An assessment of toxicity in profundal lake sediment due to deposition of heavy metals and POPs from the atmosphere

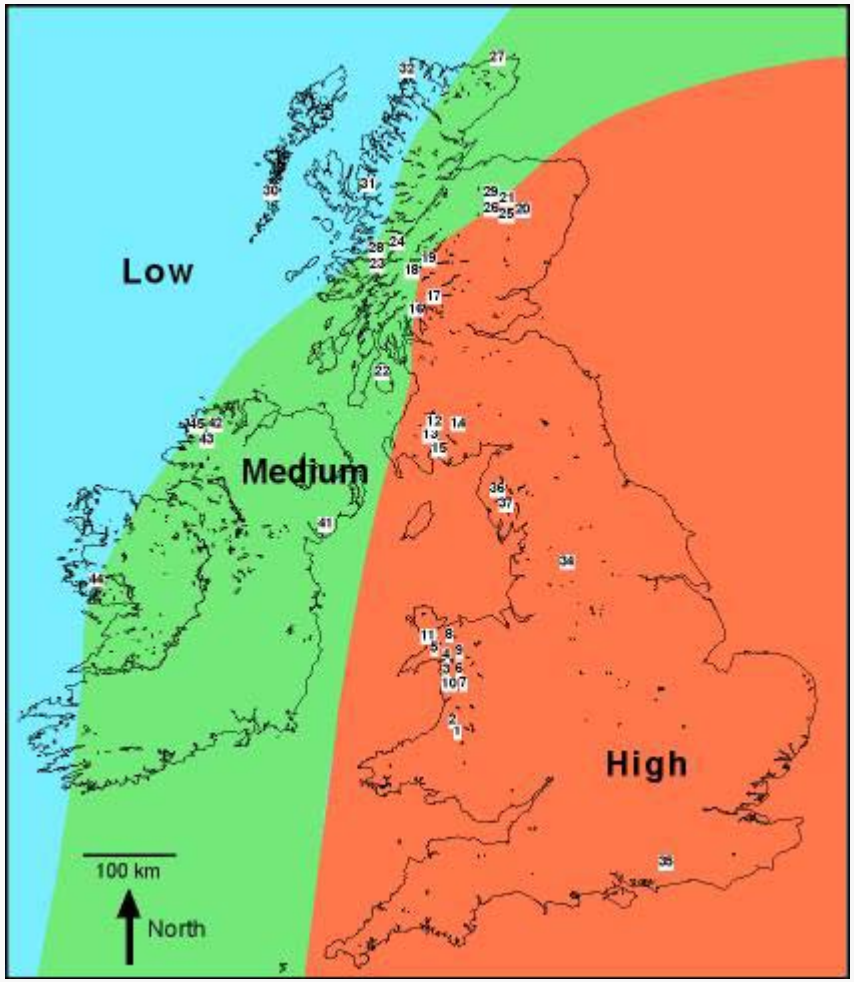
Brian Rippey[†], Neil Rose[††], Handong Yang[††], Stuart Harrad [†††],

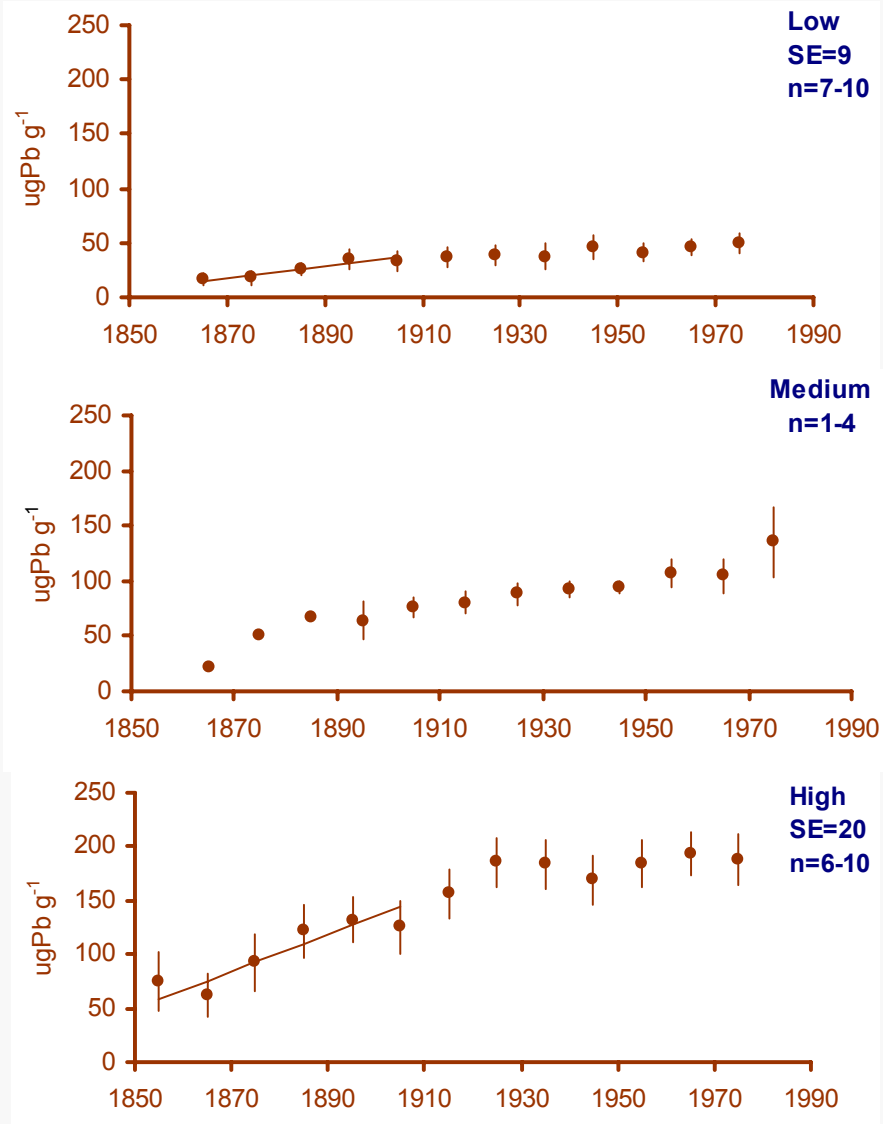
Mat Robson[†††] and Sarah Travers[†]

[†] University of Ulster

[††] University College London

[†††] University of Birmingham





Forty-nine sediment cores from forty-one lakes in three contamination regions

Rippey & Douglas (2004) Global Biogeochemical Cycles 18, GB4026, doi:10.1029/2004GB002305, 2004

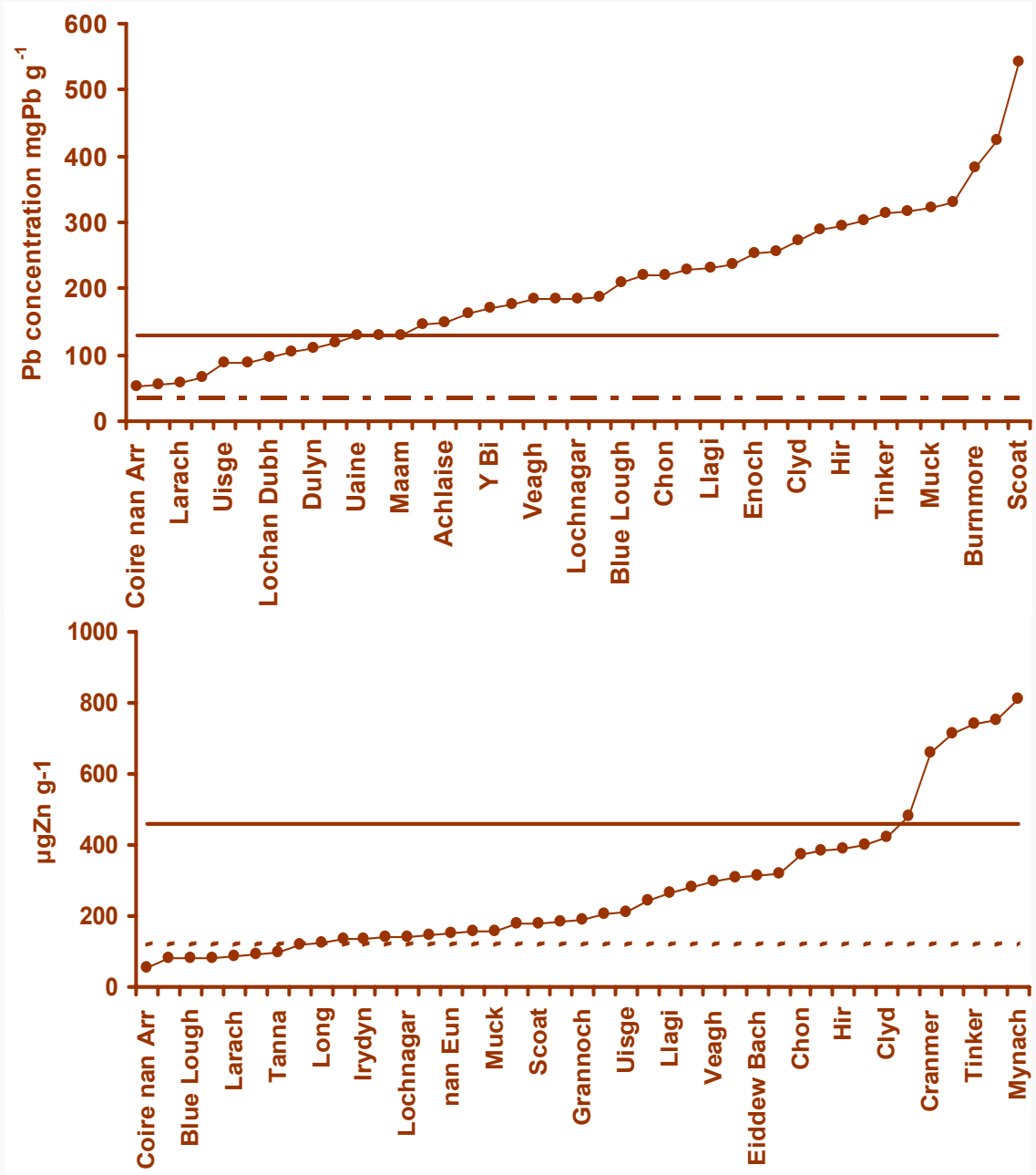
Sediment Quality Guidelines
MacDonald et al. (2000)

Pb

PEC = 128 µg/g
TEC = 35.8 µg/g
Uncontaminated = 31 µg/g

Zn

PEC = 459 µg/g
TEC = 121 µg/g
Uncontaminated = 123 µg/g



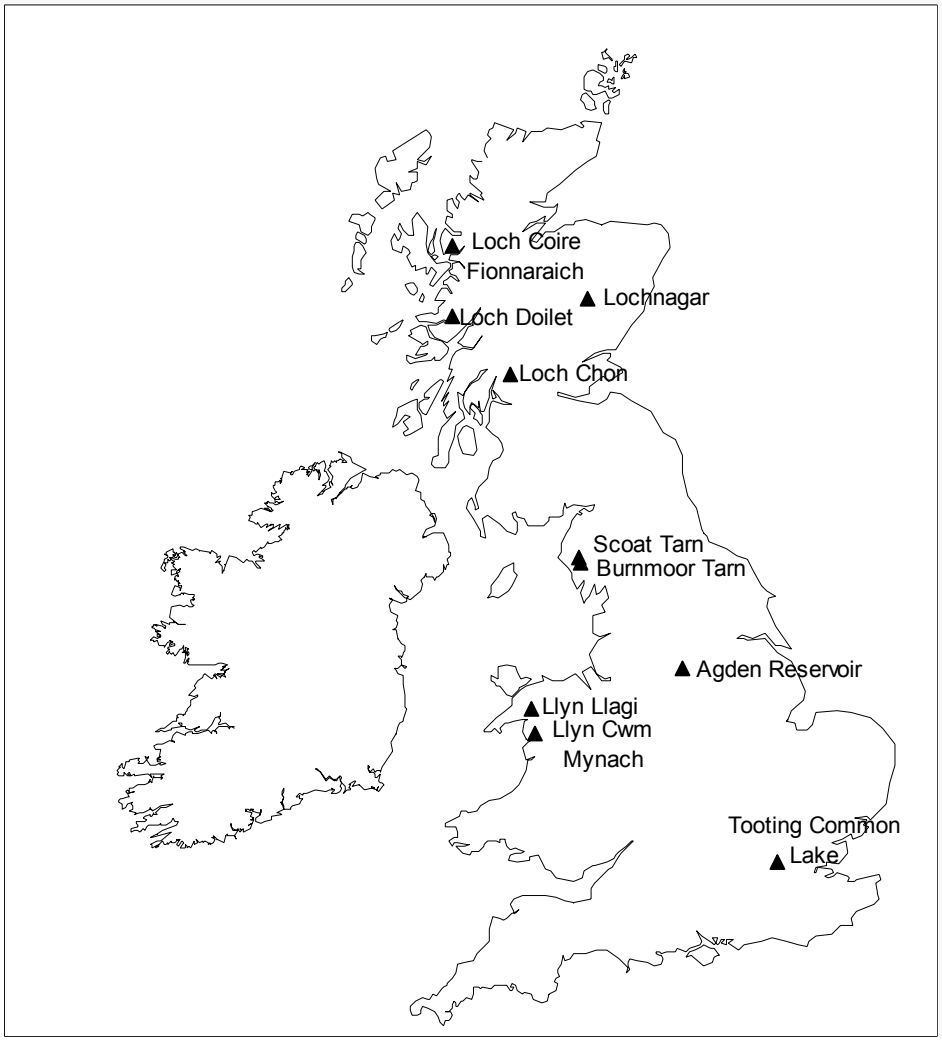
Tier I Sediment Ecological Risk Assessment of profundal lake sediment contaminated by heavy metals and POPs deposited from the atmosphere

1 Determine the concentrations of a range of relevant contaminants of profundal lake sediments; heavy metals and POPs

2 Compare the concentrations with sediment quality guideline values

3 Complete laboratory sediment toxicity tests

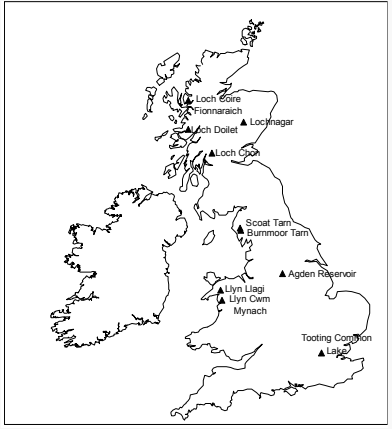
4 Evaluate the biological effects in freshwater sediment that may result from the contamination found


Loch Coire
Fionnaraich
Lochnagar
Loch Doilet
Loch Chon
Scoat Tarn
Burnmoor Tarn
Agden Reservoir
Llyn Llagi
Llyn Cwm
Mynach
Tooting Common
Lake

Two sediment toxicity tests

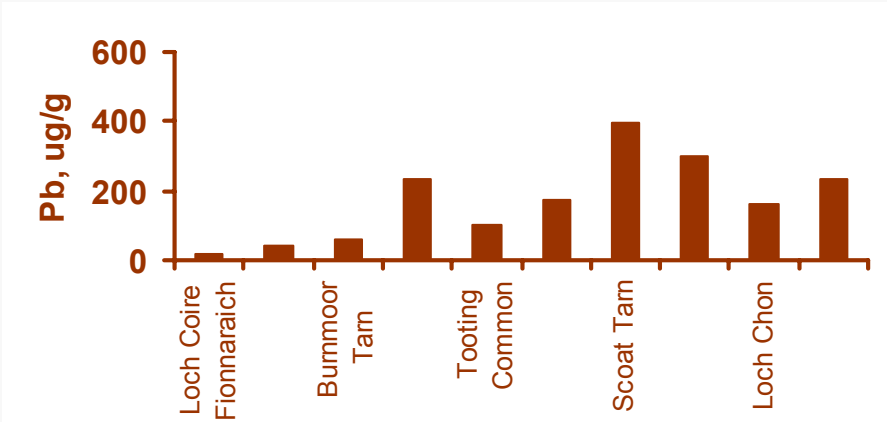
17-day chironomid survival and emergence
7-day cladoceran survival and reproduction

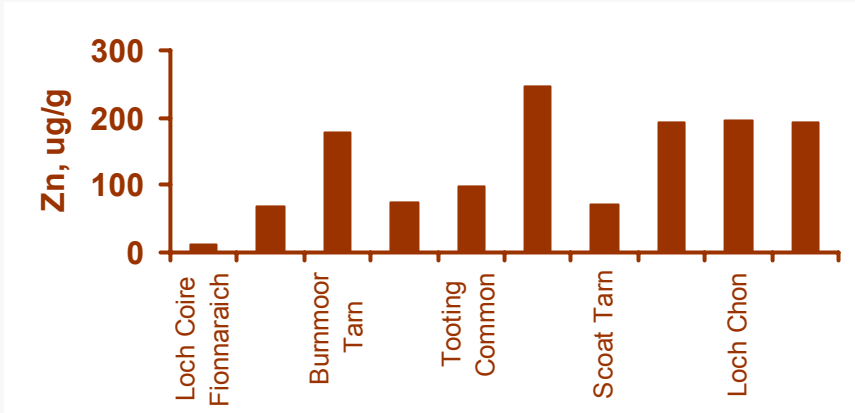
Compare profundal lake sediment samples with reference sediment

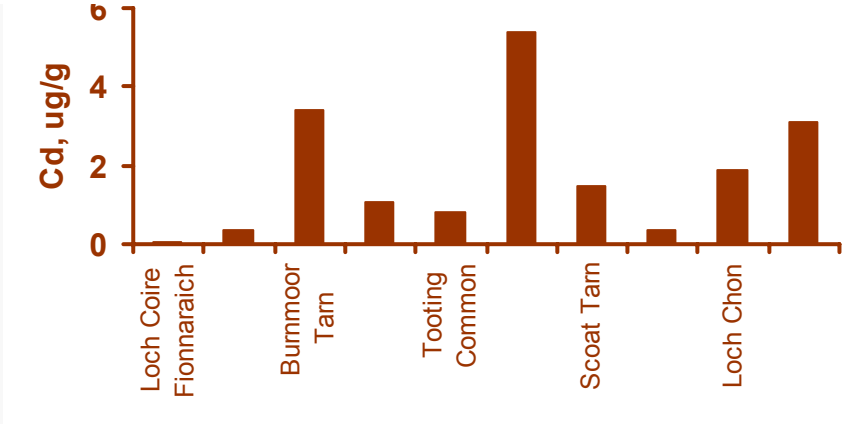


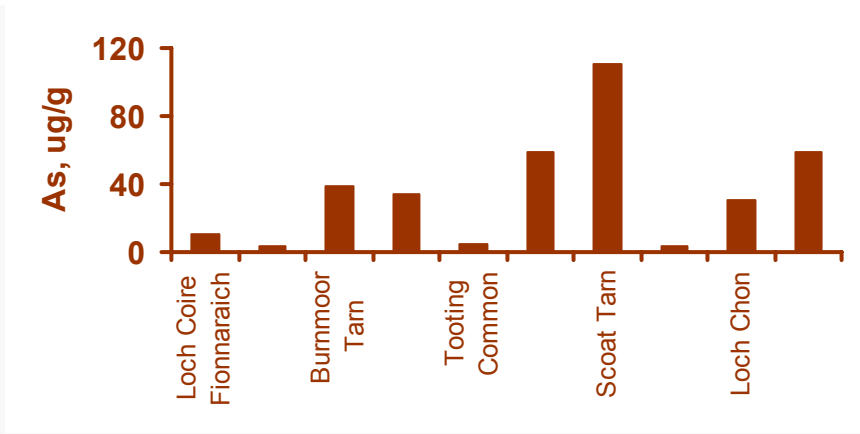
Uncontaminated sediment

Pb	31 ug/g
Zn	123 ug/g
Cd	0.46 ug/g
As	1 or 10 ug/g

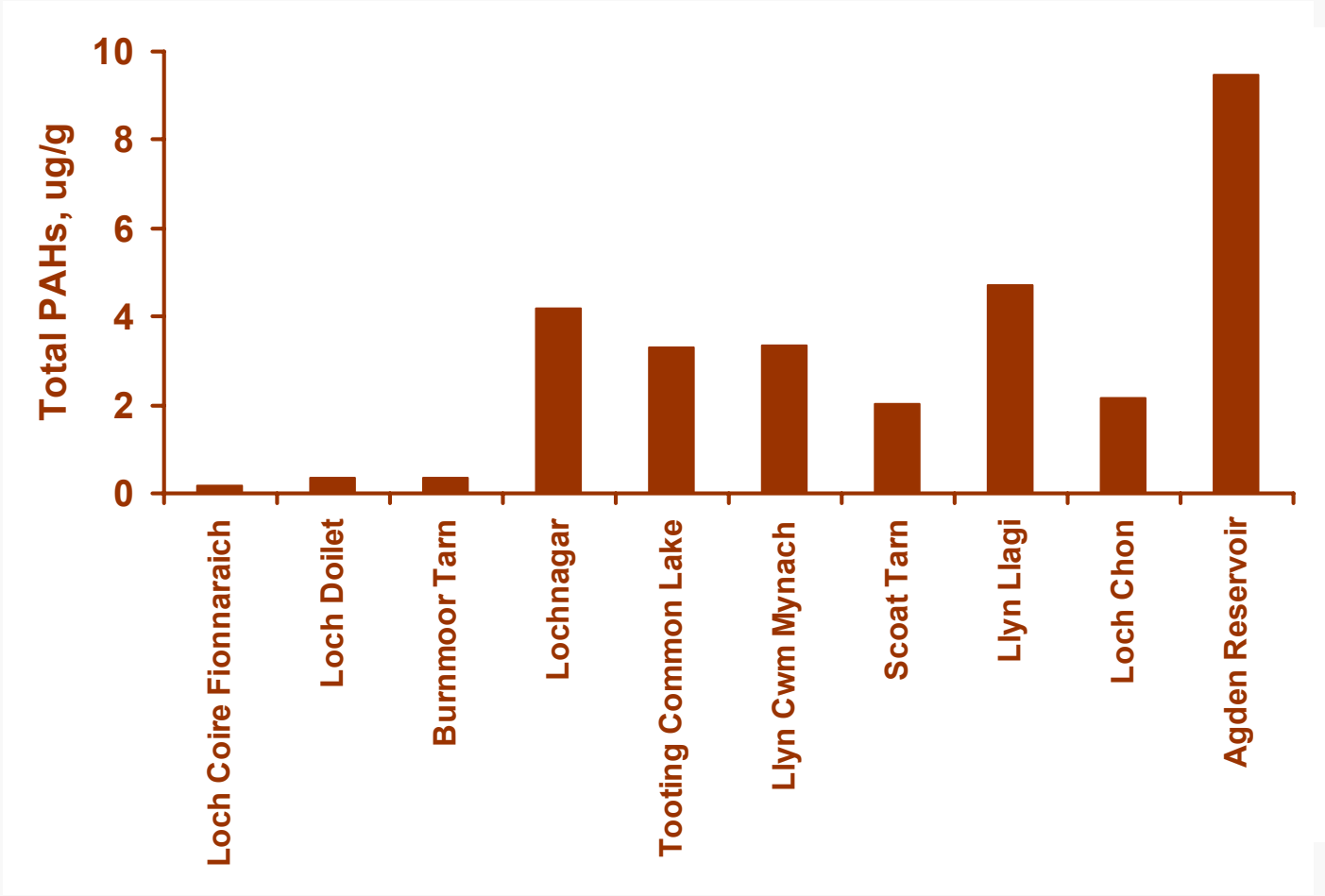








Over half of the lake sediment samples are contaminated by Pb, Zn, Cd and As

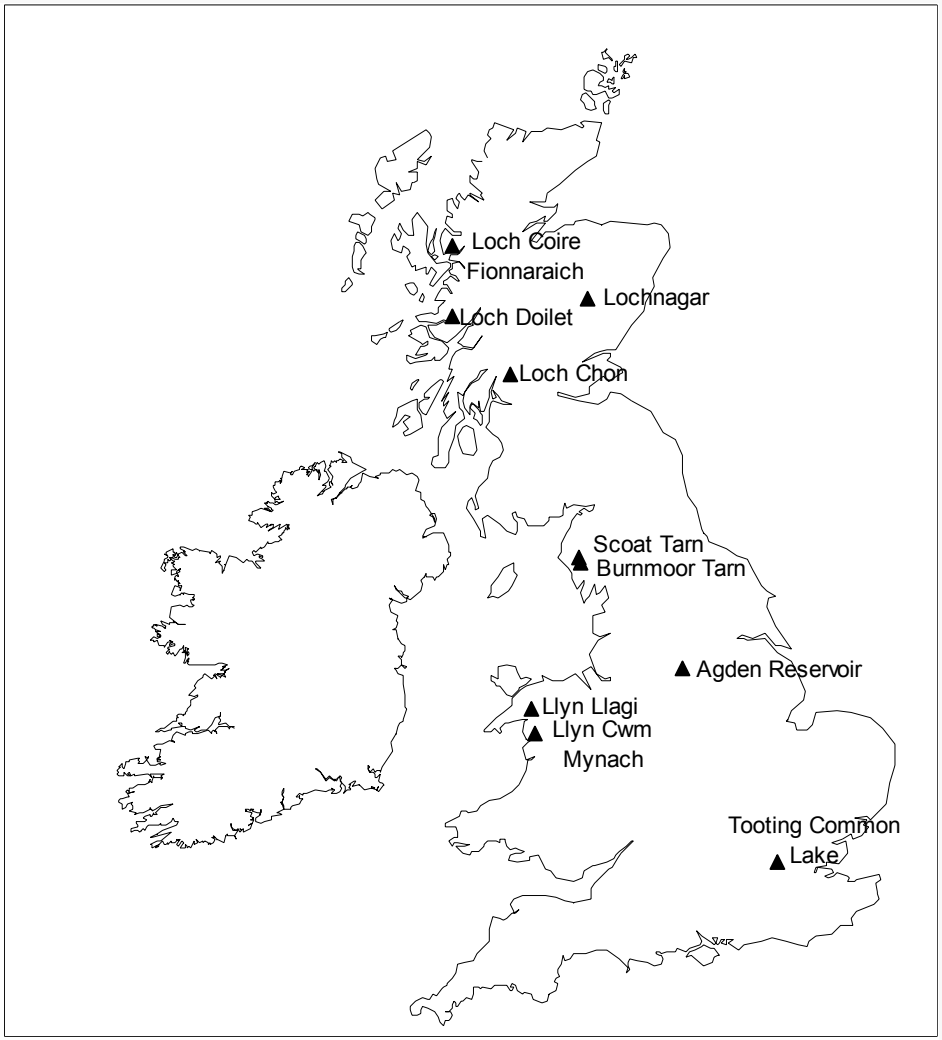


Over half of the lake sediment samples are contaminated by PCBs and PAHs

PBDEs, ng/g

	47	99	100	153	154
Loch Coire Fionnaraich	<0.4	<0.4	<0.2	<0.3	<0.2
Loch Doilet	<0.4	<0.4	<0.2	<0.3	<0.2
Burnmoor Tarn	<0.4	<0.4	<0.2	<0.3	<0.2
Lochnagar	0.9	2.0	0.2	0.5	0.2
Tooting Common Lake	<0.4	<0.4	<0.2	<0.3	<0.2
Llyn Cwm Mynach	<0.4	<0.4	<0.2	<0.3	<0.2
Scoat Tarn	<0.4	0.7	<0.2	<0.3	<0.2
Llyn Llagi	<0.4	0.6	<0.2	<0.3	<0.2
Loch Chon	0.7	1.4	<0.2	0.4	<0.2
Agden Reservoir	1.2	2.4	0.2	0.7	<0.2

Around one third of the lake sediment samples are contaminated by PBDEs



Using the concentrations of heavy metals, PCBs and PAHs

Least contaminated lakes are:

Loch Coire Fionnaraich
Burnmoor Tarn
Loch Doilet

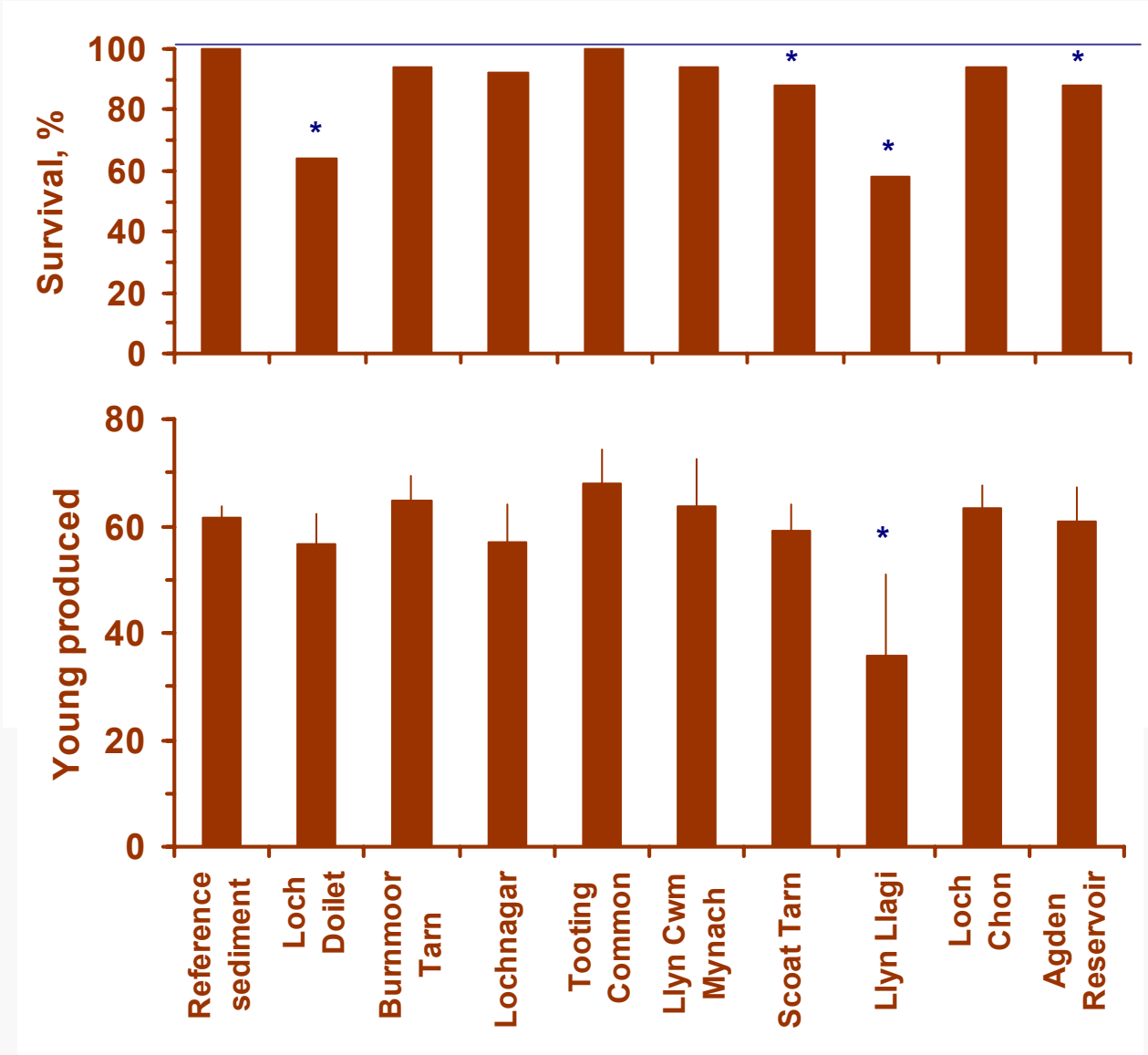
Most contaminated are:

Llyn Llagi
Lochnagar
Tooting Common Lake
Agden Reservoir

Sweden (Johansson 1989)
Norway (Rognerud & Fjeld 2001)
UK and Ireland (Rippey & Douglas 2004; Rose & Rippey 2002)
USA (Norton et al. 1992; Furlong et al 1987)

17-day chironomid survival and emergence

7-day cladoceran survival and reproduction



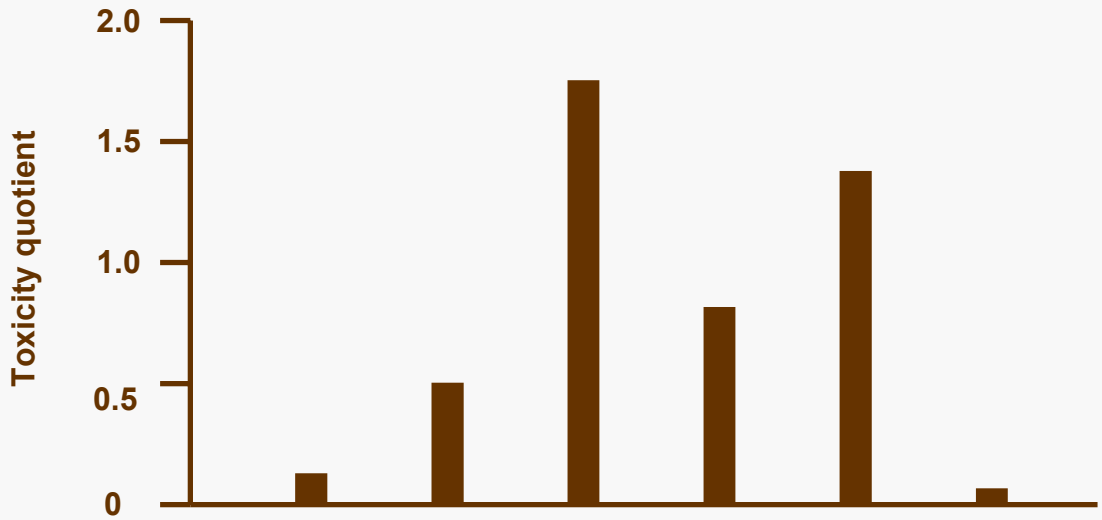
There is toxicity in four of the lake sediment samples, Loch Doilet, Scoat Tarn, Llyn Llagi and Agden Reservoir

Toxicity quotient is ratio of concentration to Sediment Quality Guideline value

Use PEC of MacDonald et al. (2000)

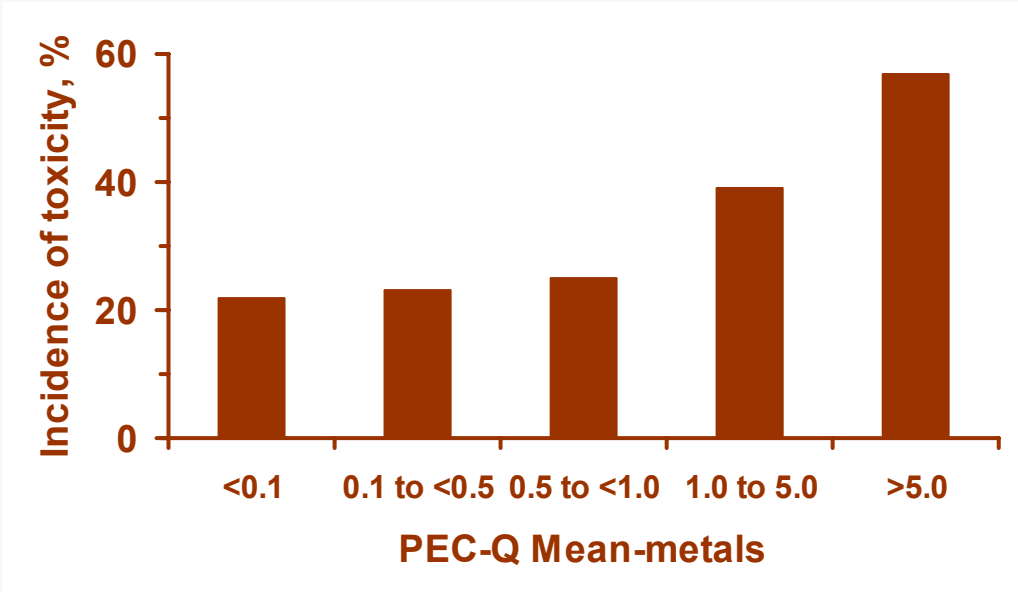
Can also calculate quotients for groups of chemicals

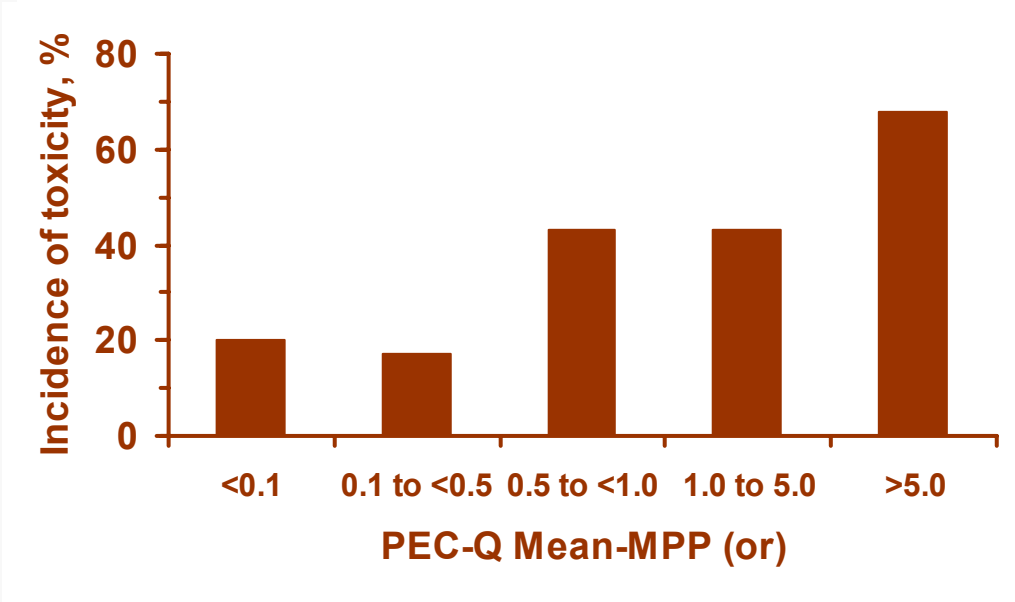
PEC-Q Mean-metals uses average quotient for seven heavy metals
PEC-Q OCs uses the sum of the concentrations of five OCs
PEC-Q PCBs uses concentration of total PCBs
PEC-Q PAHs uses concentration of total PAHs
PEC-Q MPP (and) is mean of metals, PCBs and PAHs
PEC-Q MPP (or) is mean of metals and either PCBs or PAHs

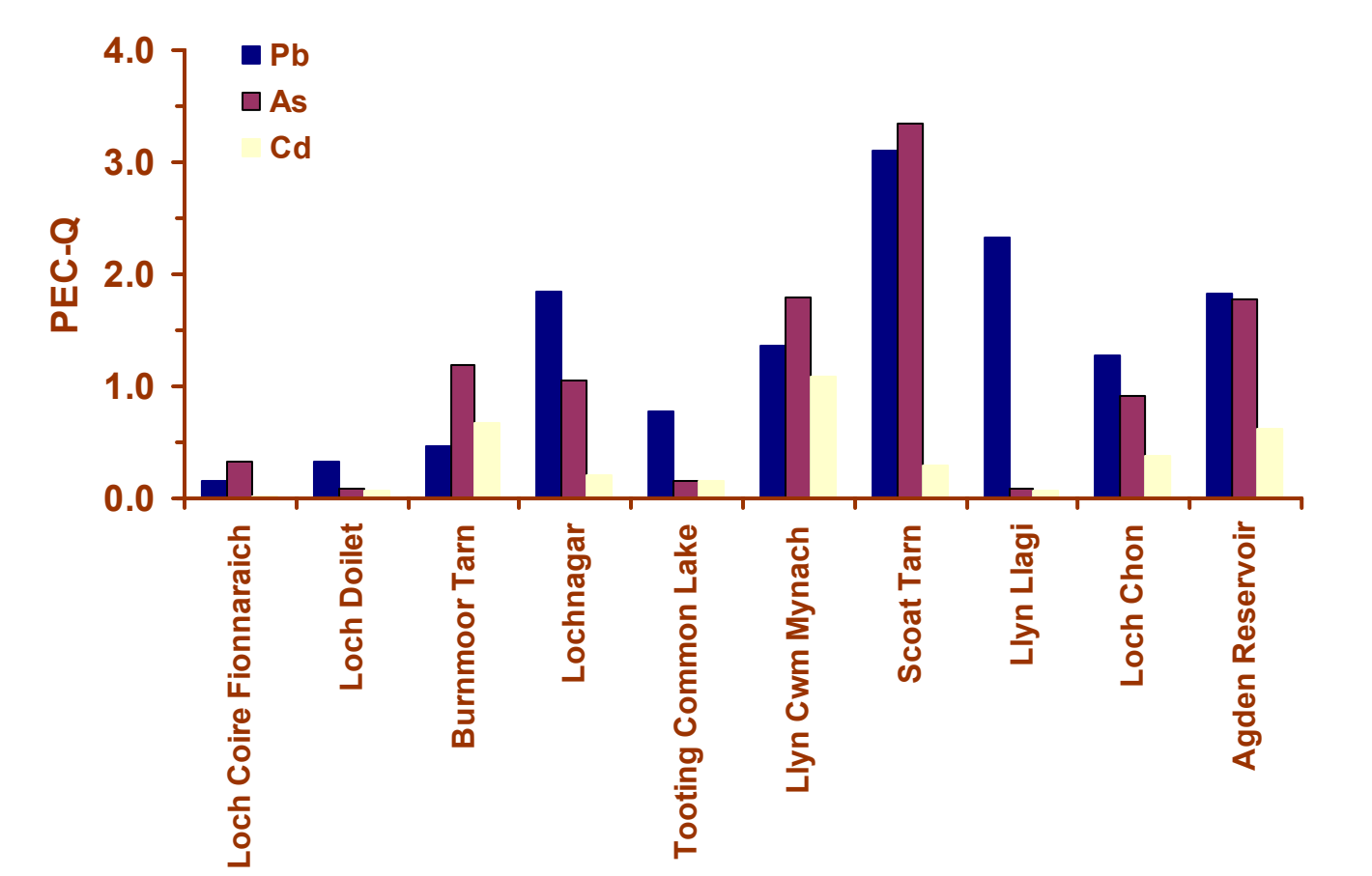


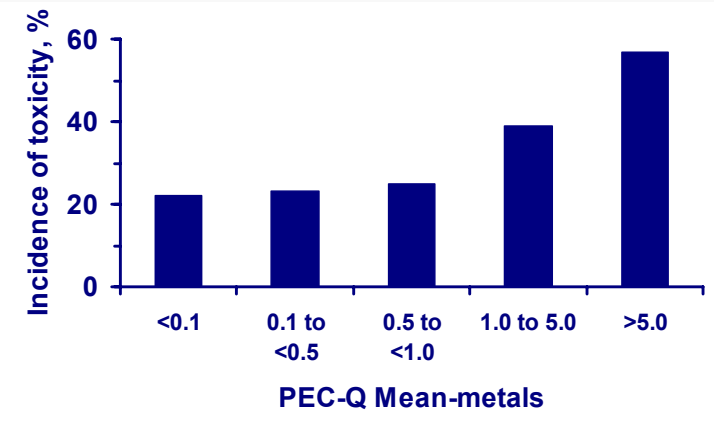
PEC OCs = 571 ng/g
PEC PCBs = 676 ng/g
PEC PAHs = 22,800 ng/g

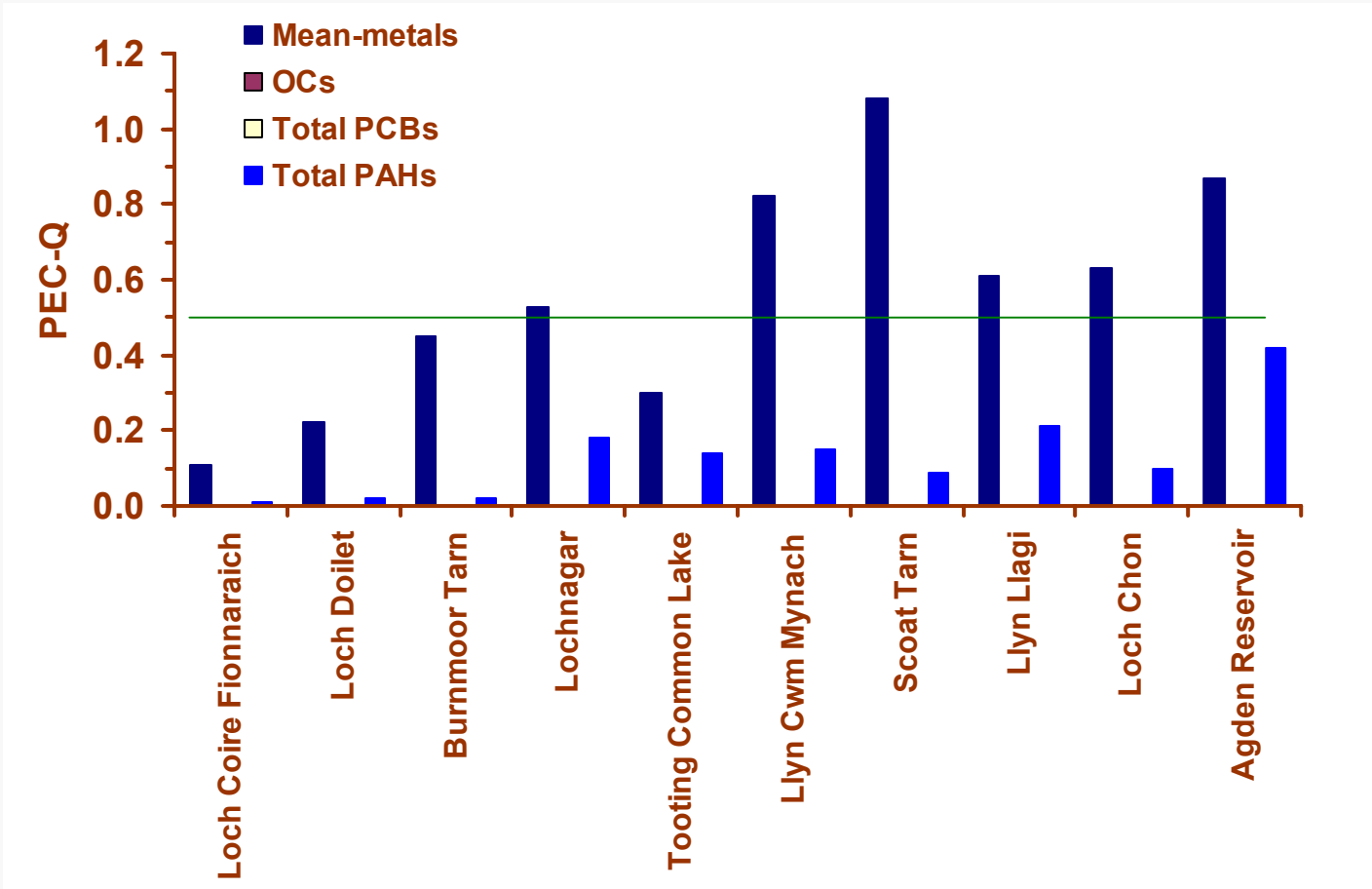
There may be a risk if PEC-Q value is greater than 0.5 (Ingersoll et al. 2001)

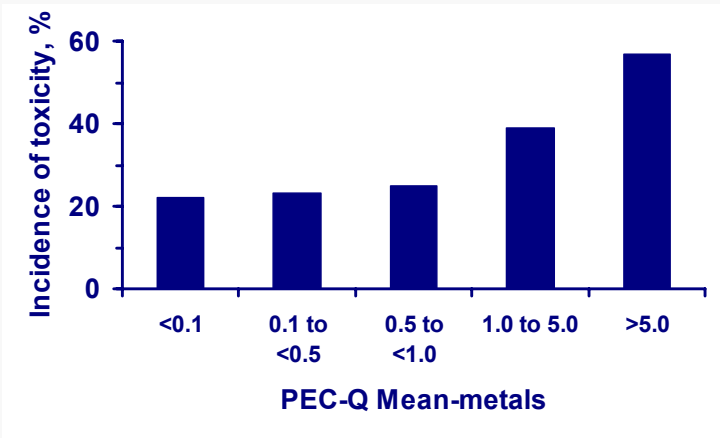


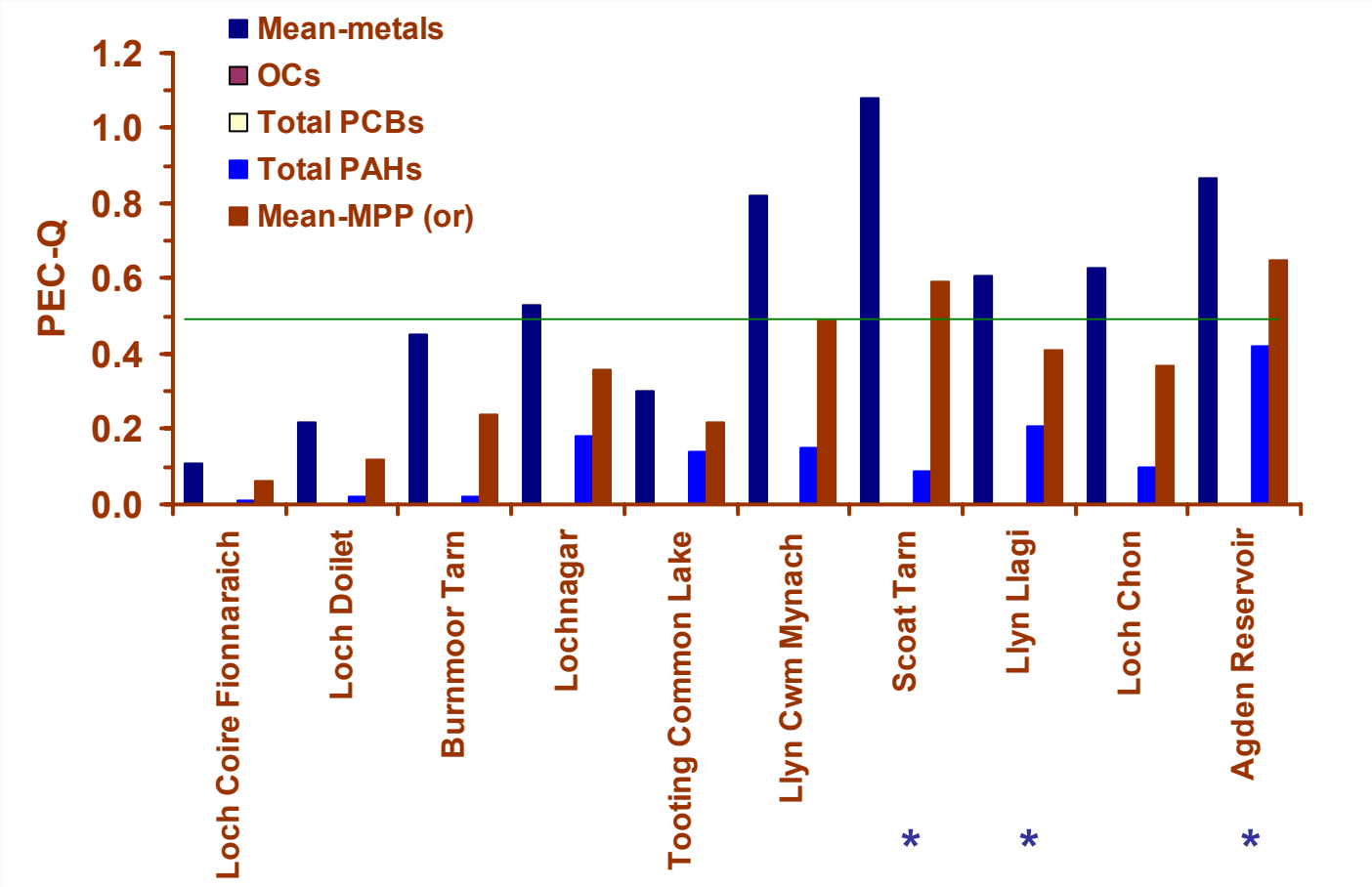


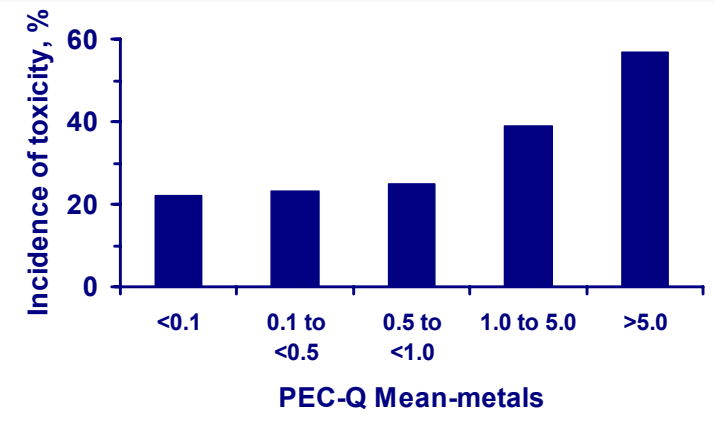

4.0
3.0
2.0
1.0
0.0
PEC-Q
Pb
As
Cd
Loch Coire Fionnaraich
Loch Doilet
Burnmoor Tarn
Lochnagar
Tooting Common Lake
Llyn Cwm Mynach
Scoat Tarn
Llyn Llagi
Loch Chon
Agden Reservoir

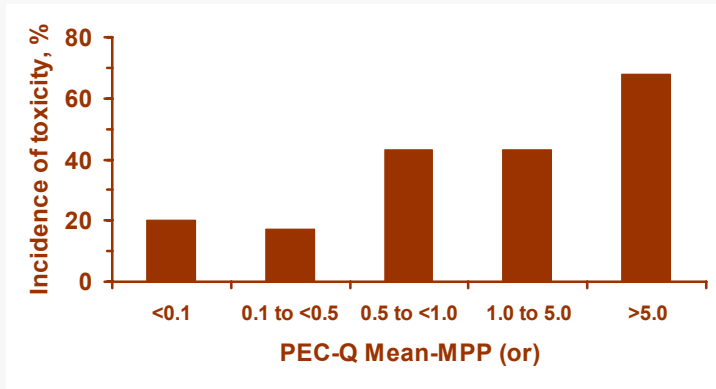

Incidence of toxicity, %
60
40
20
0
<0.1
0.1 to <0.5
0.5 to <1.0
1.0 to 5.0
>5.0
PEC-Q Mean-metals


Mean-metals
OCs
Total PCBs
Total PAHs
PEC-Q
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Loch Coire Fionnaraich
Loch Doilet
Burnmoor Tarn
Lochnagar
Tooting Common Lake
Llyn Cwm Mynach
Scoat Tarn
Llyn Llagi
Loch Chon
Agden Reservoir


Incidence of toxicity, %
60
40
20
0
<0.1
0.1 to <0.5
0.5 to <1.0
1.0 to 5.0
>5.0
PEC-Q Mean-metals


Mean-metals
OCs
Total PCBs
Total PAHs
Mean-MPP (or)
PEC-Q
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Loch Coire Fionnaraich
Loch Doilet
Burnmoor Tarn
Lochnagar
Tooting Common Lake
Llyn Cwm Mynach
Scoat Tarn
Llyn Llagi
Loch Chon
Agden Reservoir
*
*
*


Incidence of toxicity, %
60
40
20
0
<0.1
0.1 to <0.5
0.5 to <1.0
1.0 to 5.0
>5.0
PEC-Q Mean-metals


Incidence of toxicity, %
80
60
40
20
0
<0.1
0.1 to <0.5
0.5 to <1.0
1.0 to 5.0
>5.0
PEC-Q Mean-MPP (or)

PEC-Q Mean-metals			
0.1 to <0.5	1/3	33.3	23
0.5 to 1.0	3/6	50.0	25

PEC-Q Mean-MMP (or)			
0.1 to <0.5	2/7	28.6	17
0.5 to 1.0	2/2	100.0	43

The concentrations of Pb and As are high enough in Scoat Tarn, Llyn Llagi and Agden Reservoir to cause the toxicity found, with contributions by PAHs in Agden Reservoir

Maximum PEC-Q Mean-metals is 1.08

PEC-Q Mean-metals			
0.1 to <0.5	1/3	33.3	23
0.5 to 1.0	3/6	50.0	25

PEC-Q Mean-MMP (or)			
0.1 to <0.5	2/7	28.6	17
0.5 to 1.0	2/2	100.0	43

The concentrations of Pb and As are high enough in Scoat Tarn, Llyn Llagi and Agden Reservoir to cause the toxicity found, with contributions by PAHs in Agden Reservoir

Maximum PEC-Q Mean-metals is 1.08

PEC-Q Mean-metals	Site	Reference
>0.3	Upper Mississippi River	Canfield et al. (1998)
0.8	Trenton Channel of the Detroit River, Michigan	Besser et al. (1996)
2.0	River Kolbacksan, Sweden	Dave (1992)
2.0	Upper Clark Fork River & Milltown Reservoir, Montana	Canfield et al. (1994)
2.5	Twelve lakes in the vicinity of the Sudbury, Canada	Borgmann et al (2001)
3.5	Buffalo River, Indiana Harbour and Saginaw River	Canfield et al. (1996)

Mean 1.9
Median 2.0

PEC-Q Mean-metals			
0.1 to <0.5	1/3	33.3	23
0.5 to 1.0	3/6	50.0	25

PEC-Q Mean-MMP (or)			
0.1 to <0.5	2/7	28.6	17
0.5 to 1.0	2/2	100.0	43

The concentrations of Pb and As are high enough in Scoat Tarn, Llyn Llagi and Agden Reservoir to cause the toxicity found, with contributions by PAHs in Agden Reservoir

Maximum PEC-Q Mean-metals is 1.08

There is toxicity in the sediments of Llyn Llagi, Scoat Tarn and Agden Reservoir in the laboratory, but are there biological effects in the lakes?