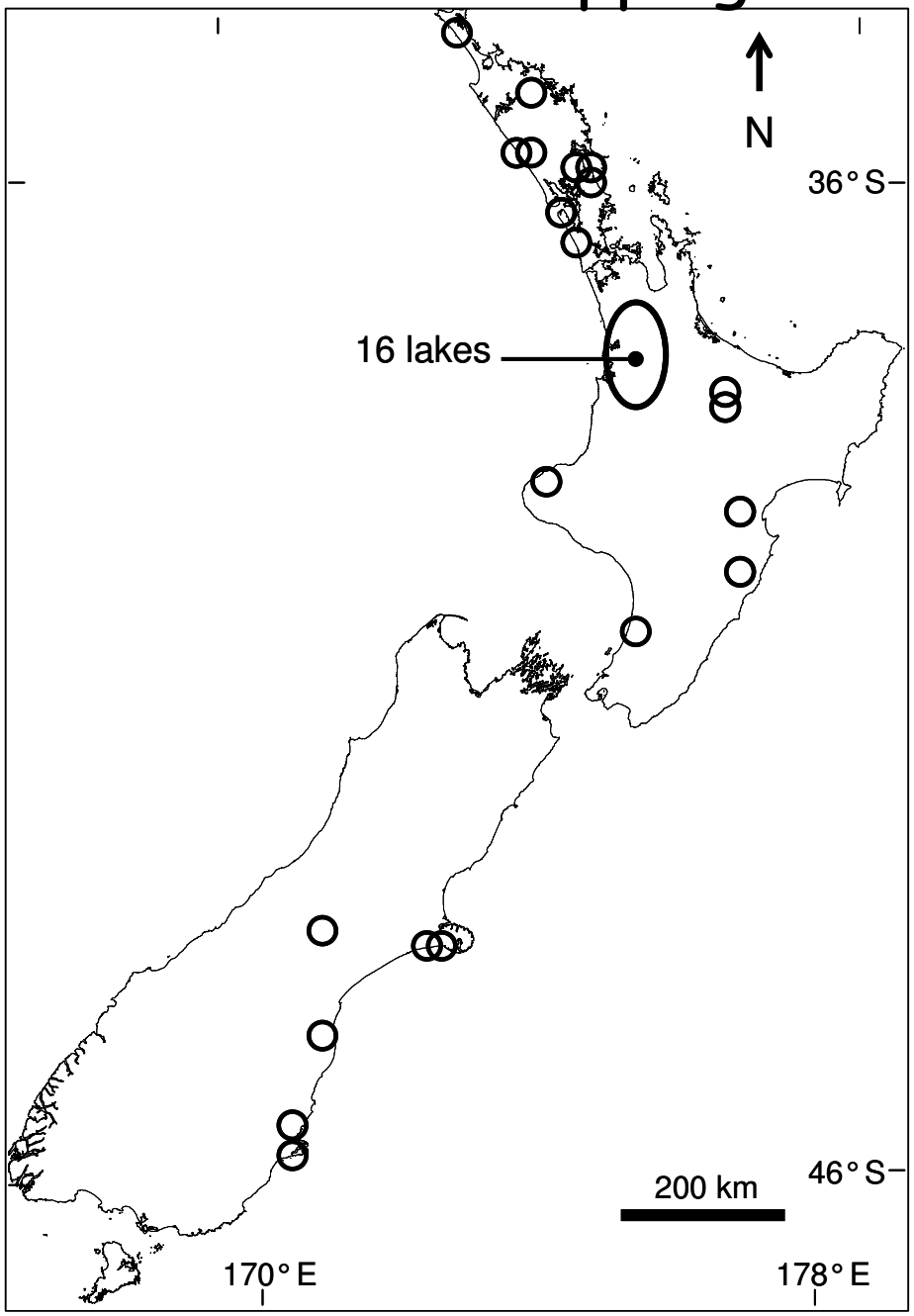
Distribution of Flipping Lakes

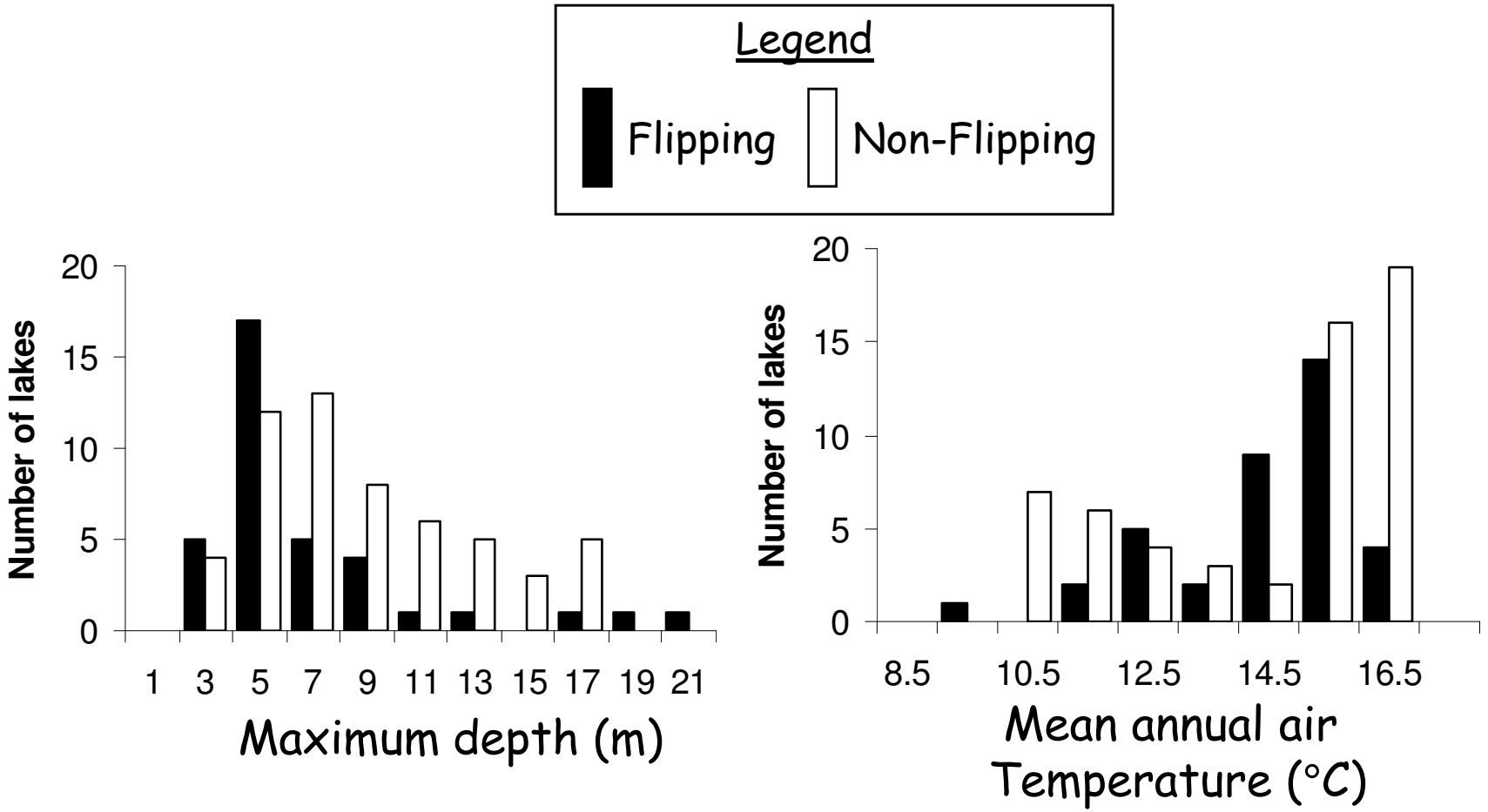
Strong evidence of 37 Flipping Lakes in New Zealand

Clear-to-Turbid
- 19 Lakes

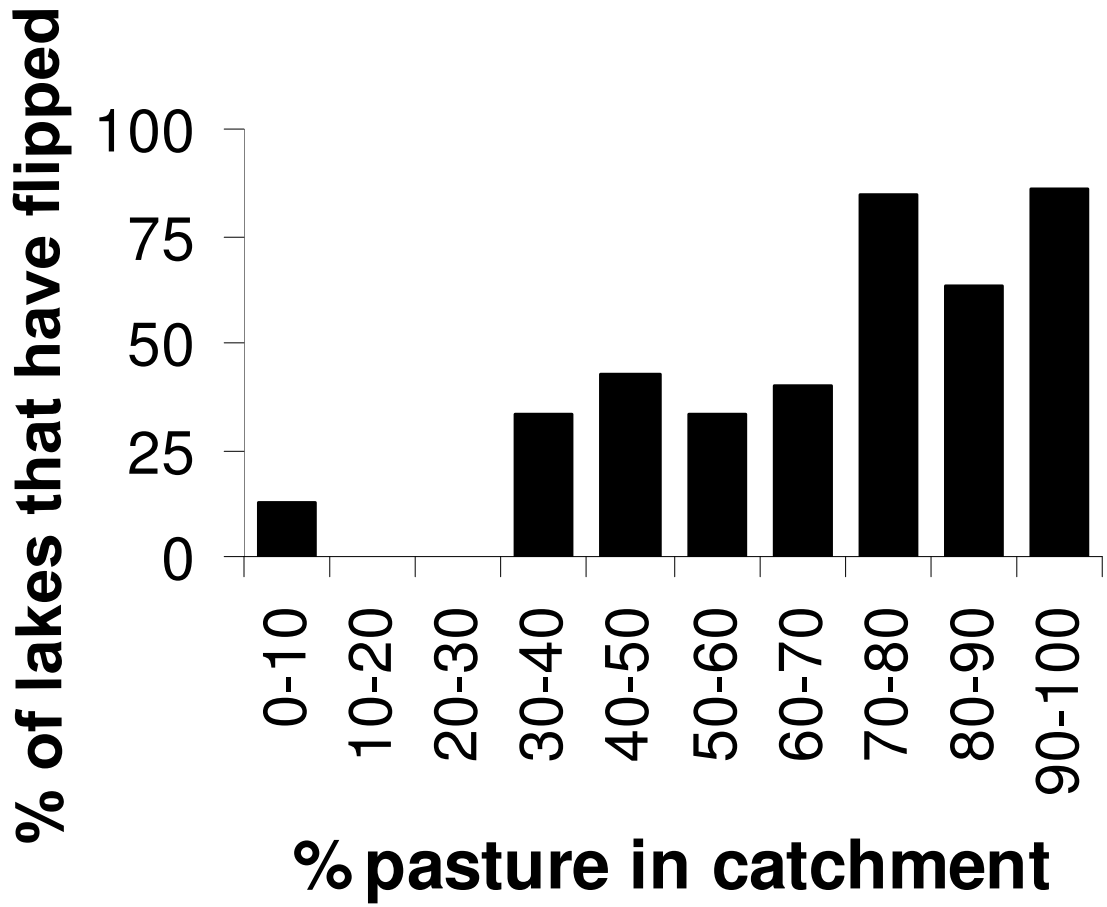
Back-and-forth
- 17 Lakes

We also identified 57 lakes of similar depths and in similar climates which have never been reported to have flipped




Legend
Flipping
Non-Flipping
Number of lakes
20
15
10
5
0
1 3 5 7 9 11 13 15 17 19 21
Maximum depth (m)
Number of lakes
20
15
10
5
0
8.5 10.5 12.5 14.5 16.5
Mean annual air Temperature (°C)

Is catchment land use related to the likelihood of flipping?



Is the presence of introduced macrophyte species correlated with flipping in lakes?

-data from NIWA Biodata Information Database
-analysis based on presence/absence

- 53% of flipping lakes had *E.densa* present
- 13% of non-flipping lakes had *E. densa* present

$P < 0.001$

South African oxygen weed (*Lagarosiphon major*)
Canadian pondweed (*Elodea canadensis*)
Hornwort (*Ceratophyllum demersum*)

} Non-significant

Is the presence of coarse fish species correlated with flipping in lakes?

-herbivorous and benthivorous fish taxa
-data from NIWA Freshwater Fish Database
-analysis based on presence/absence

Koi carp

Rudd

Brown bullhead catfish

Is the presence of coarse fish species correlated with flipping in lakes?

– Catfish ****

Goldfish ****

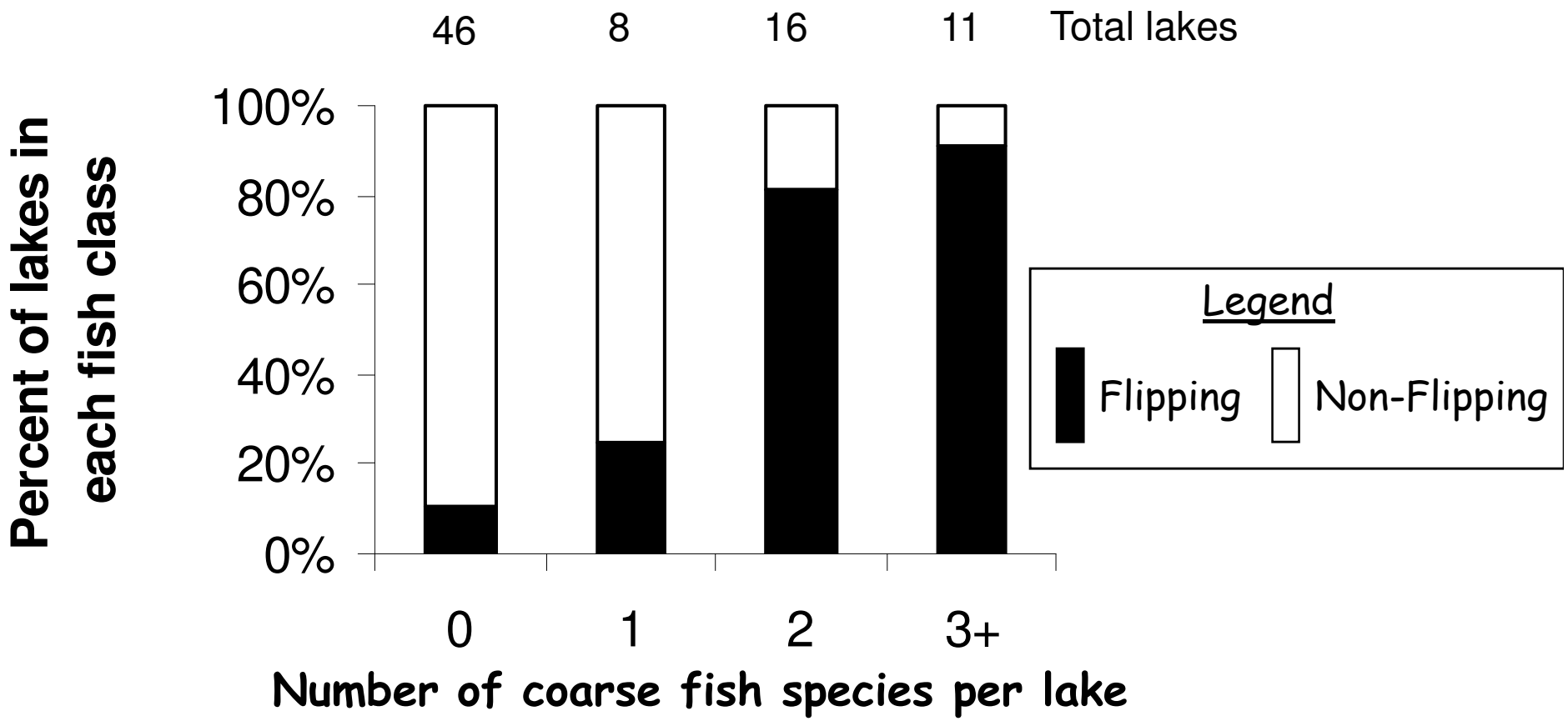
– Rudd ***

Tench **

– Koi carp *

**** P < 0.0001
*** P < 0.001
** P < 0.01
* P < 0.05

Are the effects of co-occurring coarse fish species worse?



Conclusions:

1. Flipping between alternative stable states is common in NZ shallow lakes

2. Flipping occurs in lakes from Otago to Northland, lakes up to 20m deep and lakes which have a mean annual air temperature from 8.5°C to 16.5 °C

3. The conversion of forest to pasture probably induces flips

4. The presence of *Egeria densa* probably induces flips

5. The introduction of 5 introduced fish taxa probably induces flips

6. The co-occurrence of coarse fish species is more strongly related to flipping
   - supports findings of the complementary effects of coarse fish taxa on turbidity (Rowe 2007)

7. These results, if confirmed by experiments, have obvious, direct implications for shallow lake conservation, management and restoration

8. Prior to pastoral farming, regime shifting was probably very rare in NZ

Caveat:

Results are correlational – further research is required to confirm inferred effects

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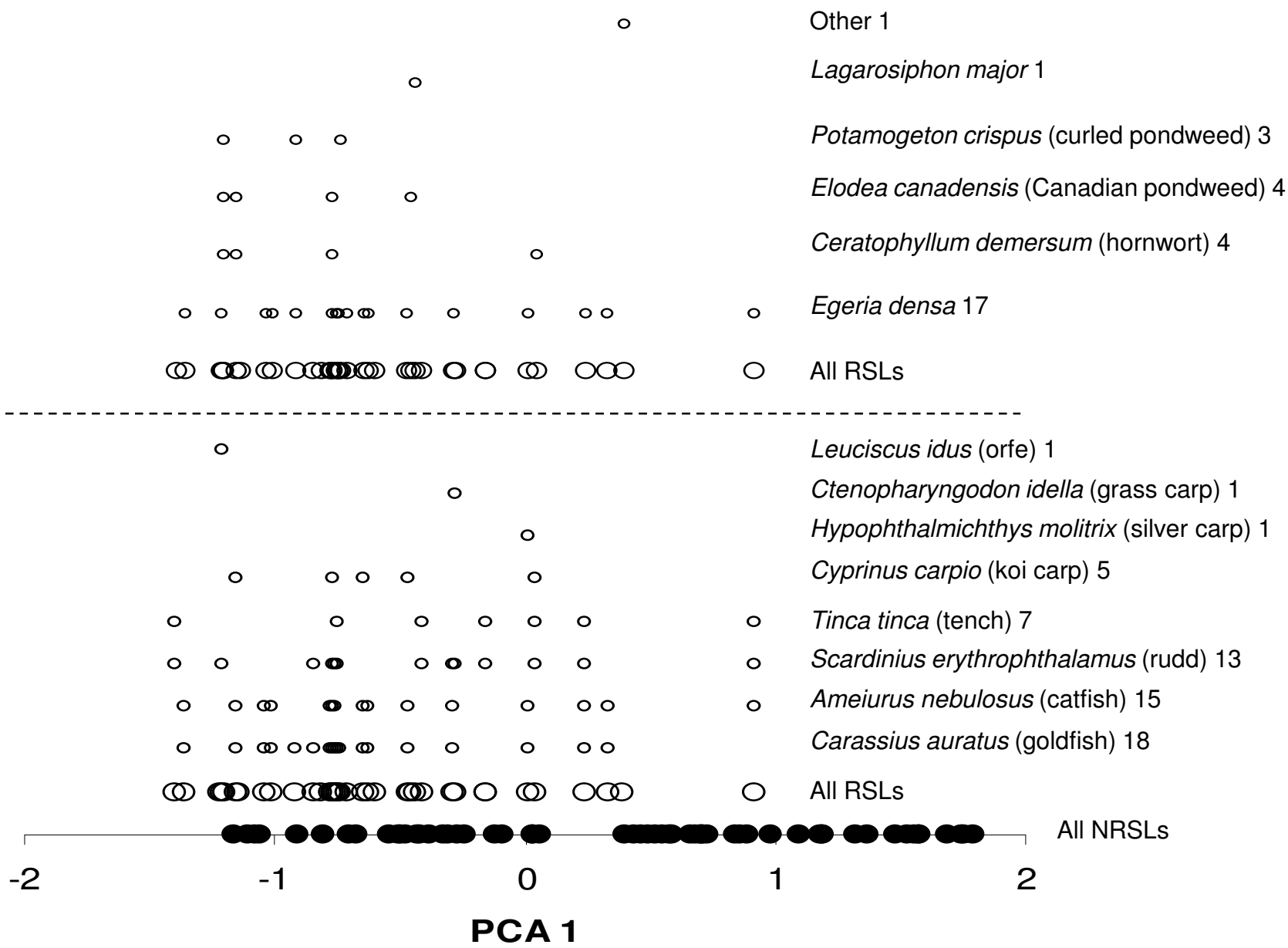
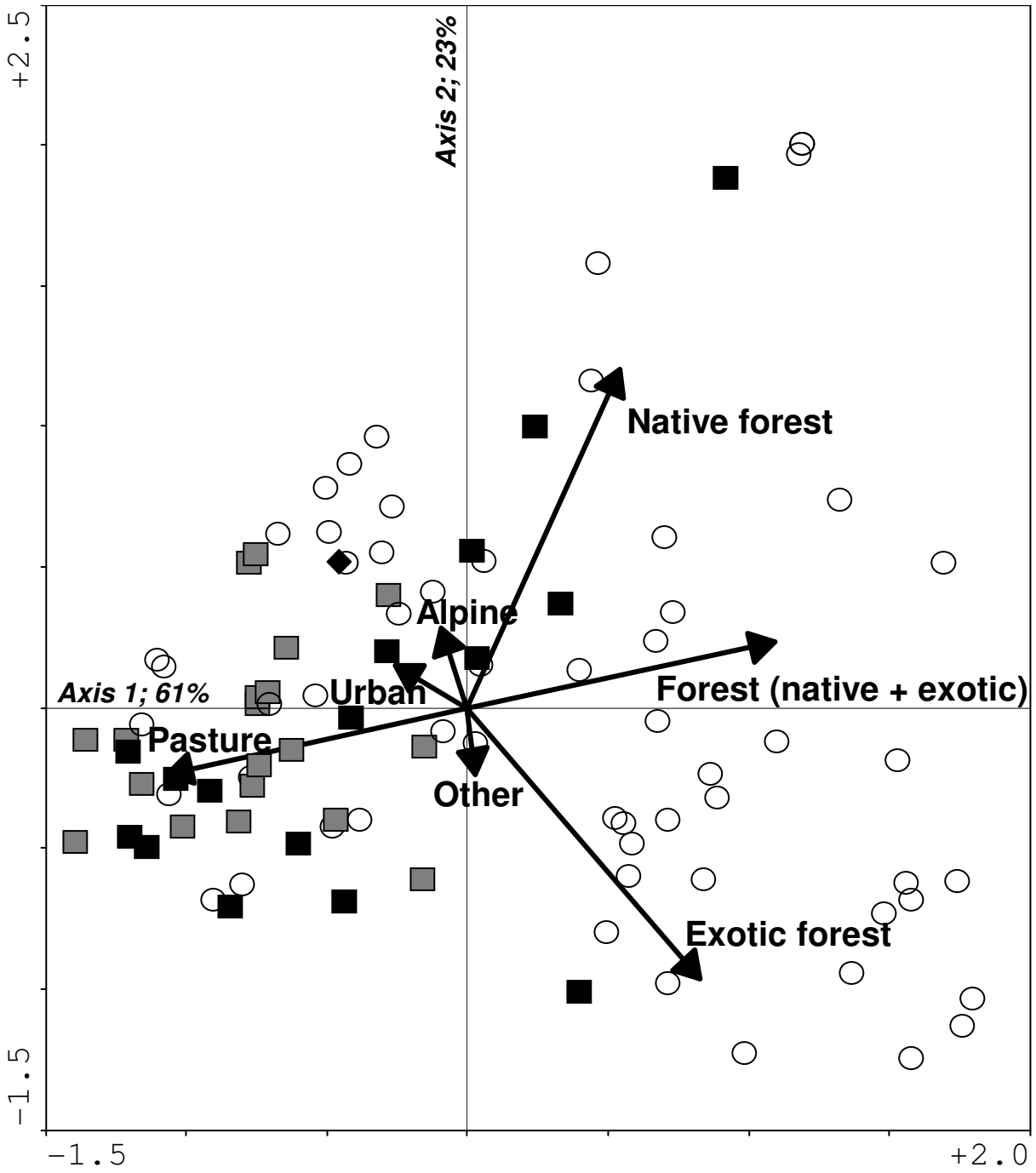
Thank you for listening

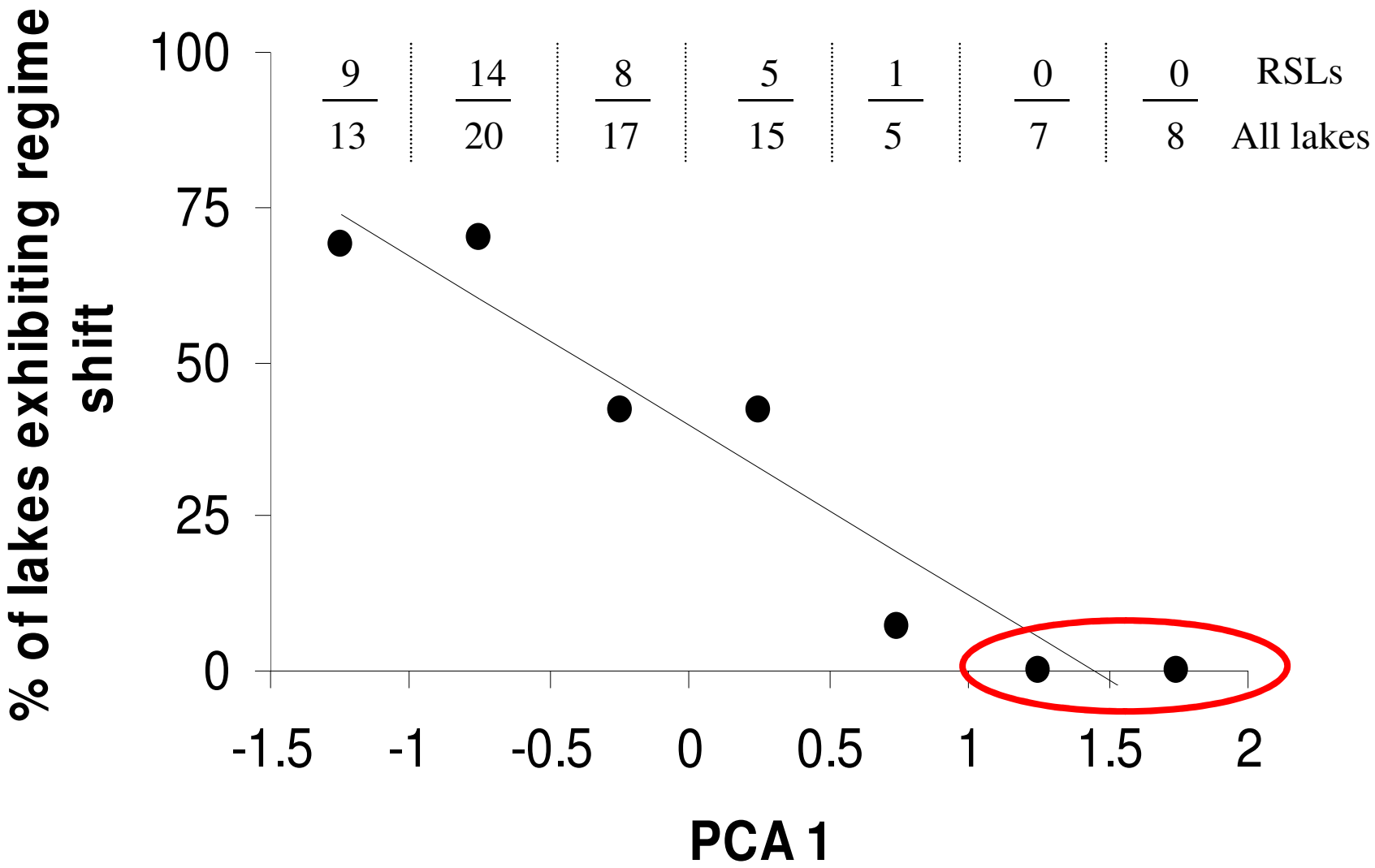

Other 1
Lagarosiphon major 1
Potamogeton crispus (curled pondweed) 3
Elodea canadensis (Canadian pondweed) 4
Ceratophyllum demersum (hornwort) 4
Egeria densa 17
All RSLs
Leuciscus idus (orfe) 1
Ctenopharyngodon idella (grass carp) 1
Hypophthalmichthys molitrix (silver carp) 1
Cyprinus carpio (koi carp) 5
Tinca tinca (tench) 7
Scardinius erythrophthalamus (rudd) 13
Ameiurus nebulosus (catfish) 15
Carassius auratus (goldfish) 18
All RSLs
All NRSLs
-2
-1
0
1
2
PCA 1



PCA – Catchment land use

- ○ Non-RSLs
- ■ RSLs - alternating
- ■ RSLs – macro-to-turbid
- ◆ RSLs – clear-to-macro

Is land use related to regime shifting in shallow lakes?



Can we predict regime shifting from catchment land use?

Discriminant Analysis **Regime shift (Y/N)** **=** **%pasture + %forest**		**Predicted group membership (number of lakes)**		**Actual group totals**
		Non-regime shift	**Regime shift**	
Actual group membership	**Non-regime shift**	48	9	57
	Regime shift	11	26	37
Predicted group totals		59	35	

78% correct classification; Wilkes Lambda $F_{2,91} = 22.2$, $P < 0.0001$

Exotic taxa	**Occurrence in RSLs (in % of RSLs)**	**Occurrence in Non-RSLs (in % of Non-RSLs)**	X^2	P
Egeria densa	17 (53)	7 (13)	16.11	$P < 0.001$
Elodea canadensis (Canadian pondweed)	4 (13)	7 (13)	0.004	n/s
Ceratophyllum demersum (hornwort)	4 (13)	6 (11)	0.04	n/s
Potamogeton crispus (curled pondweed)	3 (9)	5 (9)	0.0003	n/s
Lagarosiphon major	1 (3)	4 (7)	0.67	n/s
Other	1 (3)	6 (11)	1.71	n/s

Exotic taxa	**Occurrence in RSLs (in % of RSLs)**	**Occurrence in Non-RSLs (in % of Non-RSLs)**	X^2	P
Ameiurus nebulosus (catfish)	15 (50)	0 (0)	33.56	$P < 0.001$
Carassius auratus (goldfish)	18 (60)	6 (12)	22.82	$P < 0.001$
Scardinius erythrophthalmus (rudd)	13 (43)	6 (12)	11.52	$P < 0.001$
Tinca tinca (tench)	7 (23)	2 (4)	7.94	$0.005 > P > 0.001$
Cyprinus carpio (koi carp)	5 (17)	1 (2)	6.58	$0.025 > P > 0.01$
Hypophthalmichthys molitrix (silver carp)	1 (3)	0 (0)	n/a	
Ctenopharyngodon idella (grass carp)	1 (3)	0 (0)	n/a	
Leuciscus idus (orfe)	1 (3)	0 (0)	n/a	