About ecosystem nutrition and juvenile salmon production in Wester Ross

Peter Cunningham
Skye & Wester Ross Fisheries Trust
6th February 2020

www.wrft.org.uk

Summary

- Juvenile salmon growth
- Phosphorus budgeting
- Restoring and managing ecosystem fertility

Kinlochewe River from top of Meall Ghuibhais (Beinn Eighe NNR)

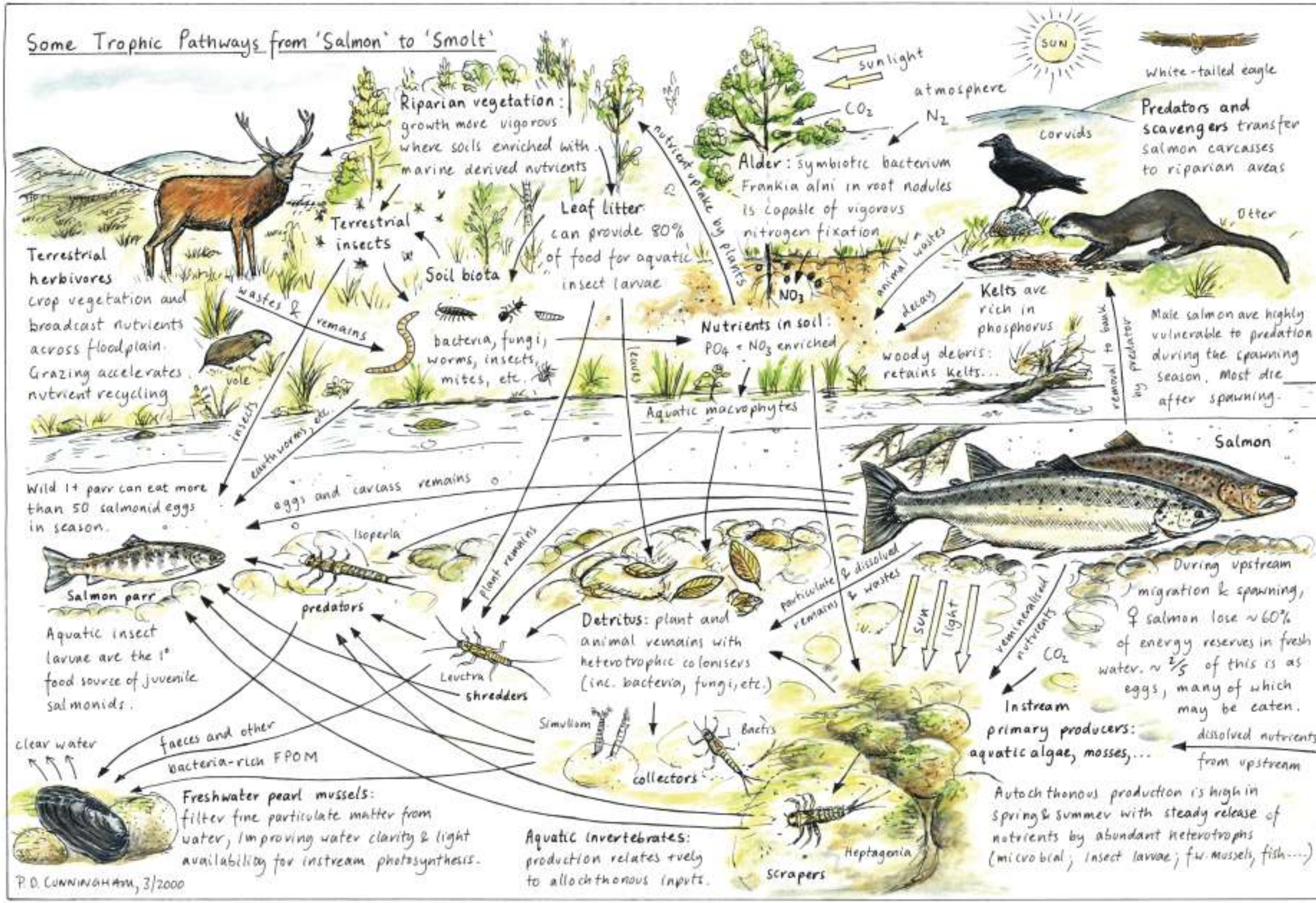
Feed the land . . .

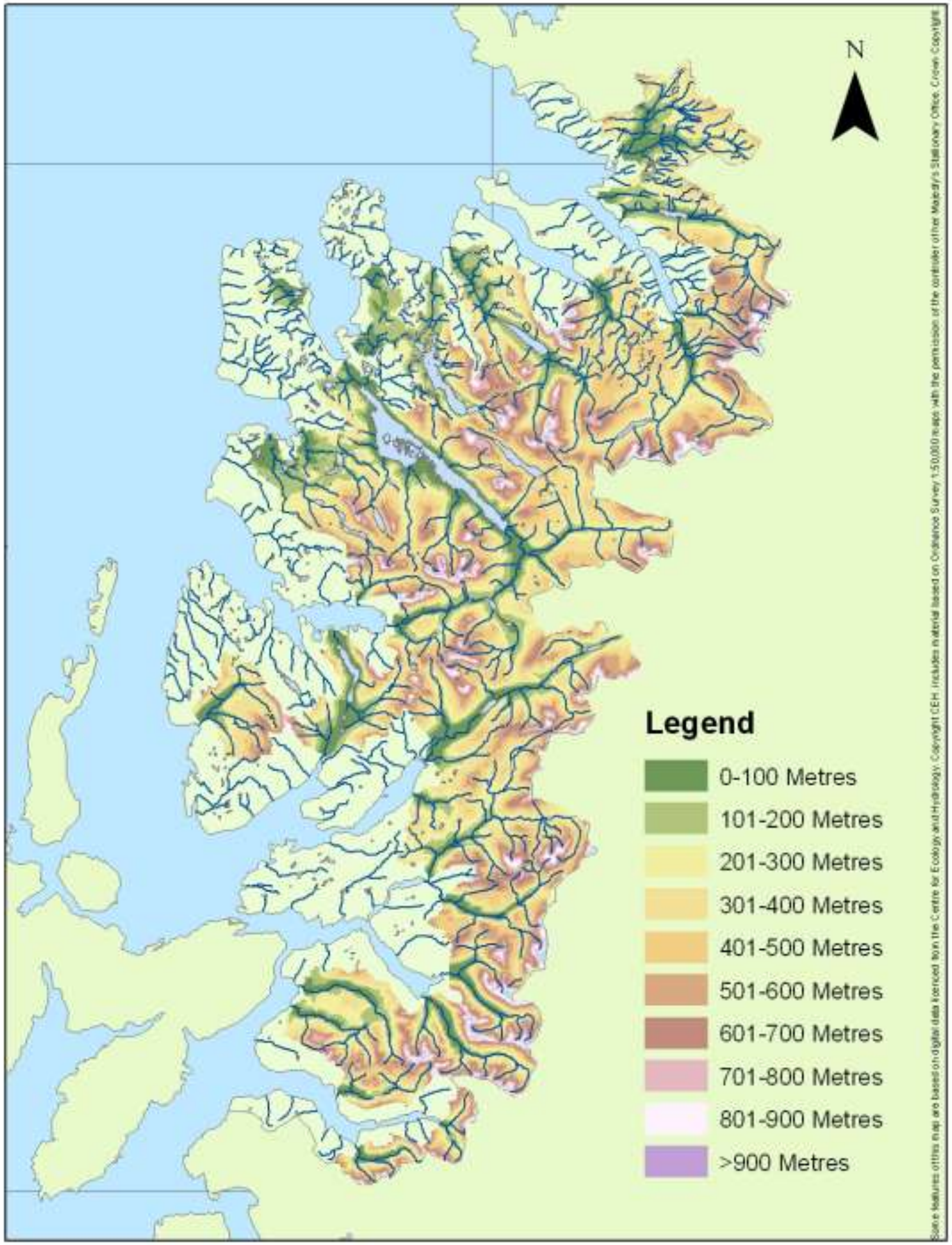
(Grazing, Trees & Trout, Aultbea June 2017 [with The Woodland Trust])

www.wrft.org.uk

1. What is fertility?
2. Fertile places in Wester Ross
3. Ecosystems and nutrient flow
4. Deforestation, fire and loss of fertility
5. Animals and phosphorus export
6. How to conserve and replenish phosphorus?

Marine nutrient seminar, Freshwater Lab, 2000

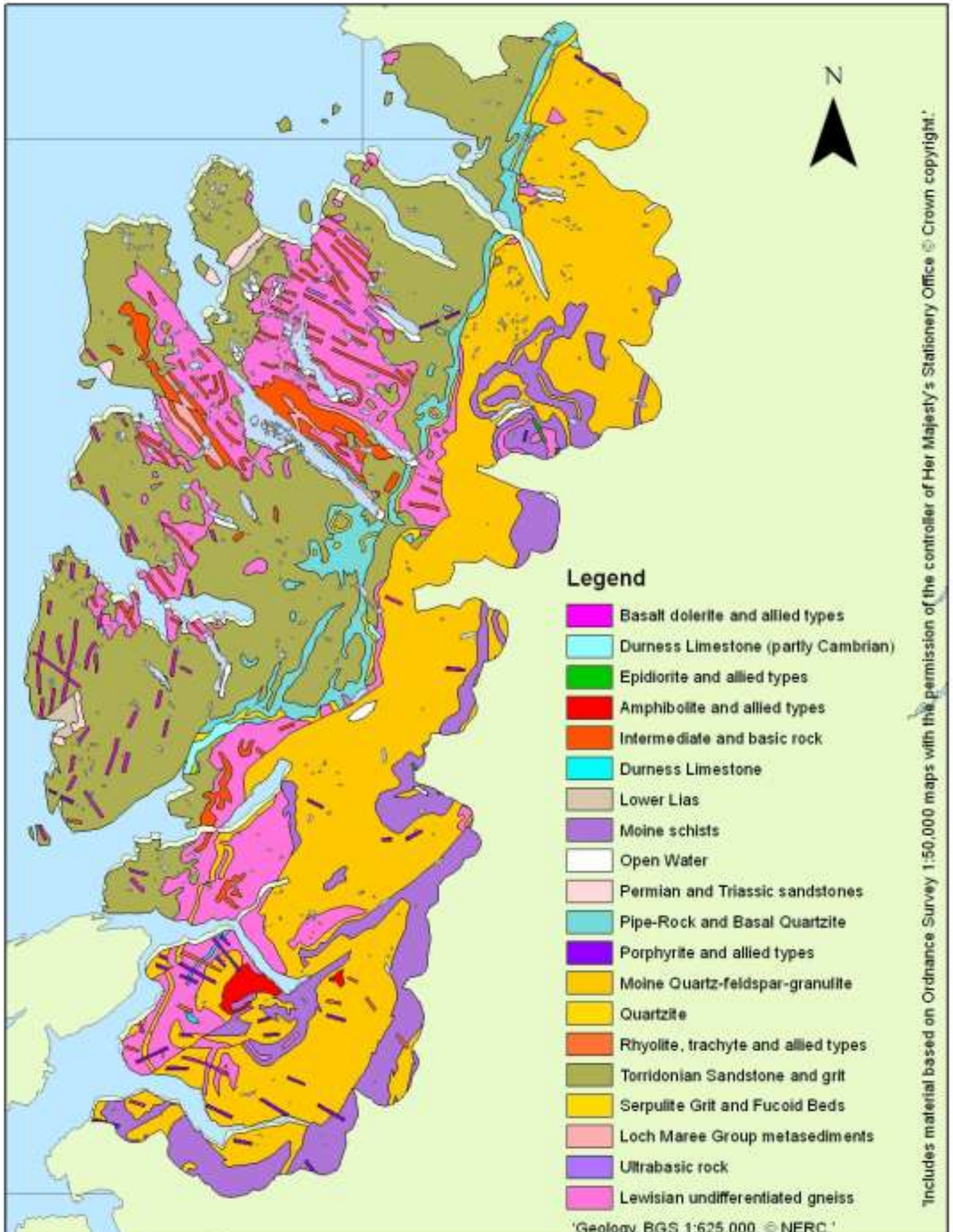




Wester Ross

Land of glaciated mountains, lochs and short, swiftly flowing salmon rivers . . .

Torridon and Liathach by Lulu Strader, Sept 2010



. . . underlain by Torridonian sandstone and Lewisian Gneiss.

hard, resistant to weathering,

un-yielding rock.

Uninhabited ‘wilderness’ . . .

Fionn loch and Dubh loch from Beinn Airigh charr

Unstable rivers

Strath na Sealga, upper Gruinard: note alder woodland along floodplain


with ‘near pristine’ oligotrophic lochs?
Loch Maree . . . .

. . . a naturally infertile, nutrient deficient, unproductive landscape?

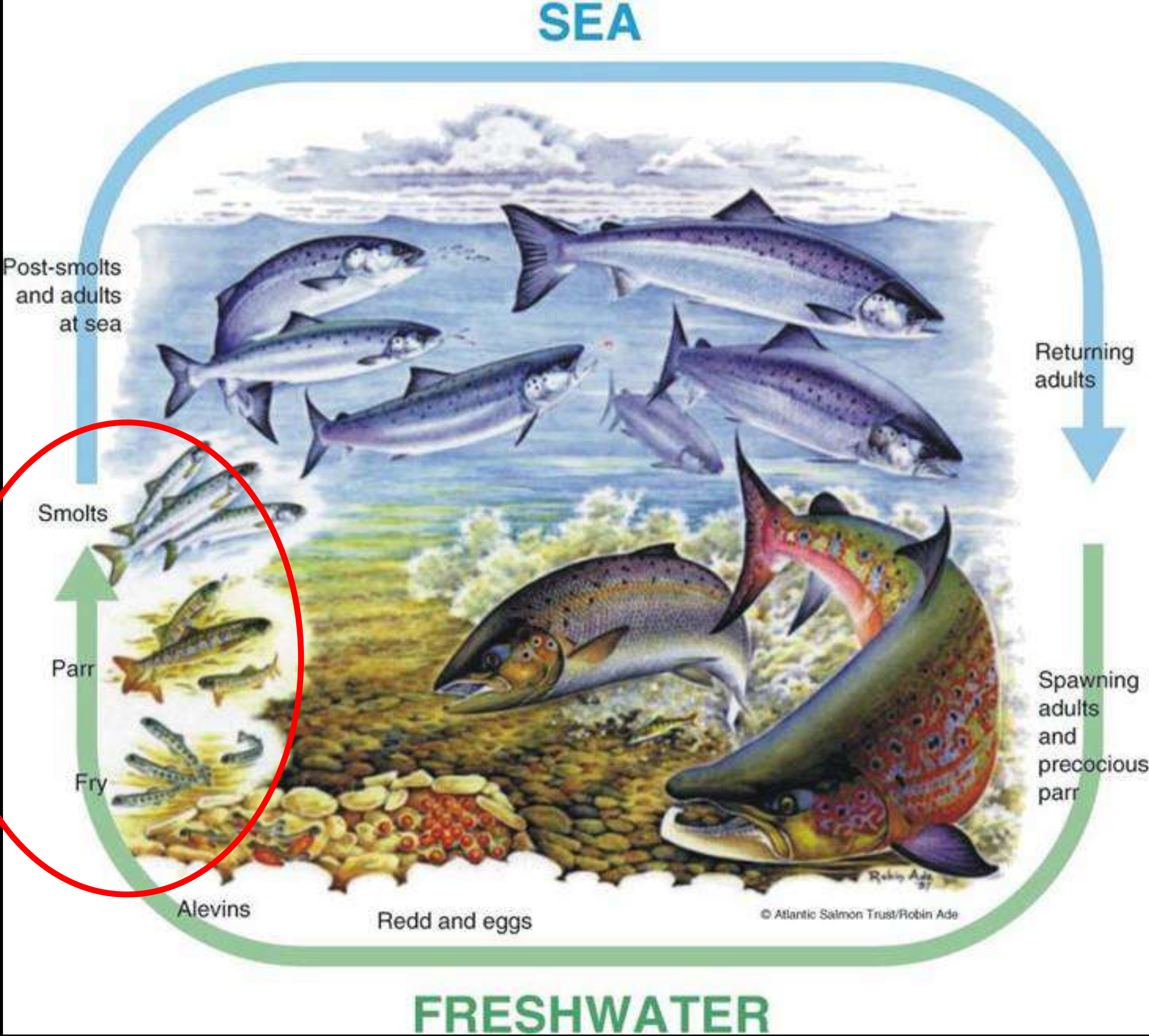
Sundew

Bog asphodel

Narthecium ossifragum

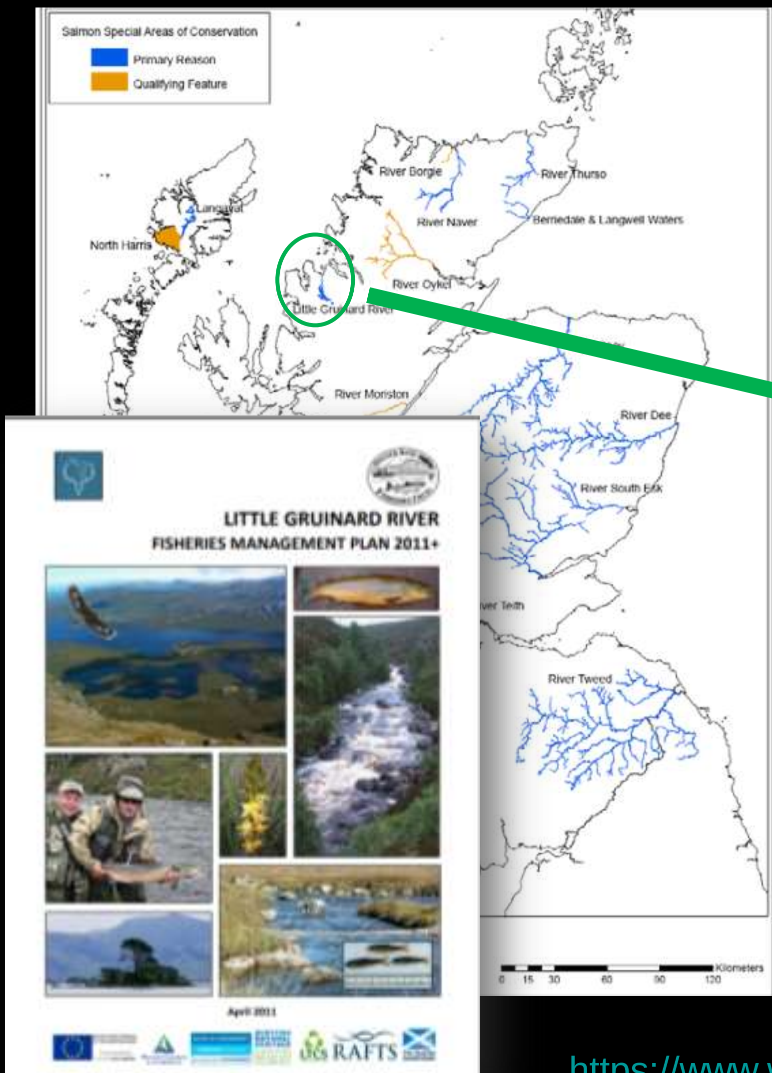
"bone breaker "

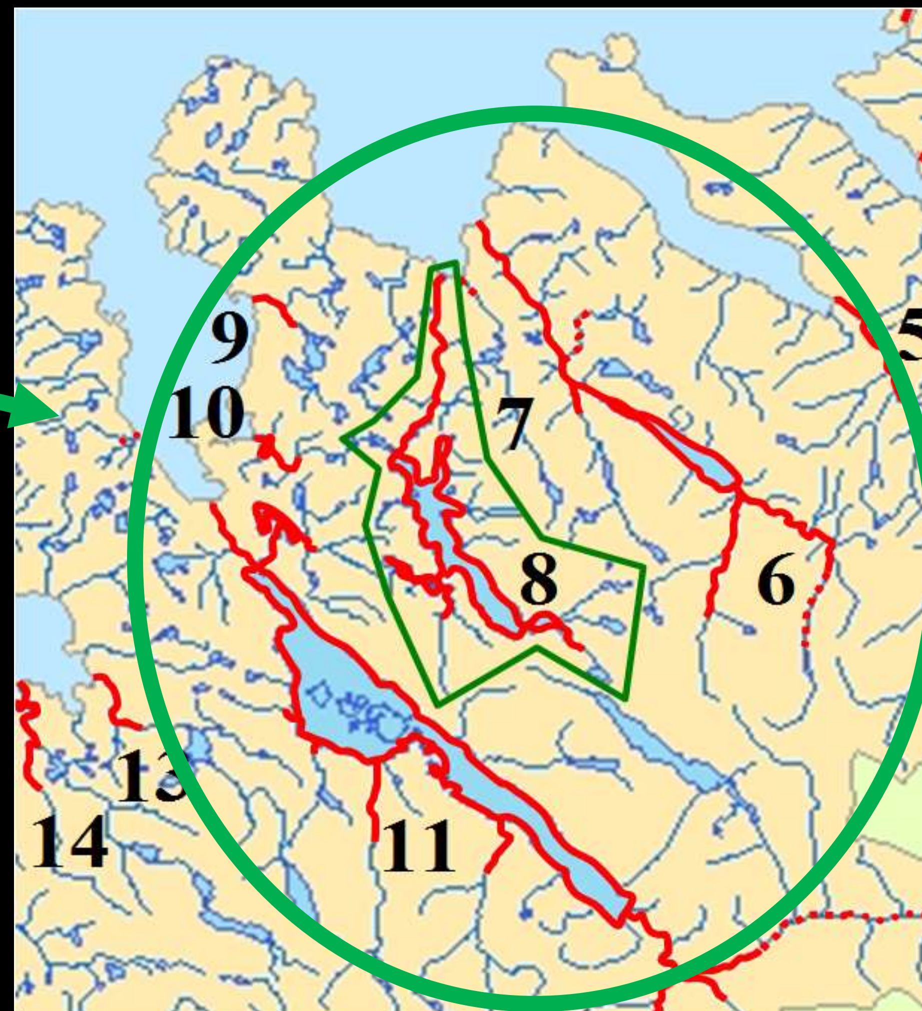
What limits juvenile salmon production in Wester Ross?



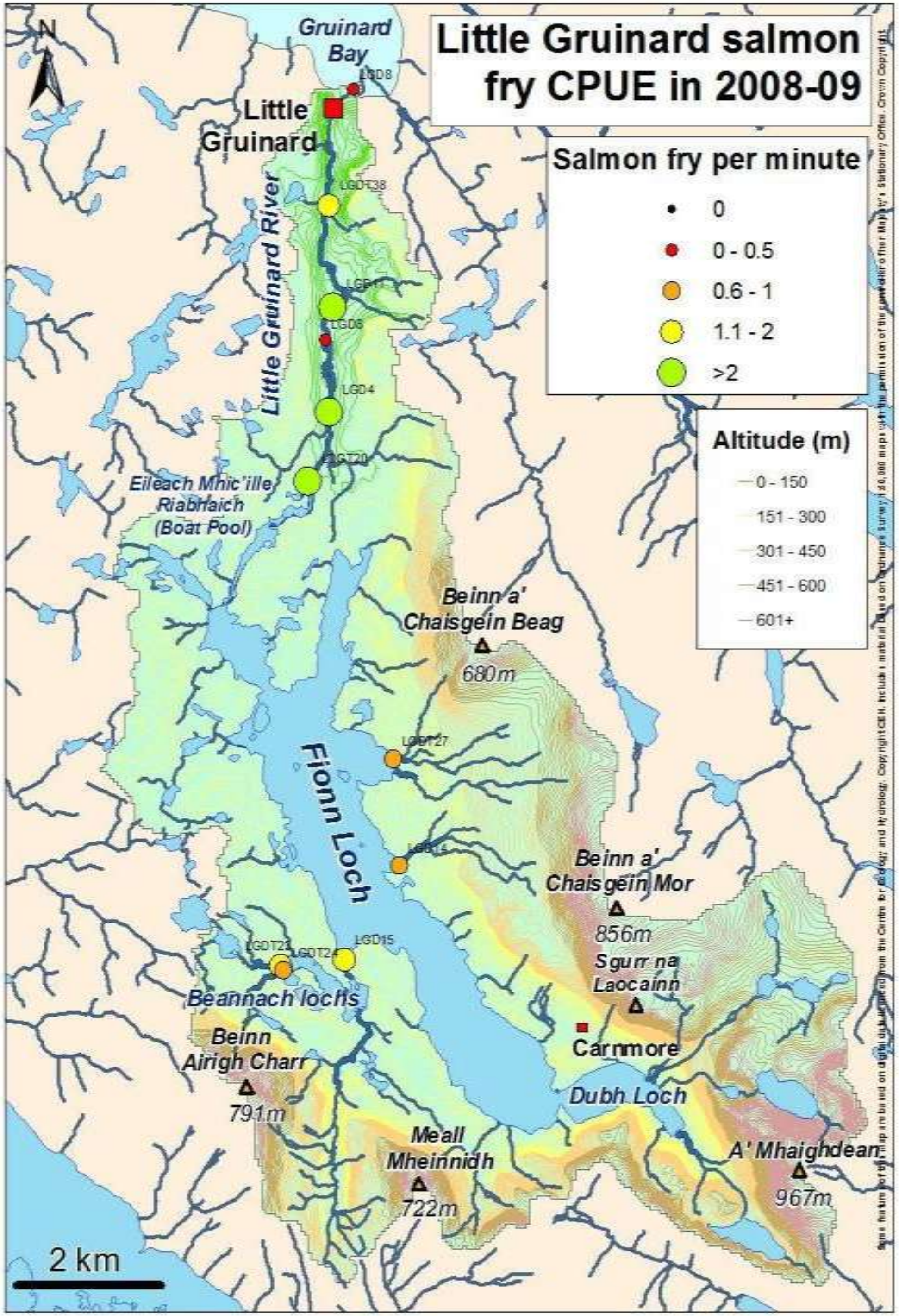
Example: **The Little Gruinard River**

Special Area of Conservation for Atlantic Salmon . . .





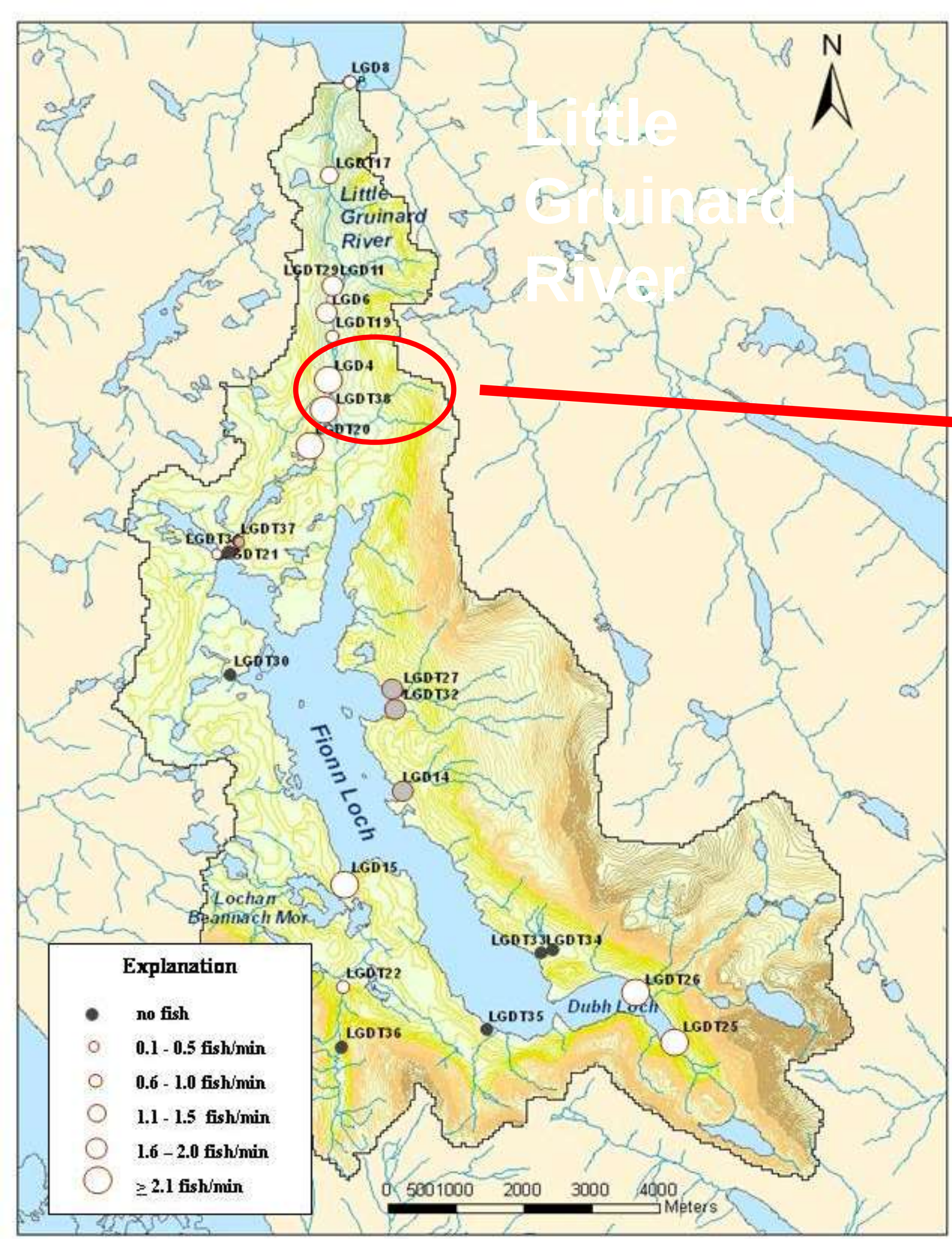
https://www.wrft.org.uk/downloads/files.cfm?id=29



Juvenile salmon survey

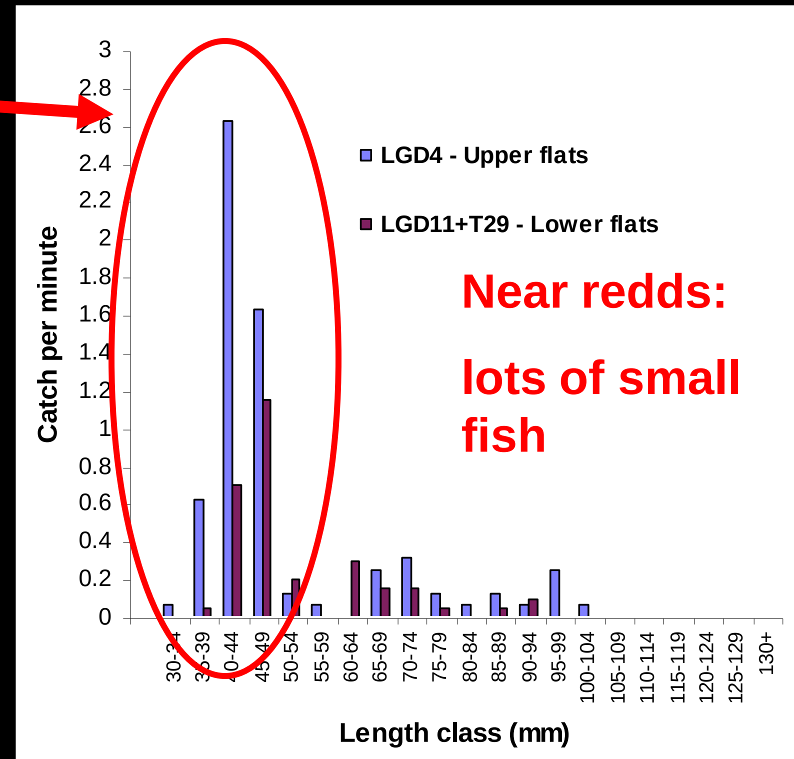
Plenty of salmon fry and parr in the main river . . .

. . . but many of them are very small . . .

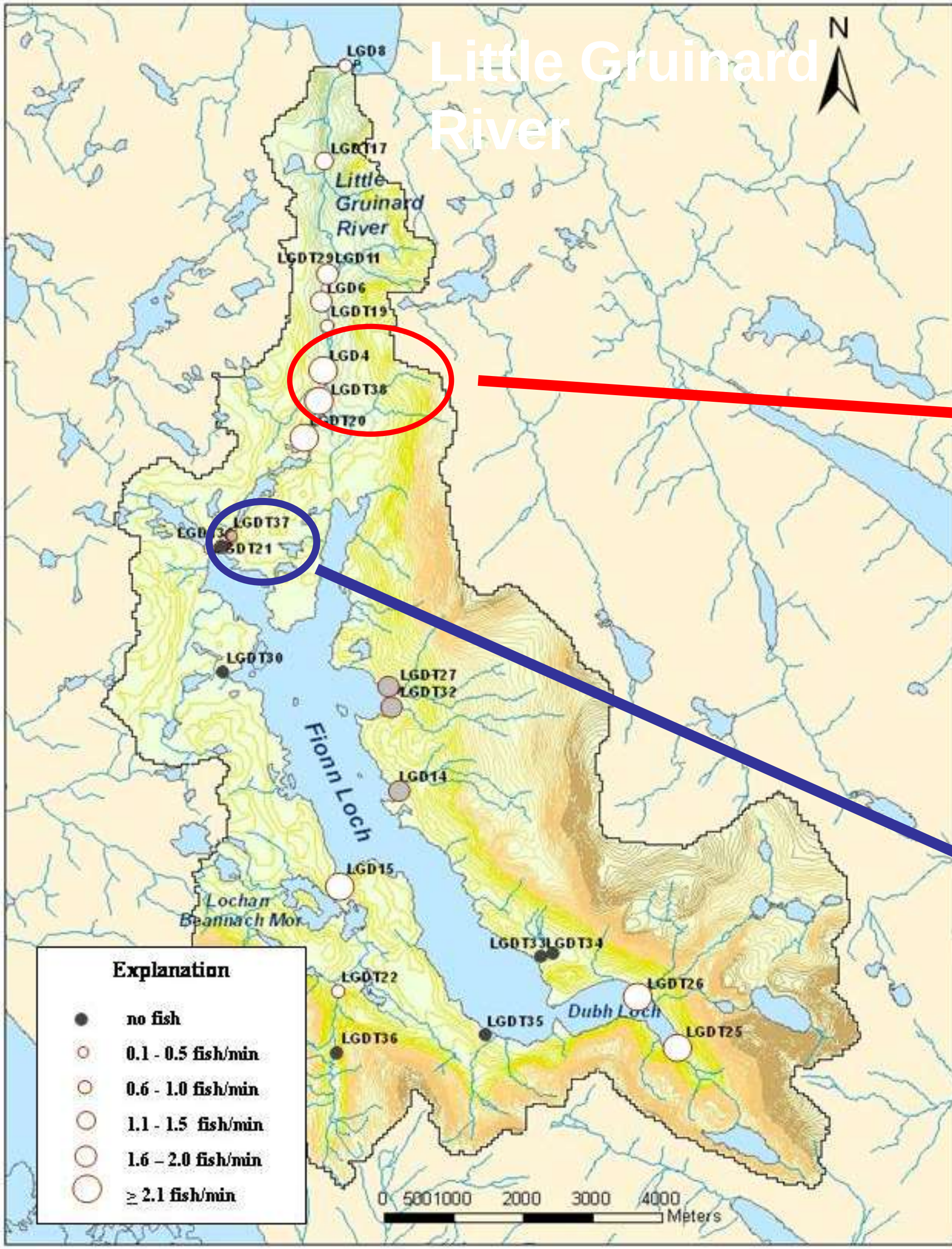


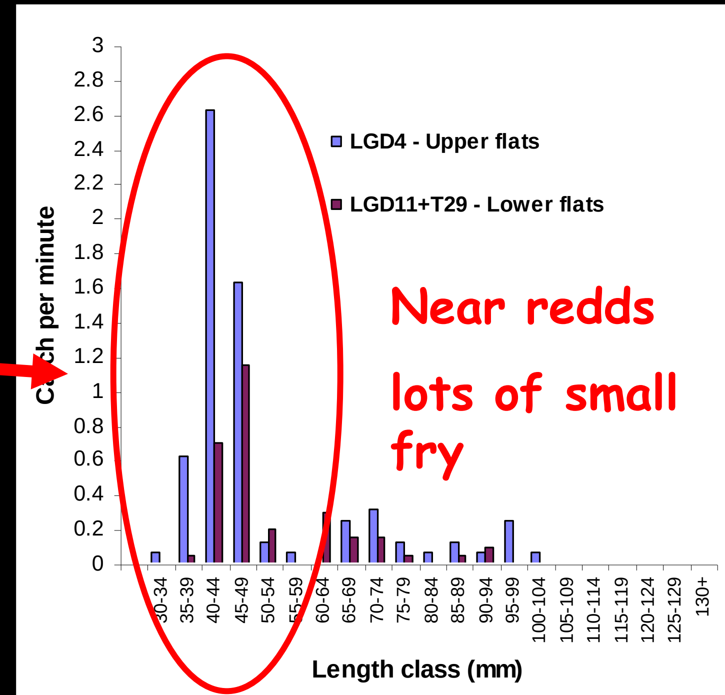
Juvenile salmon abundance

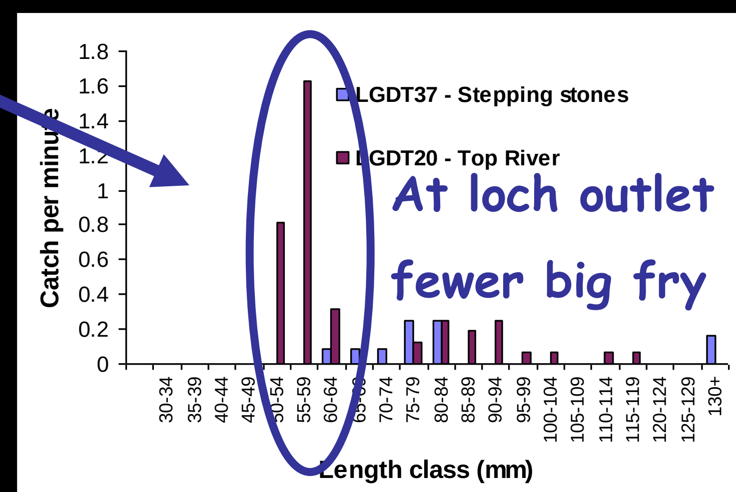
Little Gruinard River in 2006



Juvenile salmon 2006








Lower Flats of
Little Gruinard
E-fish survey 23 August 2006


Small fry . . . . and small parr
Near redds
lots of small
fry

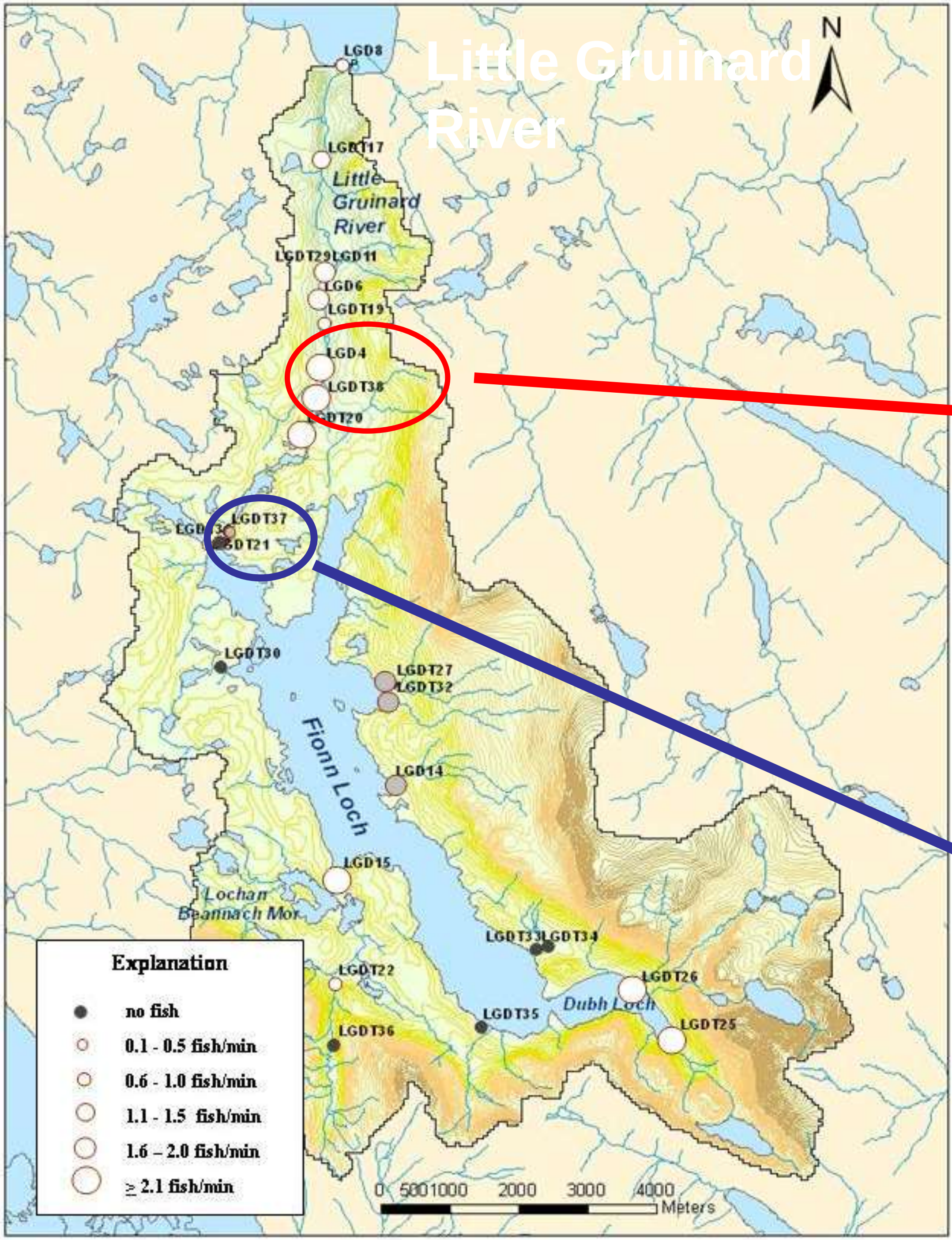
At top of Little Gruinard River below Fionn Loch

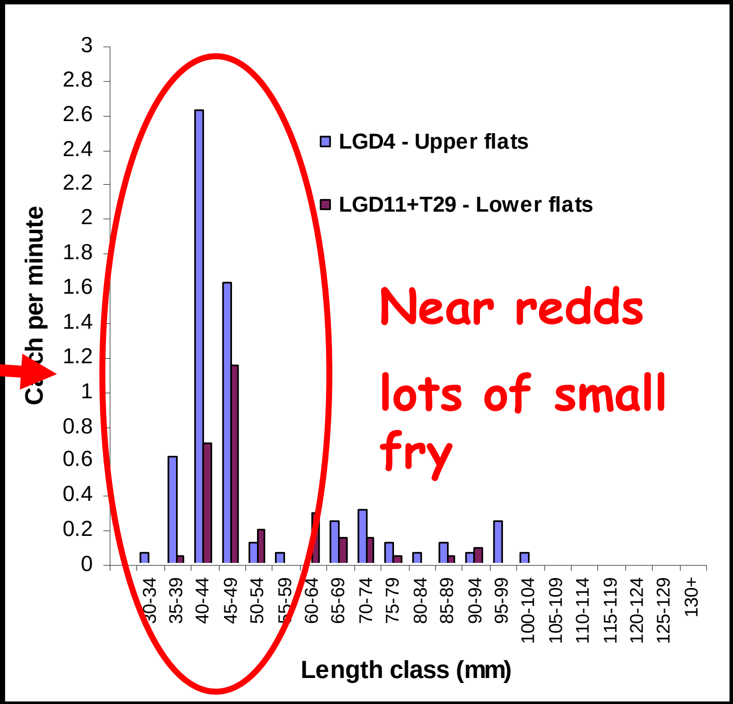
fewer big fry

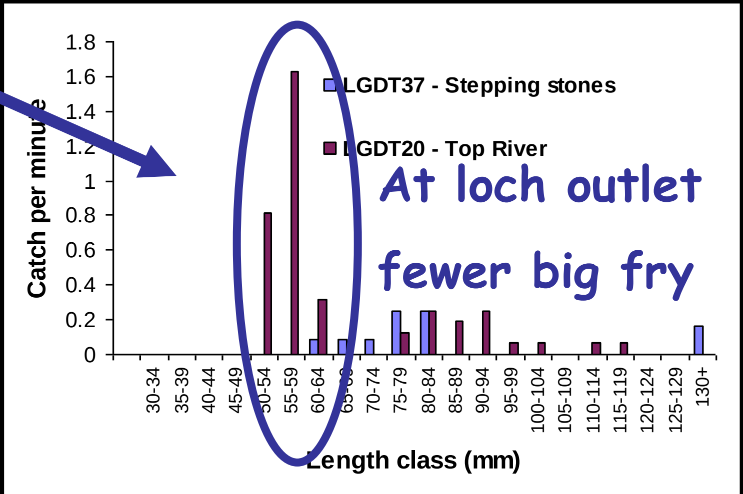
Big one year old parr

Juvenile salmon 2006

Little Gruinard River







Why is there such variation in growth rates?

photo by Nick Benge

Growth and production of juvenile salmon depends upon food availability

Stonefly and Mayfly larvae

- *Where juvenile salmon densities are high, growth tends to be slower.*
- *Where juvenile salmon densities are low, growth tends to be faster.*


What determines food availability?

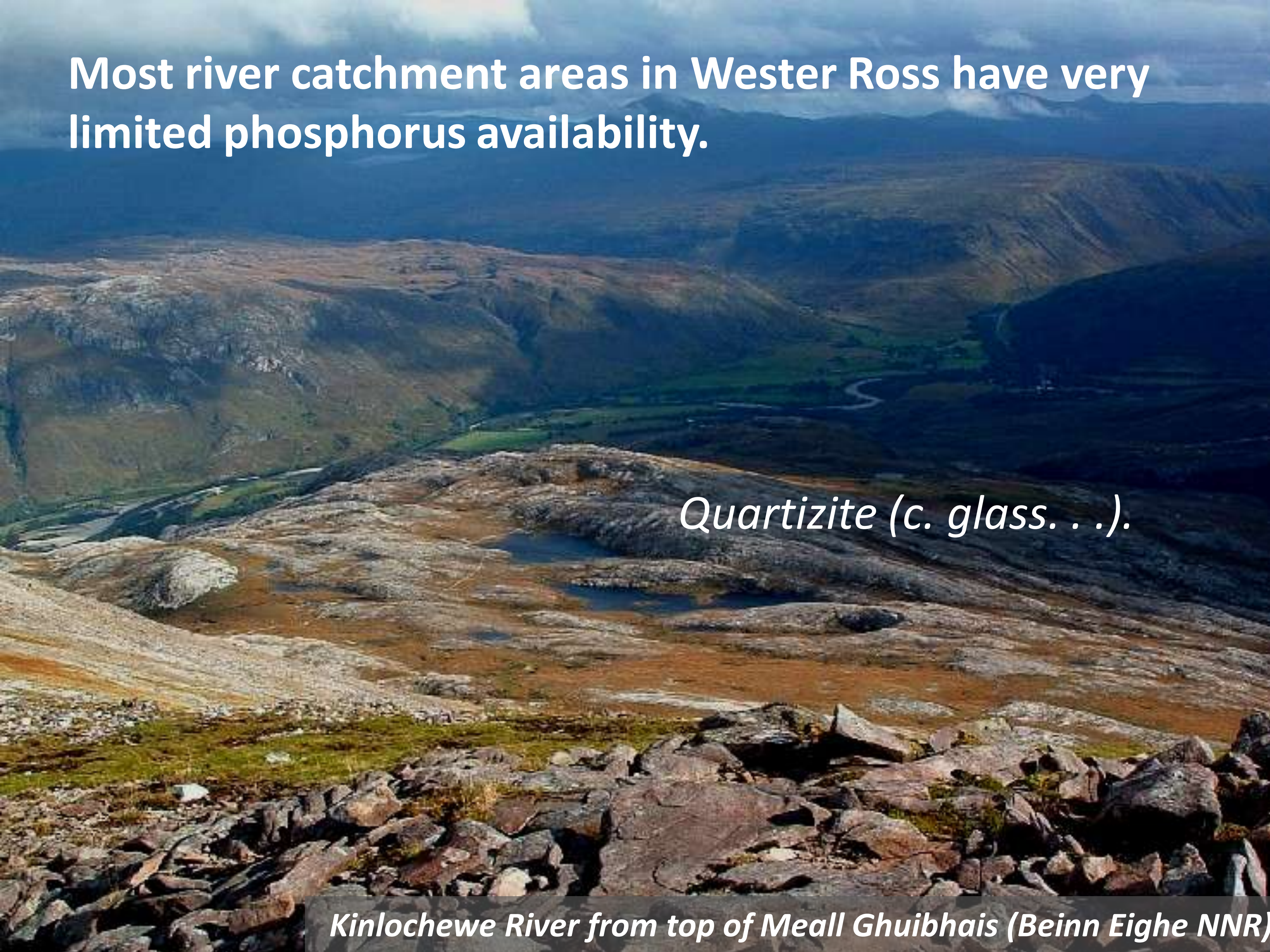
Biological productivity in Wester Ross is primarily limited by the availability of phosphorus, P

(refs: e.g. McVean’s fertilisation trials at Beinn Eighe NNR)

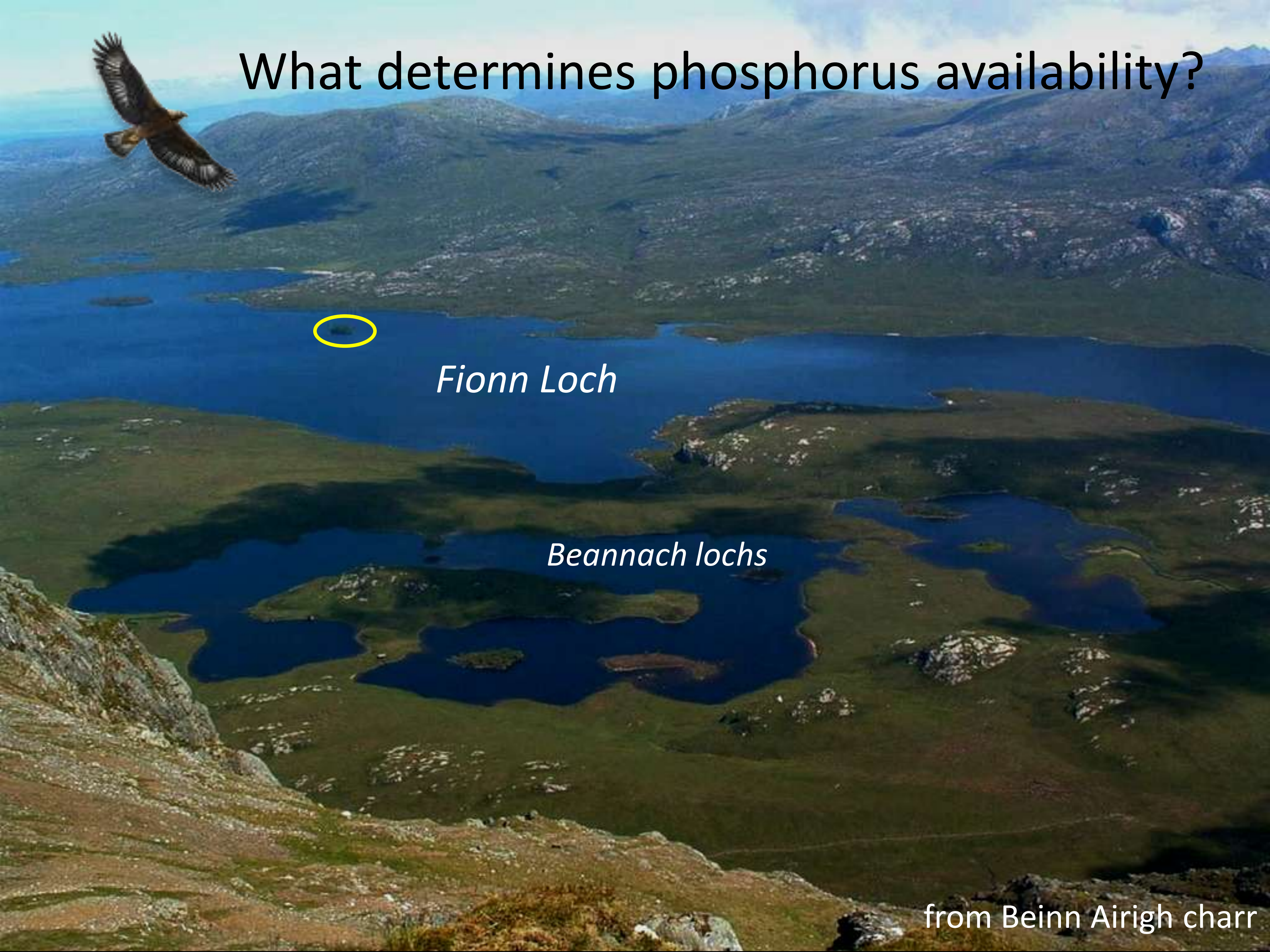
Phosphorus

Phosphorus is essential to all life forms.

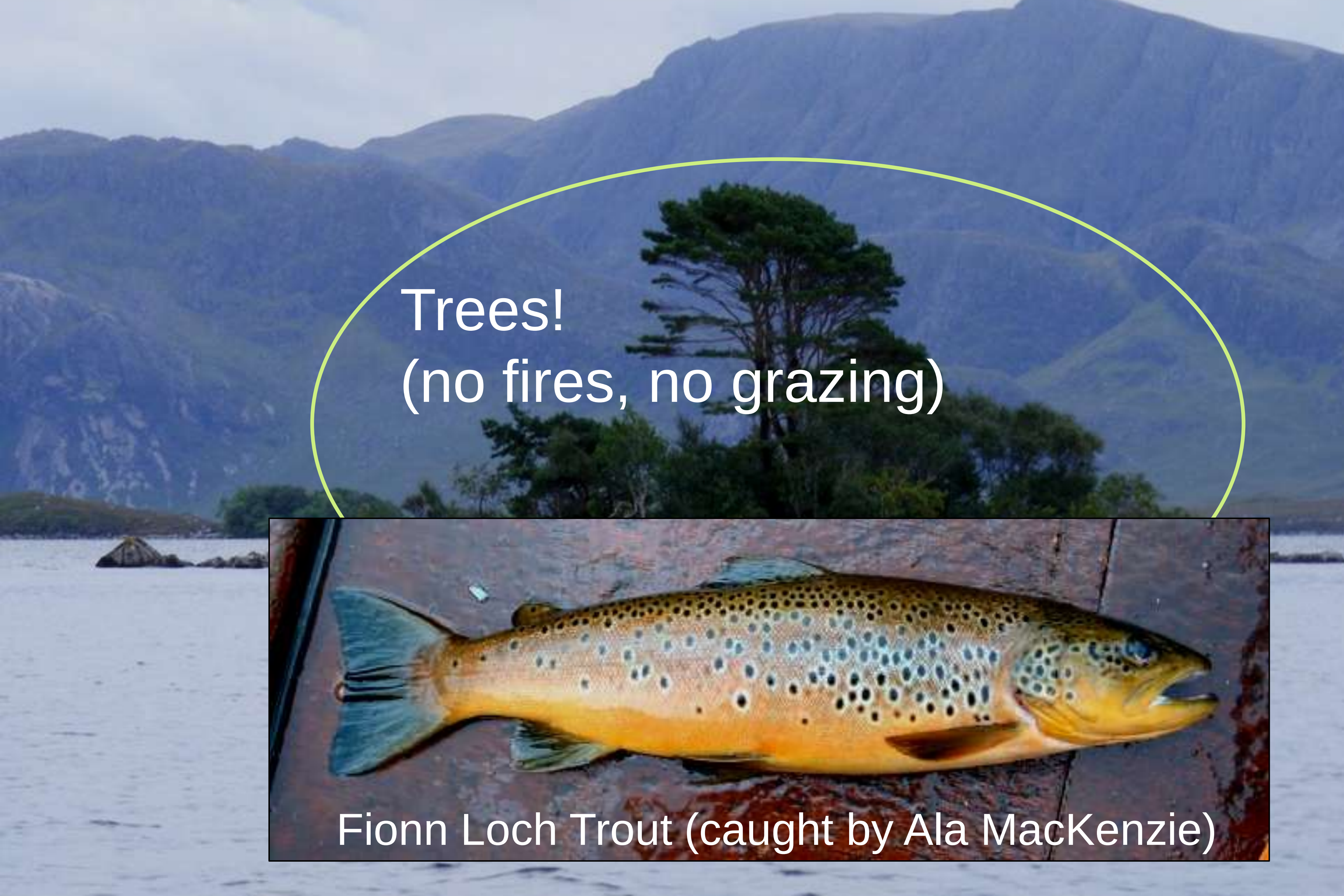
Assorted bones, Aultgrishan shore 3rd April 2016


Most river catchment areas in Wester Ross have very limited phosphorus availability.
Quartizite (c. glass. . .).
Kinlochewe River from top of Meall Ghuibhais (Beinn Eighe NNR)

What determines phosphorus availability?

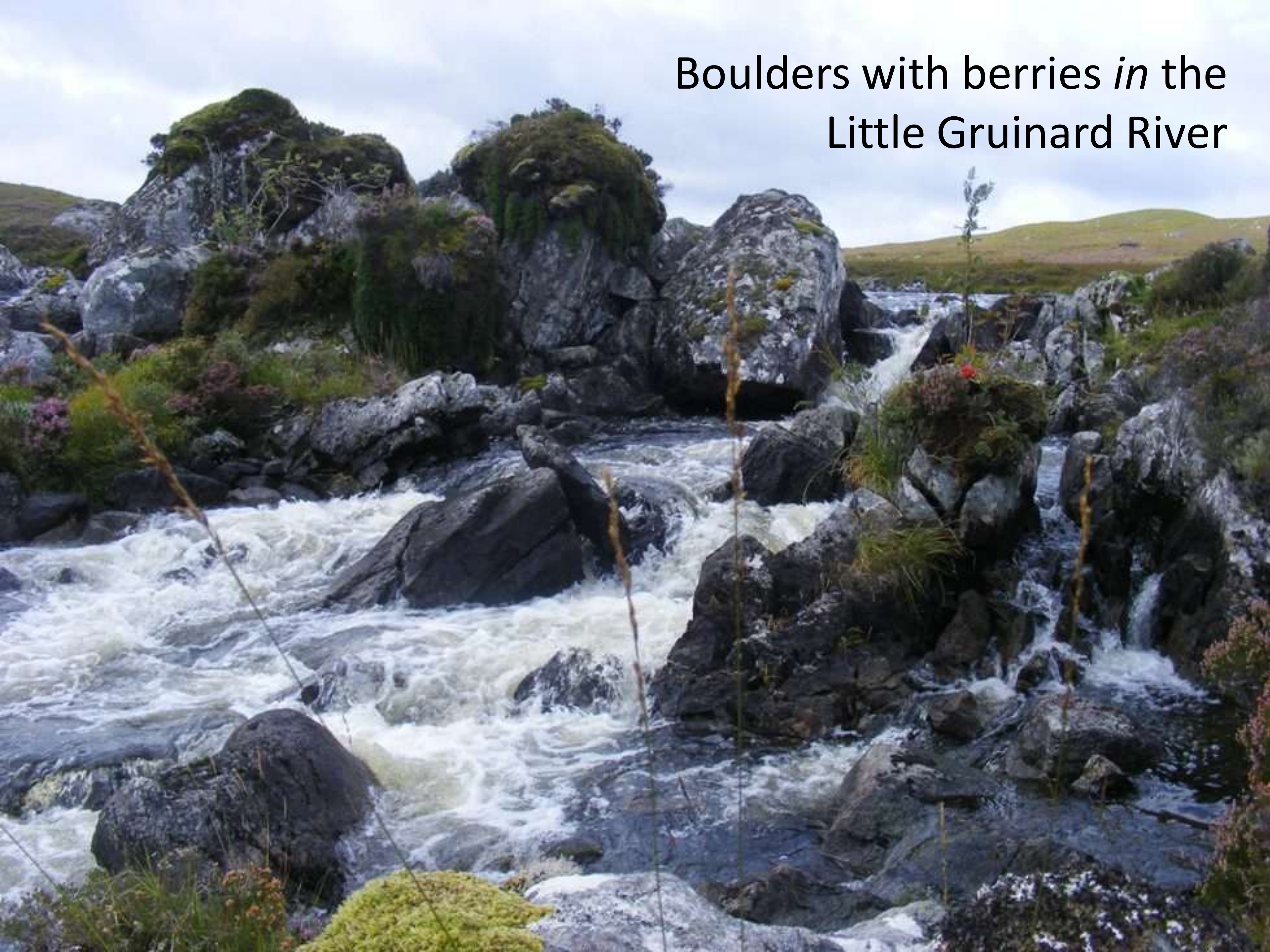


Fionn Loch islands, Little Gruinard catchment.



Fionn Loch Trout (caught by Ala MacKenzie)

Boulders with berries *in* the Little Gruinard River



Boulders with berries *in* the Little Gruinard River

Boulders by the Little Gruinard River, September 2016

Succession: ecosystem development

A boulder by the Little Gruinard River

Succession: ecosystem development

Q. Where does the phosphorus come from?

Lichen, moss;
meadow pipit.

Bird droppings.

Succession: ecosystem development

Q. Where does the phosphorus come from?

Lichen, moss; meadow pipit.

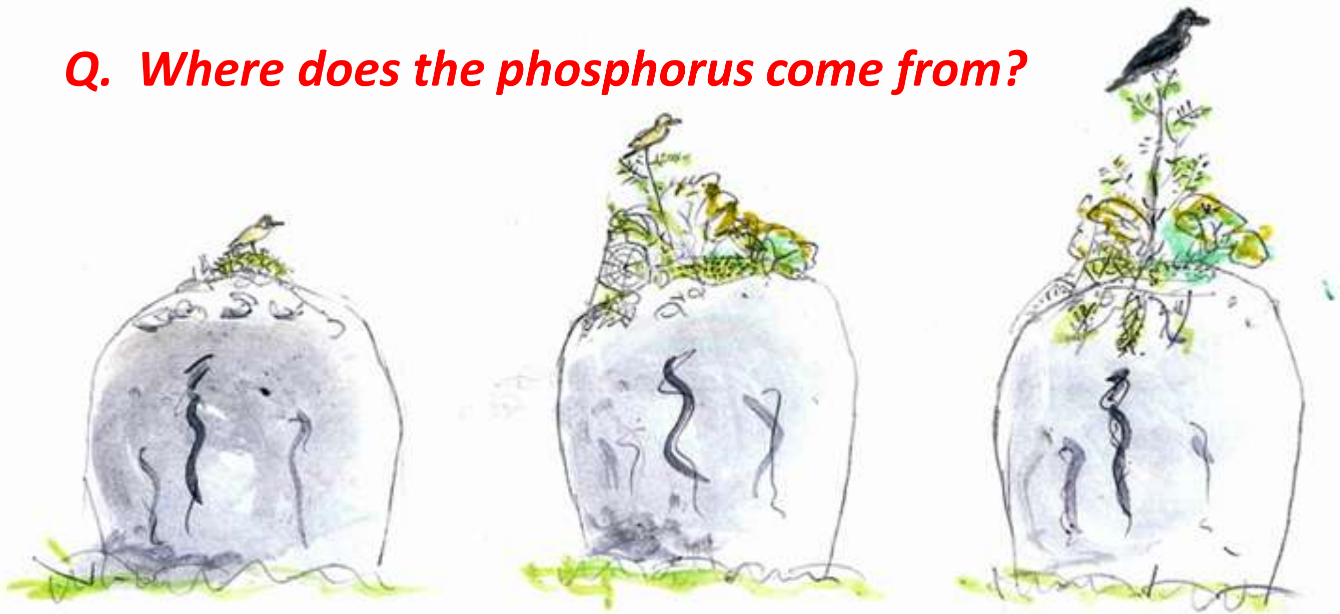
***Bird droppings**.*

Lichen, moss, grass, heather, rowan tree; spider's web, meadow pipit

Bird droppings, spider droppings, trapped midges . . .

Succession: ecosystem development

Q. Where does the phosphorus come from?



Lichen, moss; meadow pipit.	*Lichen, moss, grass, heather, rowan tree; spider's web, meadow pipit*	*Lichen, moss, grass, heather, blaeberry, rowan tree; spider's web, crow perch*
Bird droppings.	***Bird droppings, spider droppings, trapped midges . . .***	***Bird droppings: crow, thrushes, pipits, wren; spider droppings; dead insects . .***

Succession: ecosystem development

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Lichen, moss, grass,
heather, rowan tree;
spider's web, meadow
pipit

Bird droppings, spider droppings, trapped midges . . .

Lichen, moss, grass,
heather, blaeberry,
rowan tree;
spider's web, crow perch

Bird droppings: crow, thrushes, pipits, wren; spider droppings; dead insects . .

Lichen, moss, grass,
heather, blaeberry, rowan,
birch, juniper, crowberry,
bearberry, juniper, willow;
spiders web; wren,
stonechat, bird's nest . . .

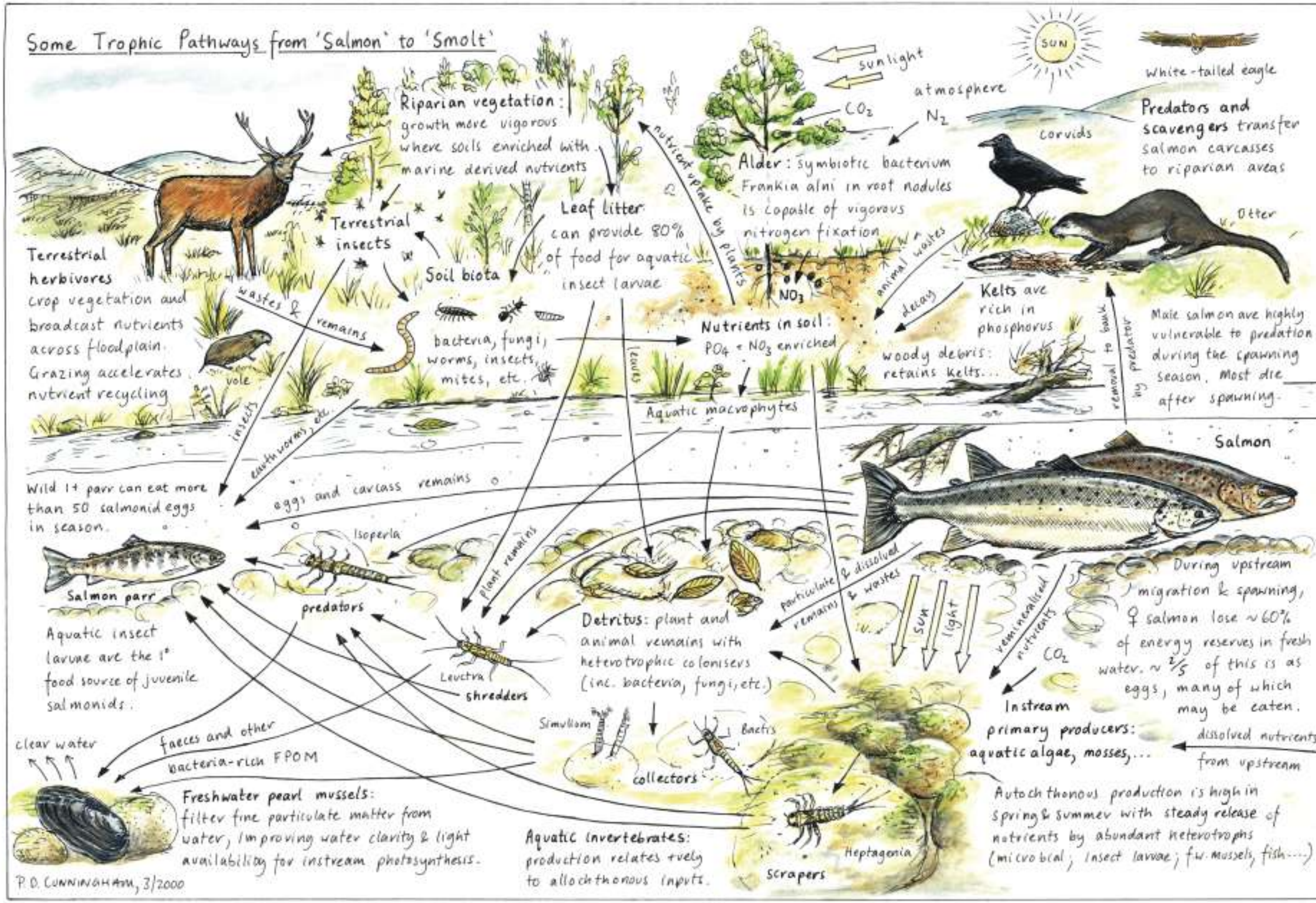
Bird droppings; Pine marten droppings; spider droppings, dead insects . . .


A rainforest ecosystem on a boulder?
out of reach of fires and grazing animals

Most Atlantic salmon return to freshwater only once to spawn . . .

Salmon jaw and primroses,
as found, May 2010

Adult salmon provide food for juvenile salmon

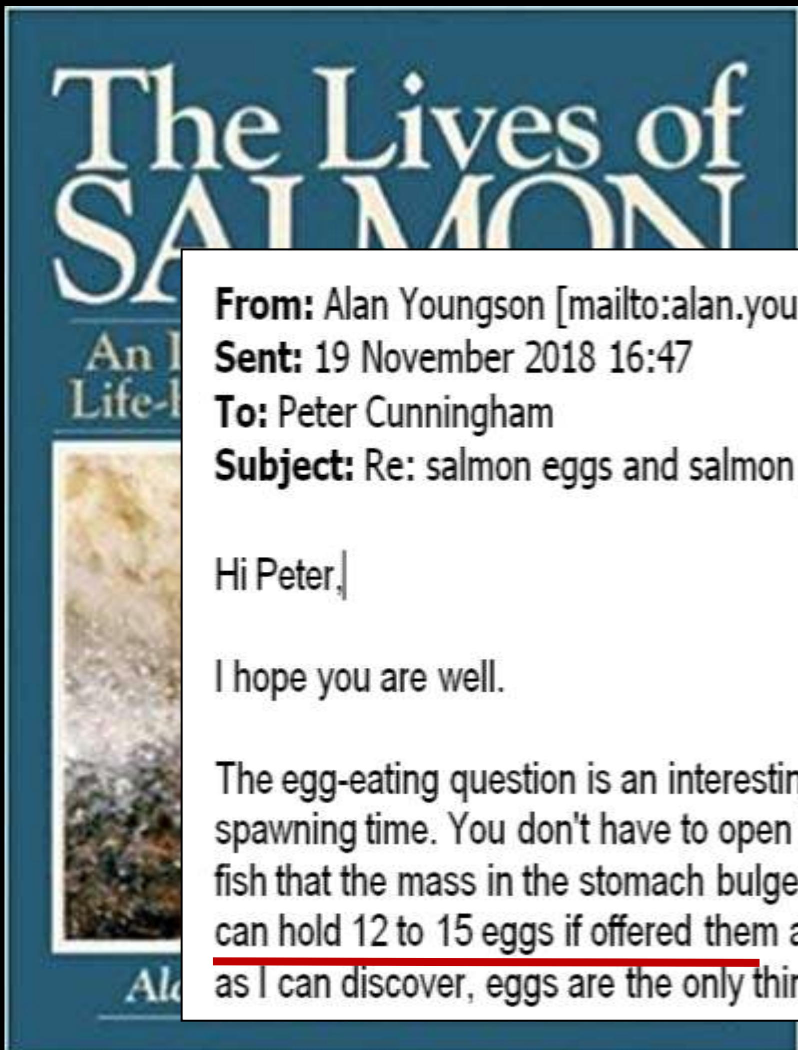


In the past, many more salmon returned to Scottish rivers from the sea each year.

How much marine nutrient was transferred to terrestrial ecosystems in Scotland in the past?

Smolt condition **is** important (e.g. Armstrong et al, 2018)

What is the importance of salmon eggs as a food for pre-smolt salmon parr in oligotrophic streams?



From: Alan Youngson [mailto:alan.youngson@bti
Sent: 19 November 2018 16:47
To: Peter Cunningham
Subject: Re: salmon eggs and salmon parr

Hi Peter,

I hope you are well.

The egg-eating question is an interesting one. As you know lots of the parr (and trout) contain eggs at spawning time. You don't have to open them up to see this because the eggs are so packed into the fish that the mass in the stomach bulges characteristically on the fishes' underside. A parr of 120mm can hold 12 to 15 eggs if offered them and parr down to 70mm can (somehow) get them down. As far as I can discover, eggs are the only thing that captive wild parr will eat.

To what extent does food availability affect the reproductive success of freshwater pearl mussels in Wester Ross?

Freshwater pearl mussels, in situ, in the **River Kerry**. Note the green periphyton growing on the mussels.

Population healthy with plenty of young ones.

(GoPro Video still)

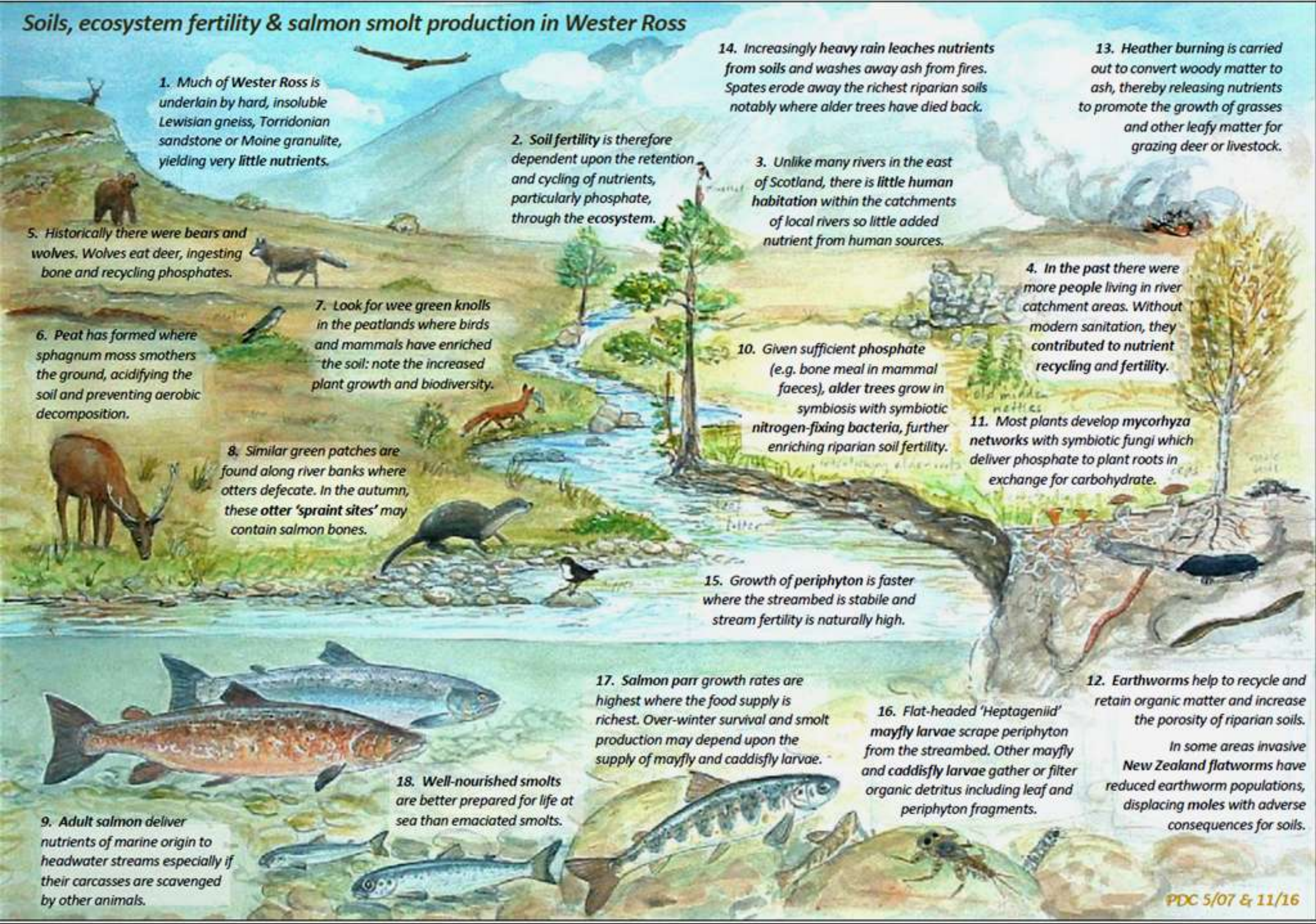
Freshwater pearl mussel, in situ, in the **Little Gruinard River.** Note the lack of green periphyton growing on the mussels and streambed.

Just a few starving old mussels here? No recent recruitment (to my knowledge).

"…what if I told you that the trees are here, in part, because of salmon? That the trees that shelter and feed the fish, that help build the fish, are themselves built by the fish?"

-- Carl Safina, essayist for *Salmon in the Trees*

photos by Amy Gulick

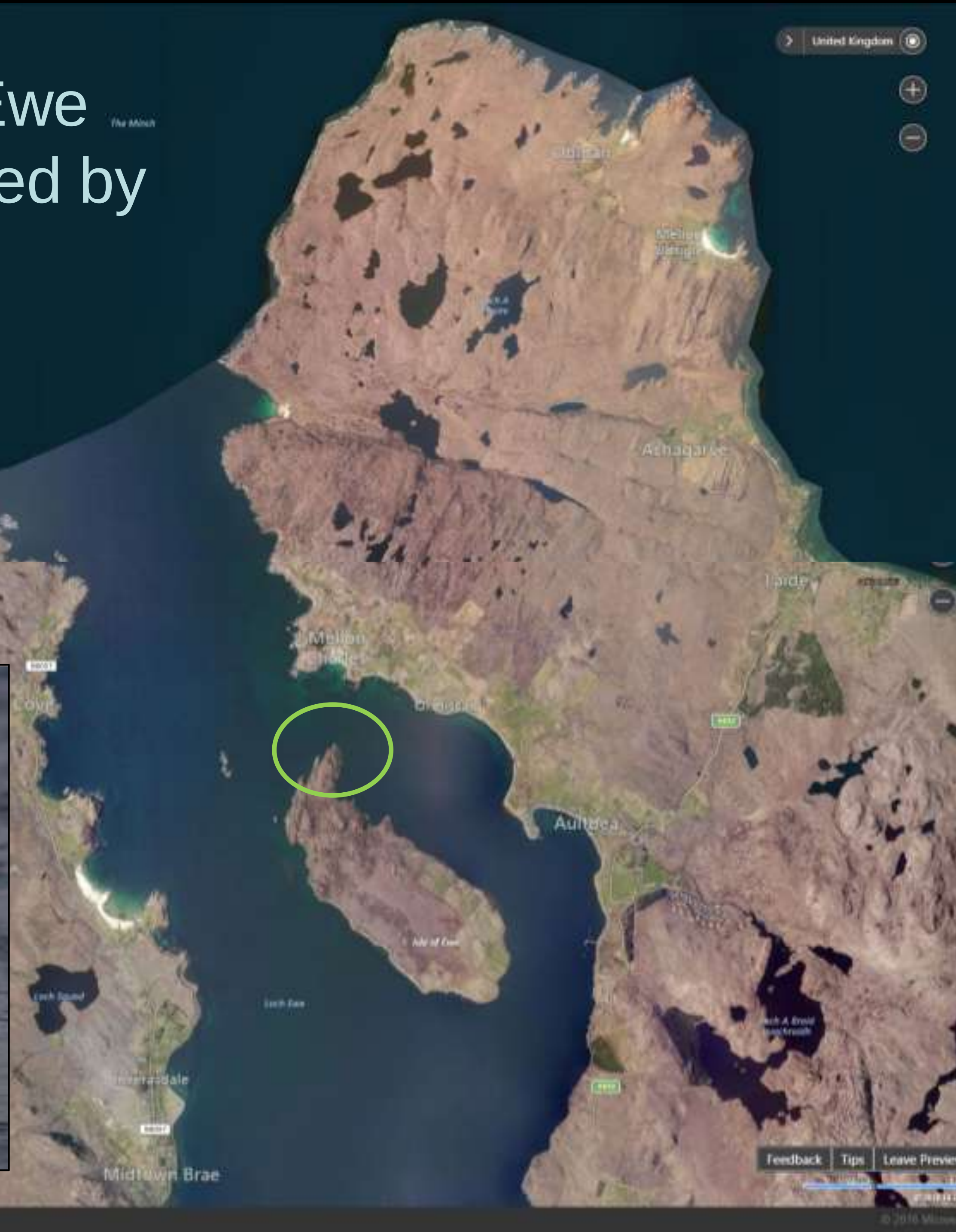


See www.wrft.org.uk

Its not just salmon that move nutrients about

The Island of Longa (Loch Gairloch) is enriched with nutrients from nesting sea birds, and provides good winter grazing for sheep.

Islands around Loch Ewe have also been fertilised by sea birds



Isle of Ewe: breeding area for Greylag geese and herring gulls

Upland areas in Wester Ross are not uniformly infertile . . .

Watching an eagle above Beinn Eighe NNR

Rocks and knolls in prominent positions in upland areas have been enriched with nutrients delivered by birds and mammals.

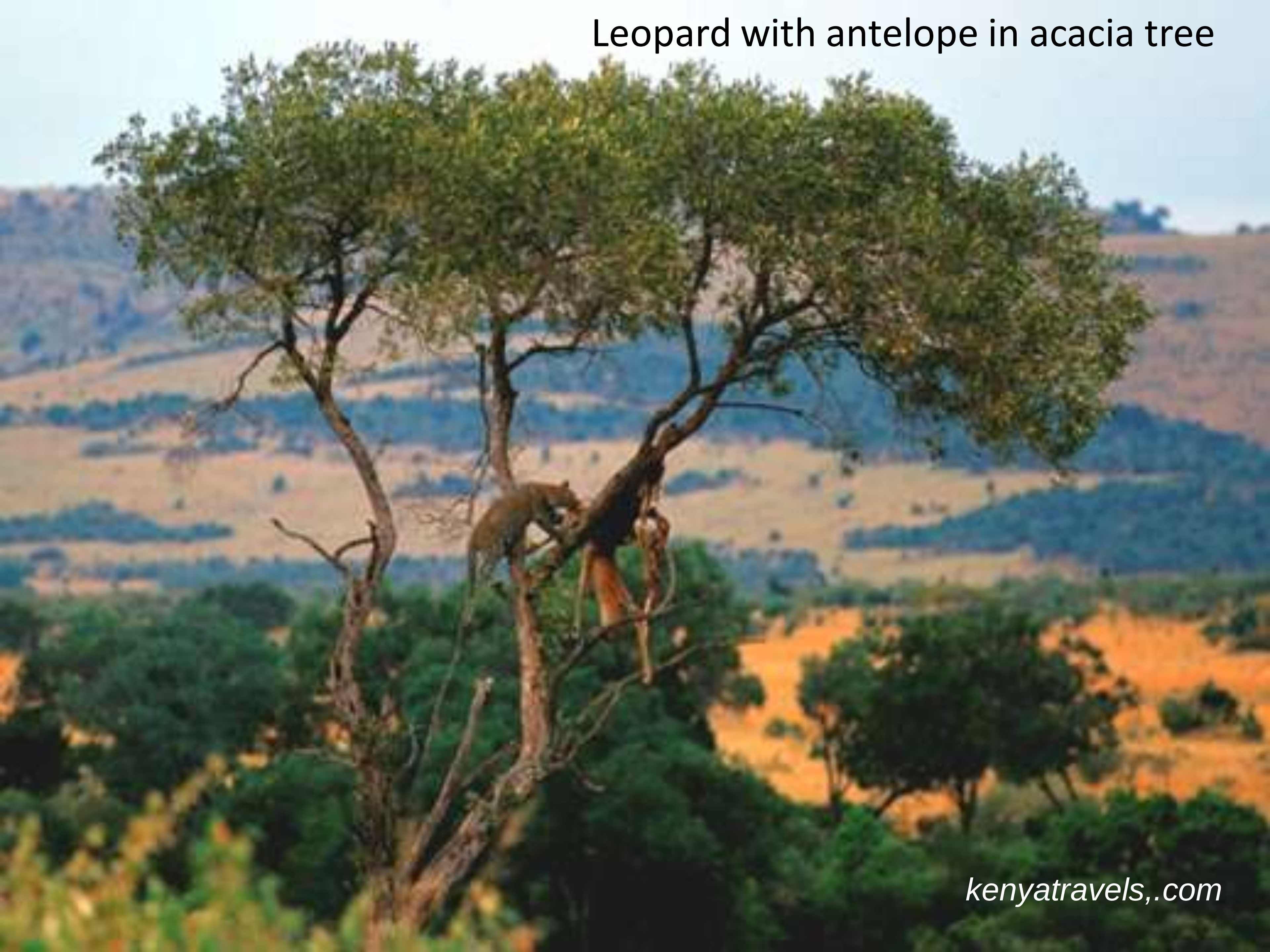
Raptor perch in Beinn Eighe NNR


Why is this rock green?
Otter spraint with fish bones.

Eagle pellet (containing fur) and grouse dropping from a green knoll in the Tollie Hills

Isolated oak tree, North Erradale (where crows and a buzzard often perch)

Leopard with antelope in acacia tree



kenyatravels,.com

http://www.pnas.org/content/113/4/868.full.pdf

Global nutrient transport in a world of giants

Christopher E. Doughty[a,1], Joe Roman[b,c], Søren Faurby[d], Adam Wolf[e], Alifa Haque[a], Elisabeth S. Bakker[f], Yadvinder Malhi[a], John B. Dunning Jr.[g], and Jens-Christian Svenning[d]

[a]Environmental Change Institute, School of Geograph
Evolutionary Biology, Harvard University, Cambridge,
[d]Section of Ecoinformatics & Biodiversity, Department
Evolutionary Biology, Princeton University, Princeton,
The Netherlands; and [g]Department of Forestry and N

Edited by John W. Terborgh, Duke University, Durham

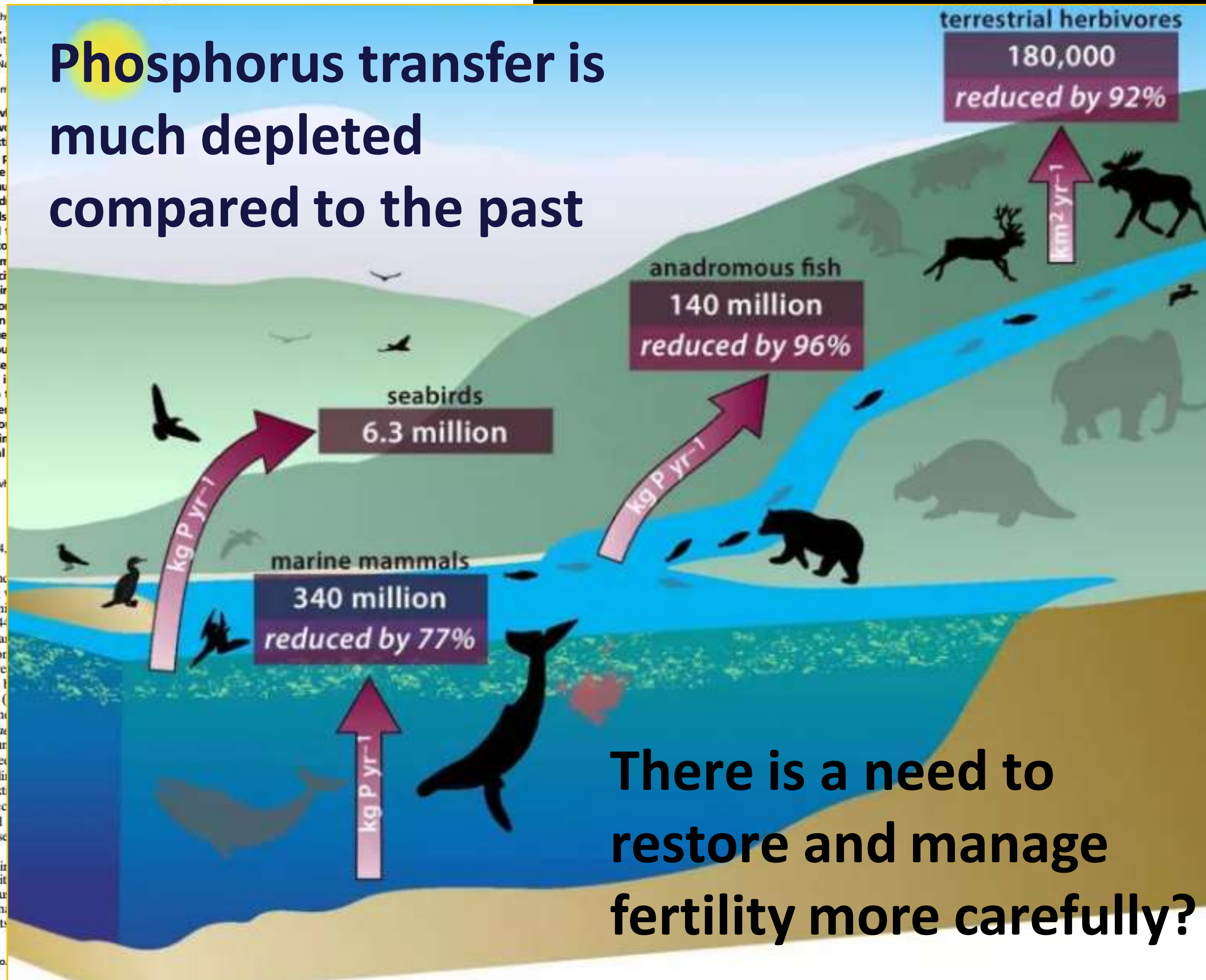
The past was a world of giants, with abundant w
large animals roaming the land. However, that w
following massive late-Quaternary megafauna ext
widespread population reductions in great whale p
past few centuries. These losses are likely to have
sequences for broad-scale nutrient cycling, becau
suggests that large animals disproportionately d
ment. We estimate that the capacity of animals
away from concentration patches has decreased
preextinction value on land and about 5% of histo
For phosphorus (P), a key nutrient, upward mover
marine mammals is about 23% of its former capac
340 million kg of P per year). Movements by seabir
fish provide important transfer of nutrients fro
totalling ~150 million kg of P per year globally in
that has declined to less than 4% of this value
decimation of seabird colonies and anadromou
We propose that in the past, marine mammals, se
fish, and terrestrial animals likely formed an i
recycling nutrients from the ocean depths to
teriors, with marine mammals moving nutrie
sea to surface waters, seabirds and anadromo
trients from the ocean to land, and large anim
ents away from hotspots into the continental

biogeochemical cycling | extinctions | megafauna | wh
anadromous fish

There were giants in the world in those days.
Genesis 6:4

The past was a world of giants, with abund
oceans and terrestrial ecosystems teeming
However, most ecosystems lost their large an
150 mammal megafaunal (here, defined as ≥44
species going extinct in the late Pleistocene a
(1, 2). These extinctions and range declines co
historical times and, in many cases, into the pre
extinctions are known for any marine whales,
might have declined between 66% and 99% (
largest species have experienced severe declin
the Southern Hemisphere, blue whales (*Bala*
have been reduced to 1% of their historical nu
commercial whaling (4). Much effort has be
termining the cause of the extinctions and decli
focusing on the ecological impacts of the ext
focus on the ecological impacts, with a spec
nutrient dynamics may have changed on land
Quaternary megafauna extinctions, and in the se
historical hunting pressures.
Most biogeochemists studying nutrient cycli
production, such as weathering or biological ni
largely ignoring lateral fluxes by animals becau
ered of secondary importance (3). The tradition
biogeochemistry is that "rock-derived" nutrient

Phosphorus transfer is much depleted compared to the past



There is a need to restore and manage fertility more carefully?

What is fertility?

Soil fertility: refers to the ability of a soil to support plant growth

Fallen Douglas fir in Flowerdale

This decomposing tree now supports a diverse assemblage of lichens, mosses, ferns, grass, blaeberry, cotoneaster, a small rowan tree, and a birch tree.

Look: . . . no soil ☺ !

(except the birch)

Nutrients are being obtained almost entirely from the decomposing tree.

Soil fertility: the ability of a soil to supply plant nutrient.

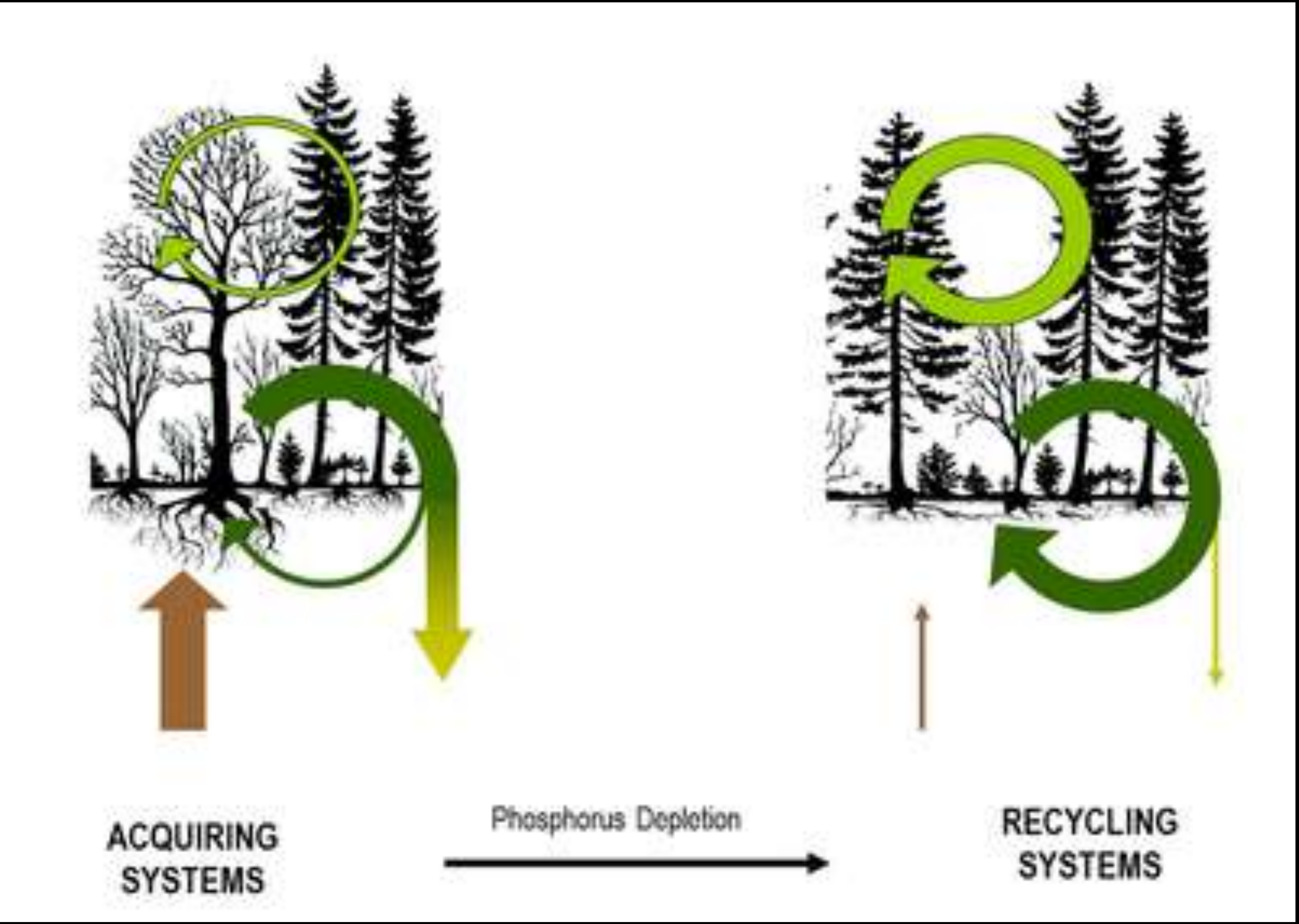
?Ecosystem fertility: the ability of an ecosystem to circulate life-sustaining nutrients to its component parts.

(from 'Refertilising Scotland' presentation at 'Reforesting Scotland' meeting in Torridon Community Centre, September 2010)

Reforesting Scotland

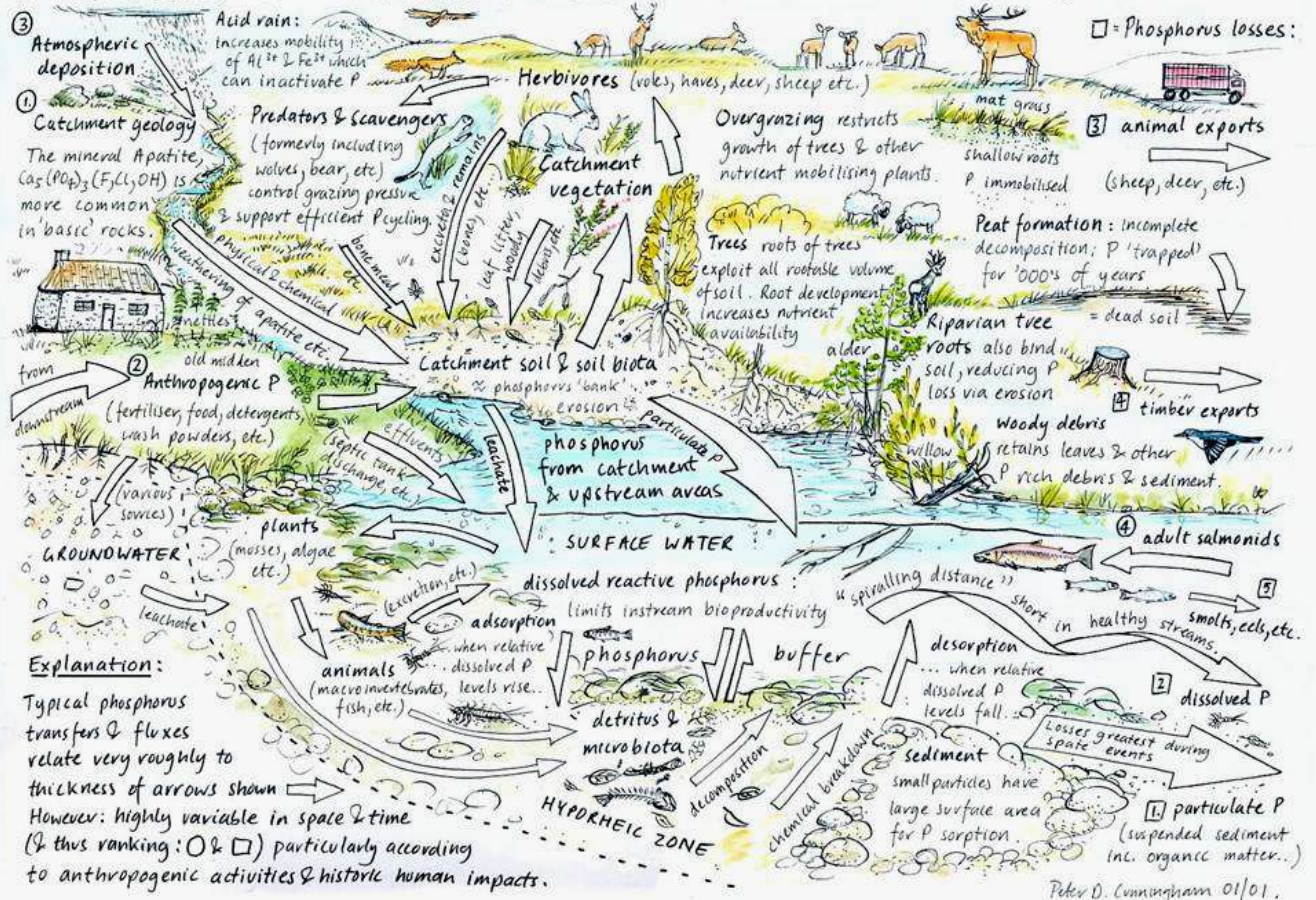
Fertile & productive ecosystems need not be dependent upon fertile soils if nutrients can be recycled and circulated within the biota.

Ecosystem nutrition: forest strategies for limited phosphorus resources

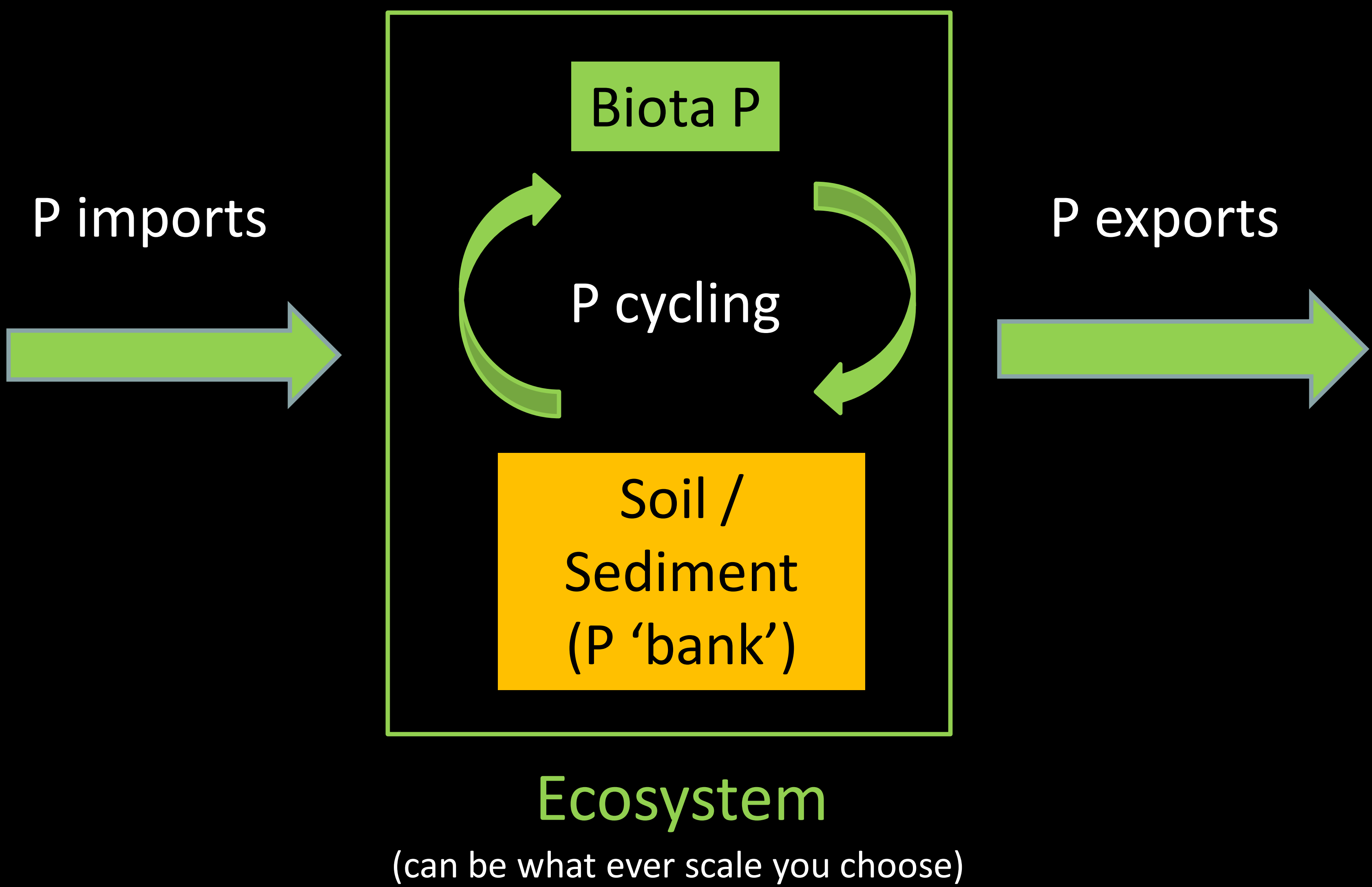


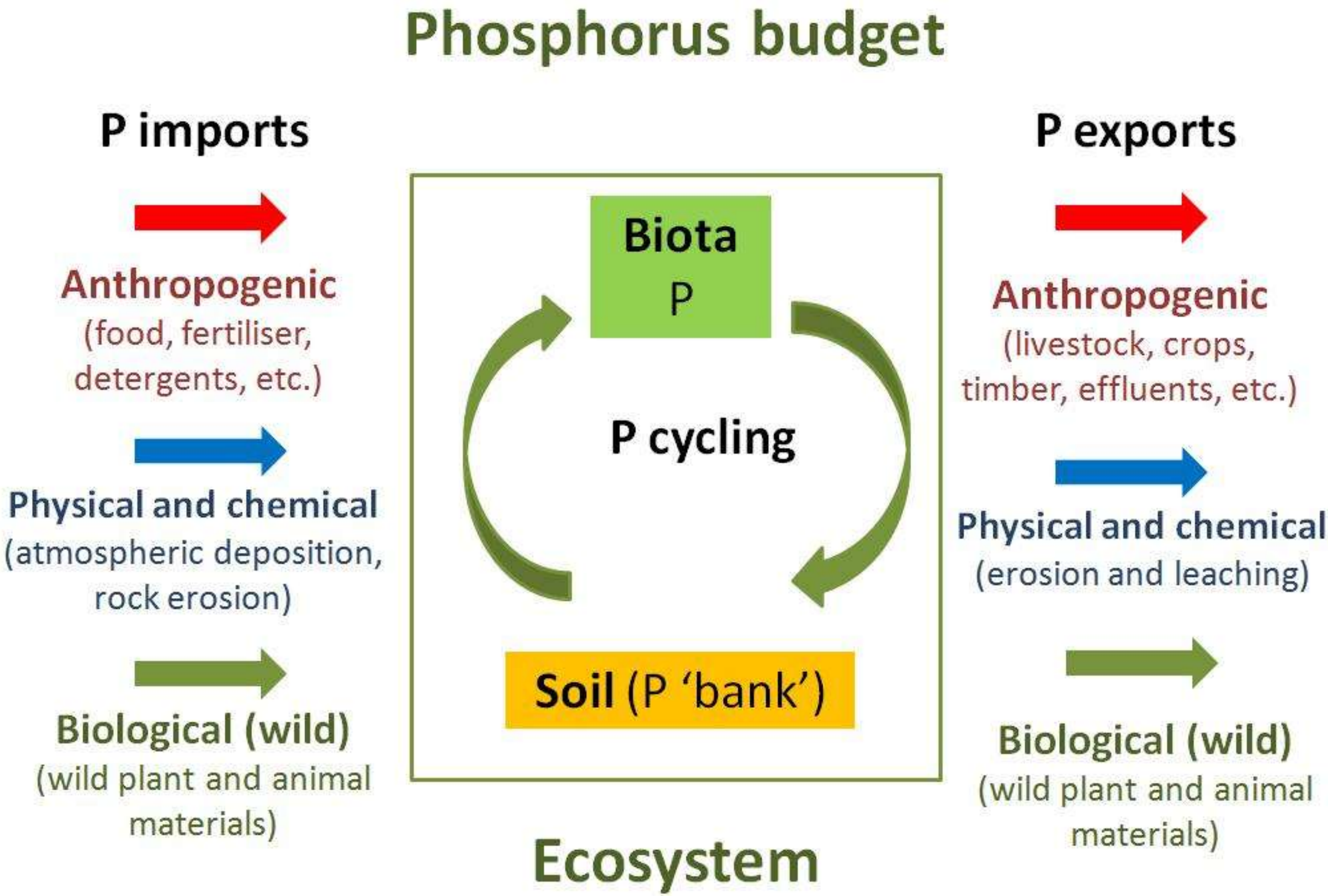
https://www.bodenkunde.uni-freiburg.de/forschung/SPP1685

Phosphorus availability is dependent upon ecosystem processes . . .

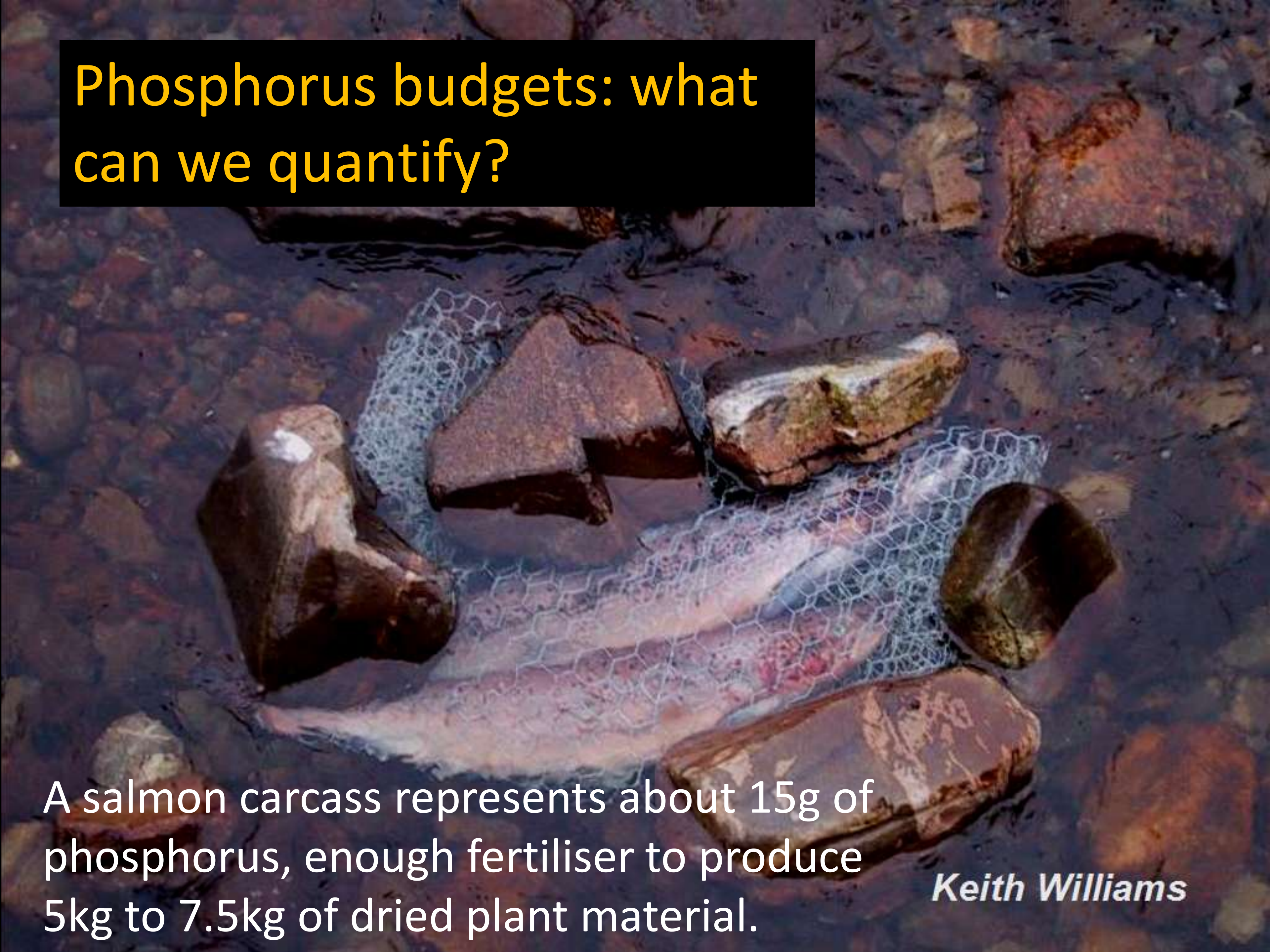


Simplified Phosphorus budget model!

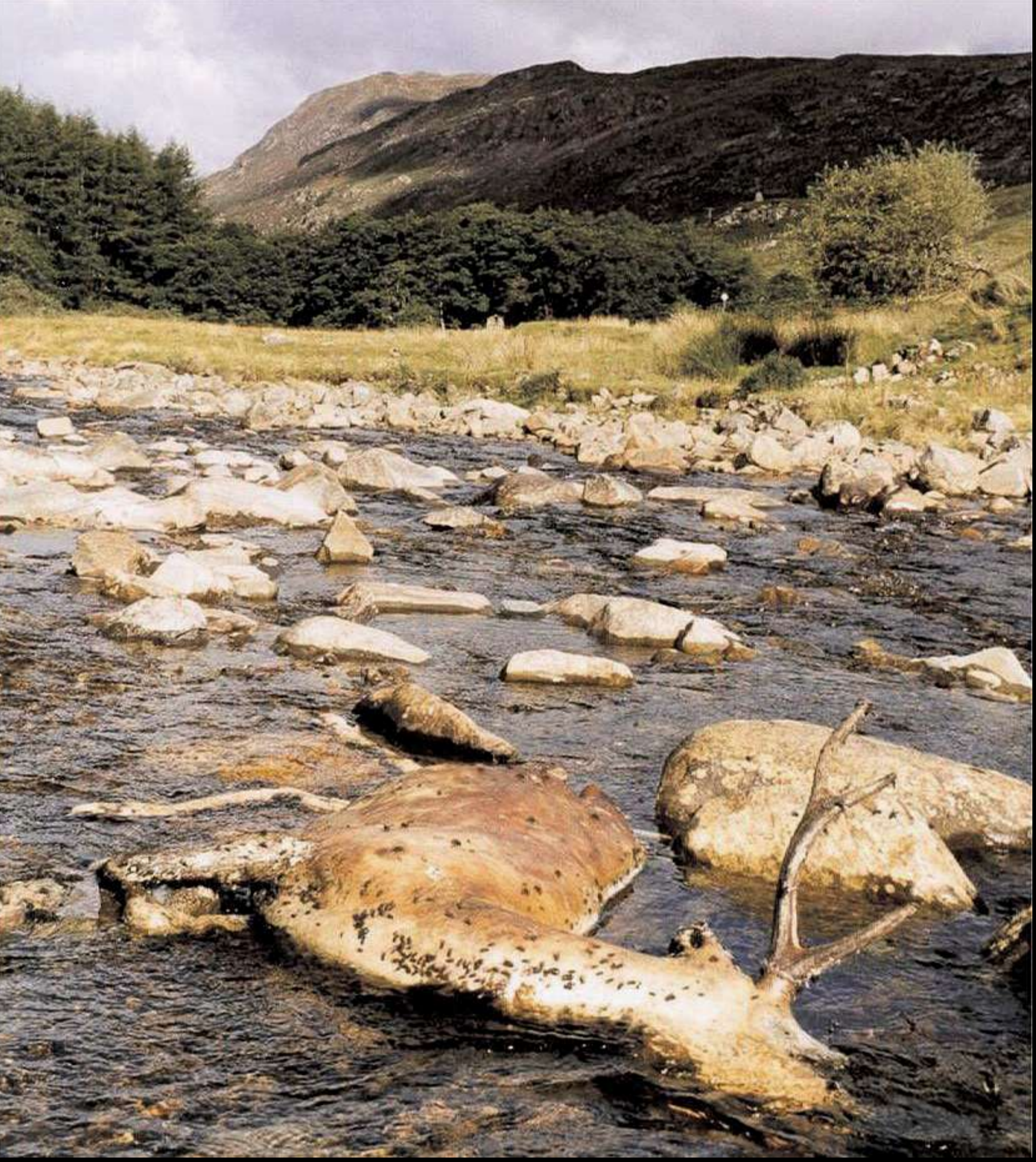



Phosphorus budget
P imports
Anthropogenic
(food, fertiliser, detergents, etc.)
Physical and chemical
(atmospheric deposition, rock erosion)
Biological (wild)
(wild plant and animal materials)
Biota
P
P cycling
Soil (P 'bank')
Ecosystem
P exports
Anthropogenic
(livestock, crops, timber, effluents, etc.)
Physical and chemical
(erosion and leaching)
Biological (wild)
(wild plant and animal materials)

Phosphorus budgets: what can we quantify?



A salmon carcass represents about 15g of phosphorus, enough fertiliser to produce 5kg to 7.5kg of dried plant material.



A deer carcass contains ~3 kg of phosphate: mainly in bones.

The removal of deer, sheep or cattle from upland catchment areas represents an unnatural loss of nutrient from the ecosystem.

Phosphorus loss of ~0.1 kg /Ha/yr of P . . . = 10kg /km^2/yr of P

http://www.thefield.co.uk/stalking-2/where-to-go-stalking-in-scotland-in-2016-29934

Phosphorus budgets

200 salmon carcasses contain roughly the same amount of phosphorus as three red deer or about 1,000kg – 1,500kg of dried plant material

x 200

or

x 1,000kg

or

x 3

= ~ 3kg of Phosphorus

Fertility studies of grazing areas in the Swiss National Park

https://www.graubuenden.ch/en/discover-our-regions/swiss-national-park-and-further-parks

https://www.graubuenden.ch/sites/default/files/styles/grf_global_s/public/story_image/natur-essvm-rothirsch-nationalpark.jpg?itok=vc9uv8I9

http://img.myswitzerland.com/mys/7398/images/buehne/STS2740-1.jpg

Ecosystems (2006) 9: 624–633
DOI: 10.1007/s10021-006-0091-4

ECOSYSTEMS

Phosphorus Translocation by Red Deer on a Subalpine Grassland in the Central European Alps

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Abstract

We examined the role of red deer (*Cervus elaphus* L.) in translocating phosphorus (P) from their preferred grazing sites (short-grass vegetation on subalpine grasslands) to their wider home range in a subalpine grassland ecosystem in the Central European Alps. Phosphorus was used because it is the limiting nutrient in these grasslands. When we compared P removal of aboveground biomass due to grazing with P input due to the deposit of feces on a grid of 268 cells (20 m × 20 m) covering the entire grassland, we detected distinct spatial patterns: the proportion of heavily grazed short-grass vegetation increased with increasing soil-P pool, suggesting that red deer preferably grazed on grid cells with a higher soil-P pool. Biomass consumption related to increased proportion of short-grass vegetation, and therefore P removal, increased with increasing soil-P pool. However, within the two vegetation types (short-grass and tall-grass), consumption was independent from soil-P pool. In addition, P input rates from defecation increased with increasing soil-P pool, resulting in a constant mean net P loss of 0.083 kg ha^{-1} y^{-1} (0.03%–0.07% of soil-P pool) independent of both soil-P pool and vegetation type. Thus, there was no P translocation between grid cells with different soil-P pools or between short-grass and tall-grass vegetation. Based on these results, it is likely that the net rate of P loss is too small to explain the observed changes in vegetation composition from tall-herb/meadow communities to short-grass and from tall-grass to short-grass on the grassland since 1917. Instead, we suggest that the grazing patterns of red deer directly induced succession from tall-herb/meadow communities to short-grass vegetation. Yet, it is also possible that long-term net soil-P losses indirectly drive plant succession from short-grass to tall-grass vegetation, because nutrient depletion could reduce grazing pressure in short-grass vegetation and enable the characteristic tall-grass species *Carex sempervirens* Vill. to establish.

Key words: *Cervus elaphus*; elimination pattern; grazing pattern; phosphorus removal/input; succession; Swiss National Park.

Shultz et al (2006) demonstrated that within the Swiss National Park [SNP] red deer move phosphorus by defecating in different areas from where they graze.

They recognised a long term nutrient depletion from grazed areas within the SNP.

http://www.fs.fed.us/rm/pubs_other/rmrs_2006_schutz_m001.pdf


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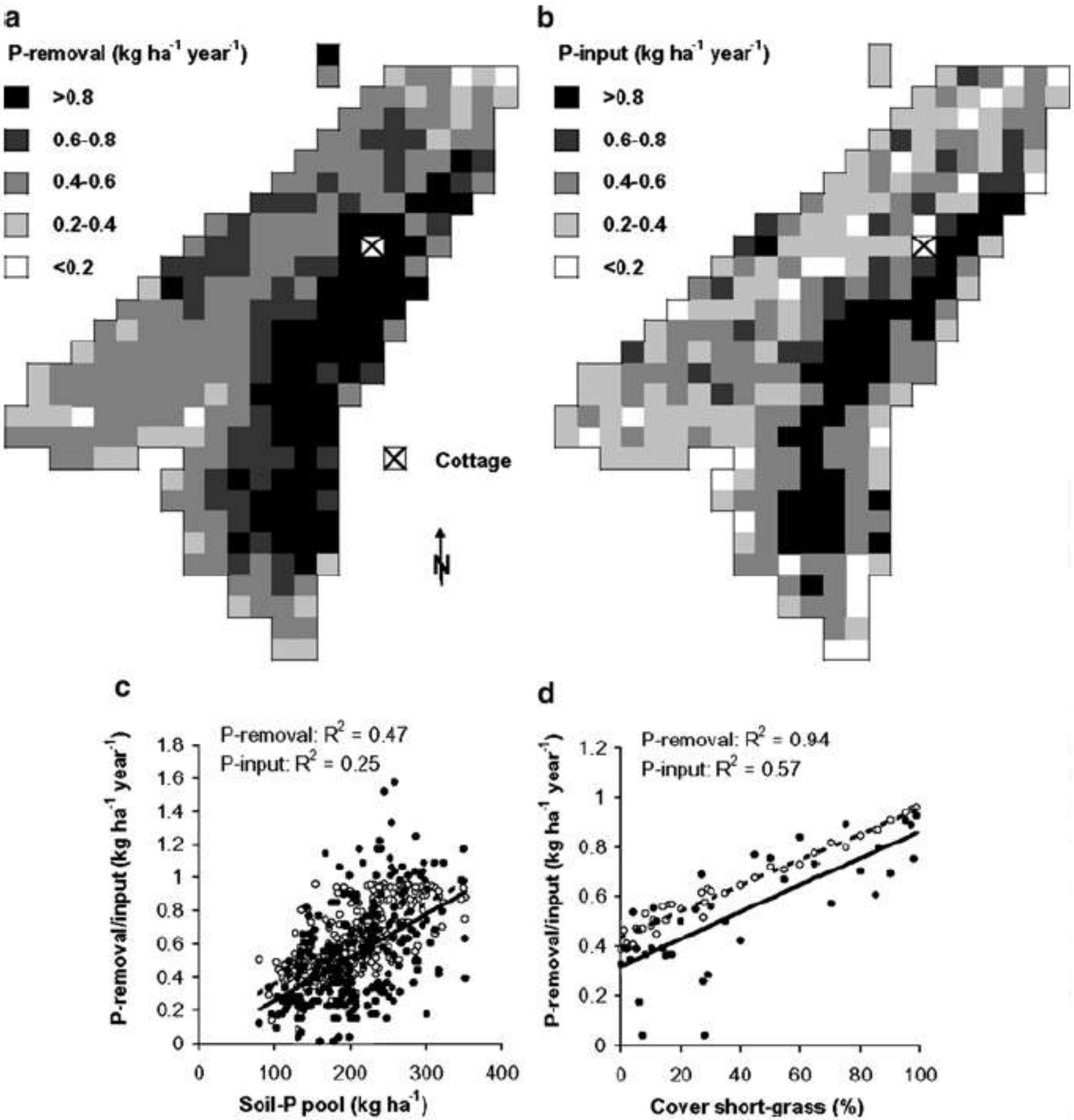


Figure 3. Spatial patterns of **A** phosphorus (P) removal by red deer grazing offtake, and **B** P input by red deer dung deposition on the subalpine grassland of Alp Stabelchod **C** Relationship between P removal/P input and soil-P pool. **D** Relation between P removal/P input and short-grass cover. P removal, ○—*dashed line*; P input, ●—solid line.

http://www.fs.fed.us/rm/pubs_other/rmrs_2006_schutz_m001.pdf

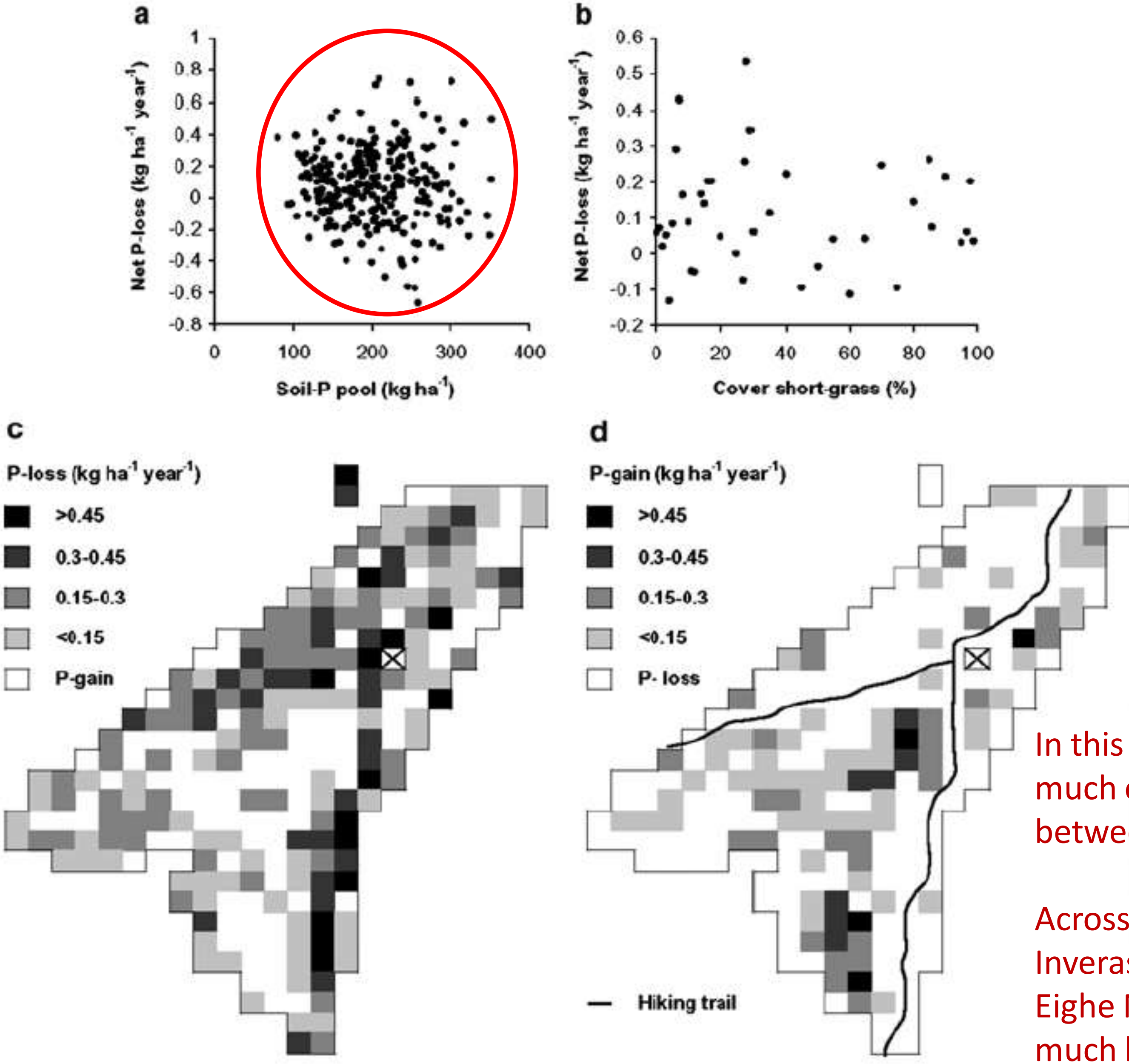


Figure 4. Relationship between **a** net phosphorus (P) loss and soil-P pool, **b** net P loss and cover of short-grass vegetation. Spatial patterns of **c** net P loss (removal > input) and **d** net P gain (input > removal) on the subalpine grassland of Alp Stabelchod.

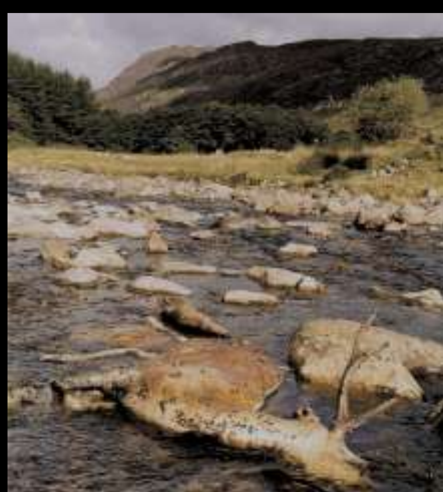
In this study, the **soil P pool** over much of the study area was typically between 200 and 300 kg P /ha.

Across much of Wester Ross (e.g. Inverasdale grazings area; Beinn Eighe NNR) it is probably usually much less than that . . .

http://www.fs.fed.us/rm/pubs_other/rmrs_2006_schutz_m001.pdf

Subsequently, Flueck (2009) produced much larger estimate **of 0.32 kg/ha/yr of P** transfer from out of the Swiss National Park on the basis that most deer die or are killed by hunters outside the park during autumn and winter months.

Is this the sort of analyses that could be repeated for individual estates, Beinn Eighe NNR & Deer Management Group areas to understand long term changes in P availability, and the size of the P deficit?



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Article

Biotic Translocation of Phosphorus: The Role of Deer in Protected Areas

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Abstract: Biogeochemical cycles are cornerstones of biological evolution. Mature terrestrial ecosystems efficiently trap nutrients and certain ones are largely recycled internally. Preserving natural fluxes of nutrients is an important mission of protected areas, but artificially leaky systems remain common. Native red deer (*Cervus elaphus*) in the Swiss National Park (SNP) are known to reduce phosphorus (P) in preferred feeding sites by removing more P than is returned with feces. At larger scales it becomes apparent that losses are occurring due to seasonal deer movements out of the SNP where most deer end up perishing. Thus, the SNP contributes to producing deer which translocate P to sink areas outside the SNP due to several artificial factors. An adult female dying outside of SNP exports about 1.8 kg of P, whereas a male dying outside of SNP at 8 years of age exports 7.2 kg of P due also to annual shedding of antlers. Averaged over the vegetated part of the SNP, the about 2,000 deer export 0.32 kg/ha/yr of P. Other ungulate species using the SNP and dying principally outside of its borders would result in additional exports of P. Leakiness in this case is induced by: a) absence of the predator community and thus a lack of summer mortalities and absence of several relevant non-lethal predator effects, b) hunting-accelerated population turnover rate, and c) deaths outside of SNP principally from hunting. The estimated export rate for P compares to rates measured in extensive production systems which receive 10-50 kg/ha/yr of P as fertilizer to compensate the losses from biomass exports. Assumptions were made regarding red deer body weight or population turnover rate, yet substituting my estimates with actual values from the SNP would only affect somewhat the magnitude of the effect, but not its direction. The rate of P loss is a proxy for losses of other elements, the most critical ones being those not essential to autotrophs, but essential to heterotrophs. High deer turnover rates combined with accelerated biomass export warrants detailed mass balances of macro and micro nutrients, and studies of biogeochemical cycles in protected areas are essential if preserving natural processes is a mandate.

Keywords: Cervus elaphus; Phosphorus; Biogeochemical cycle; Protected areas; Biomass export.

NORTH ROSS DEER

MANAGEMENT GROUP

(VERSION May 2016)

DEER MANAGEMENT PLAN
2014 - 2019

http://nrossdmg.deer-management.co.uk/wp-content/uploads/2016/06/Deer-Management-Plan-2014-2019.pdf

2. AIMS & OBJECTIVES

2.1 Guiding Principles

The Members have adopted the Principles of Collaboration created by the ADMG which are as follows:-

- to acknowledge what we have in common - namely a shared commitment to a sustainable and economically viable Scottish countryside;
- to make a commitment to work together to achieve that;
- to accept that we have a diversity of management objectives and that we respect each other's objectives;
- to undertake to communicate openly with all relevant parties;
- to commit to negotiate and where necessary compromise in order to accommodate the reasonable land management requirements of our neighbours;
- to undertake that where there are areas of disagreement, we will work to resolve these.

In addition Members have adopted the Code of Practice on Deer Management (Appendix II) and aim to deliver the terms of the code through the Groups policies and objectives.

2.2 The Group's Objectives:-

- To foster best practice in all aspects of deer management.
- To adopt a constitution suitable for the running of the NRDMG
- To ensure full participation throughout the Group area
- To ensure that ownership objectives (be they sporting, forestry, agricultural, fishing, conservation, etc) are achievable whilst maintaining designated features in favourable condition or working towards favourable/unfavourable recovering condition.
- To maintain a sustainable Group sporting stag cull and associated socio-economic benefits.
- Minimise spread of sika and any other non-native deer species within the DMG area and report sightings to SNH
- Minimise the incidents of deer poaching.
- Minimise negative impacts associated with access legislation.
- To adhere to the Deer Management Group benchmark (Appendix III)
- to achieve a relatively stable deer population capable of sustaining sporting requirements along with other land uses and habitat requirements of the area;
- to ensure sufficient on going training is carried out to enable the aims and objectives of the Group to be met
- to ensure an effective system of communications is in place both within the Group and with the general public and to engage positively and actively.
- to ensure such there are sufficient resources carry out the aims and objectives of the Group

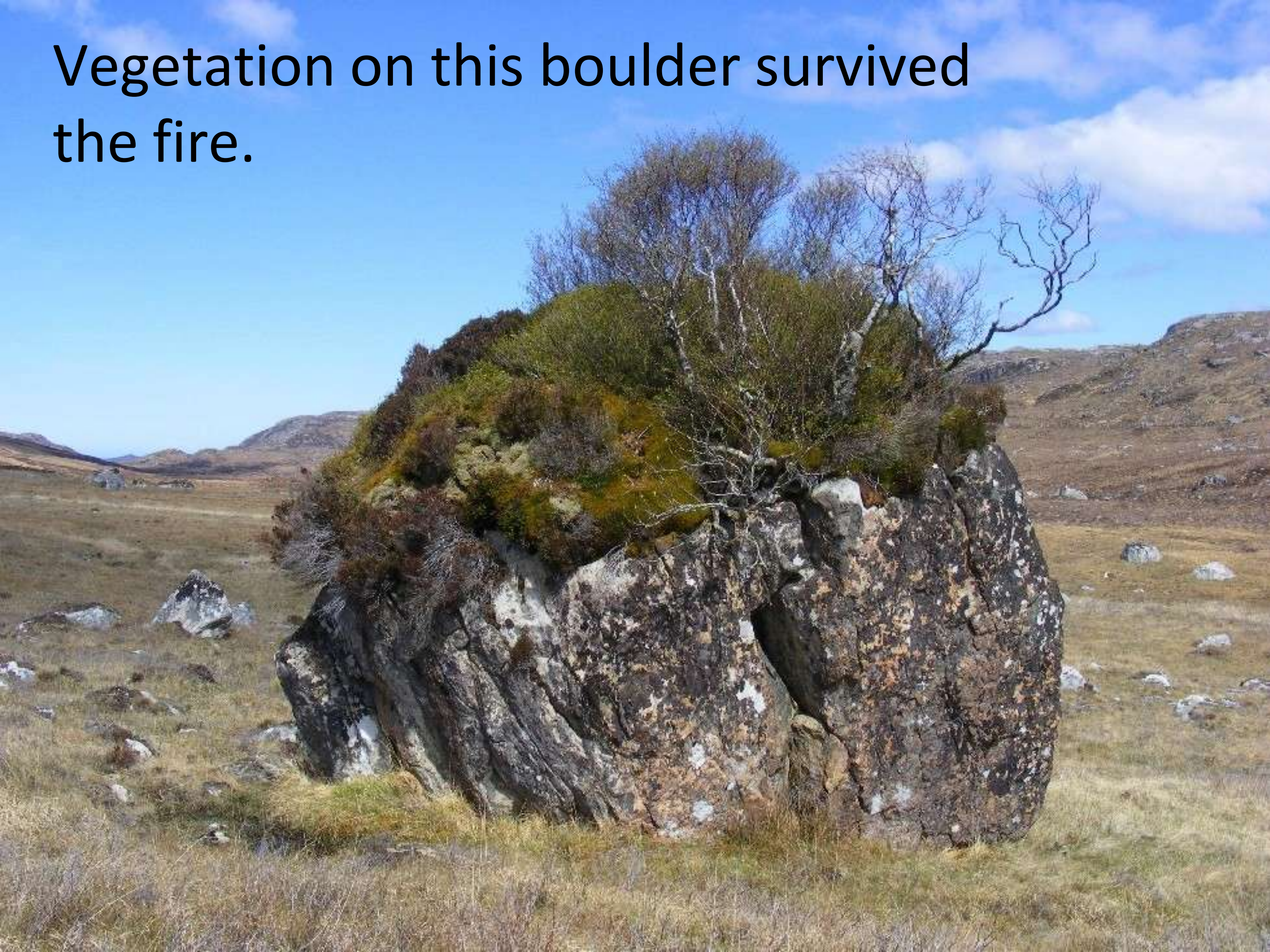
I can't find any targets for maintaining the P fertility of deer pasture areas, to sustain levels of deer production?

Has this been investigated?

Picture by Sue Holland

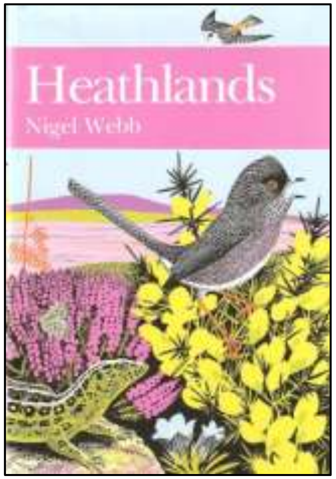

Little Gruinard River, May 2010 (inside fenced enclosure)
Wildfire in 2007

Vegetation on this boulder survived the fire.



How much phosphorus is lost in a moor burn?

Nutrient Balance Sheet for an Area of Lowland Heath (expressed as kg per ha)						
from Webb, 1986						
	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	**Phosphorus (P)**	Nitrogen (N)
Vegetation (heather heathland)	4.7	34.3	33	13.4	**4.1**	107.7
Leaf litter	0.7	5	15.2	3.8	**4.2**	74.5
Total	5.4	39.3	48.2	17.2	**8.3**	182.2
Soil (0-20cm)	84	288	229	236	**37**	2210
% [of P] in veg. and leaf litter lost on burning	28%	21%	26%	23%	**26%**	95%
amount remaining after burning	3.9	31	35.7	13.2	**6.1**	9.1
amount lost	1.5	8.3	12.5	4	**2.2**	173.1
Nutrient content of 1 years rainfall	25.4	1.2	4.7	5.6	**0.01**	5.2
Nutrient content of 12 years rainfall	305	14	56	67	**0.12**	62
Nutrient balance after 12 years	+303	+5.7	+43.5	+63	-2.08	-111
Figures are in kg per ha						



25% of the P in vegetation and leaf litter was lost on burning and not recovered within 10 years, representing a loss of over **2kg of P per ha**.

(**2kg P is the equivalent to that in about 4 sheep**)

Large areas in Wester Ross were burned by wildfire in 2019 and in previous recent years.

Many of the fires were started for land management purposes.

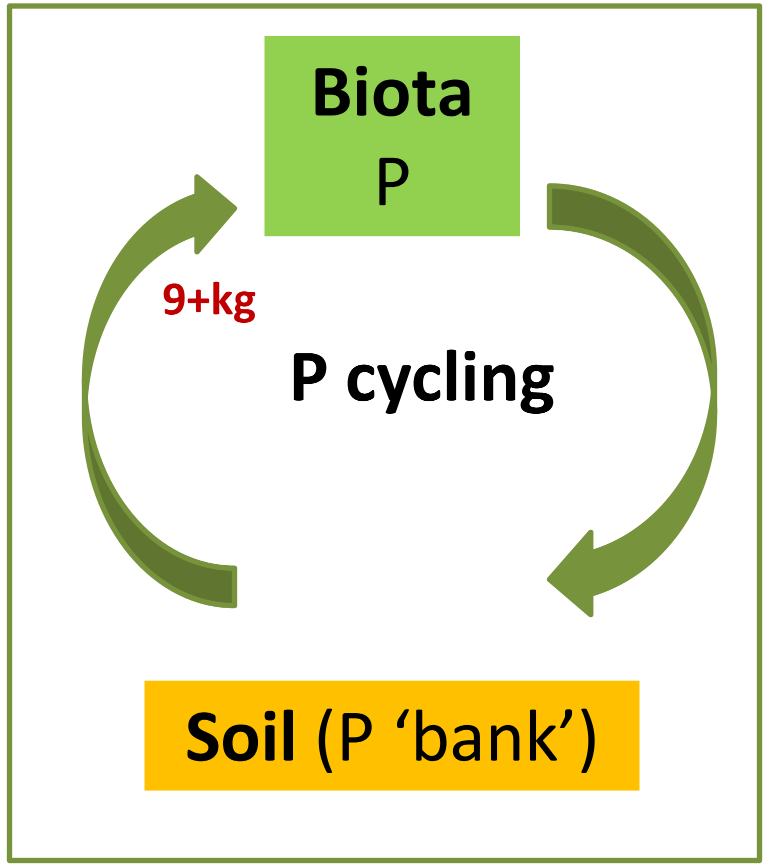
Hypothetical annual P budget example for 1km^2 of uninhabited unfertilised Wester Ross deer forest (i.e. open hill) burned every 40 years and stocked at 8 deer per km^2 where 1 deer is culled and carcass removed each year

P imports 4kg

Anthropogenic 1kg
(Feed block 0.2kg; other humans & dogs . . . 0.8kg)

Physical and chemical 2kg
(Rain 1kg P; Rock 1kg P)

Biological (wild) 1kg
(Fish, otter and birds 1kg or more if sea birds come inland)



P exports 13kg

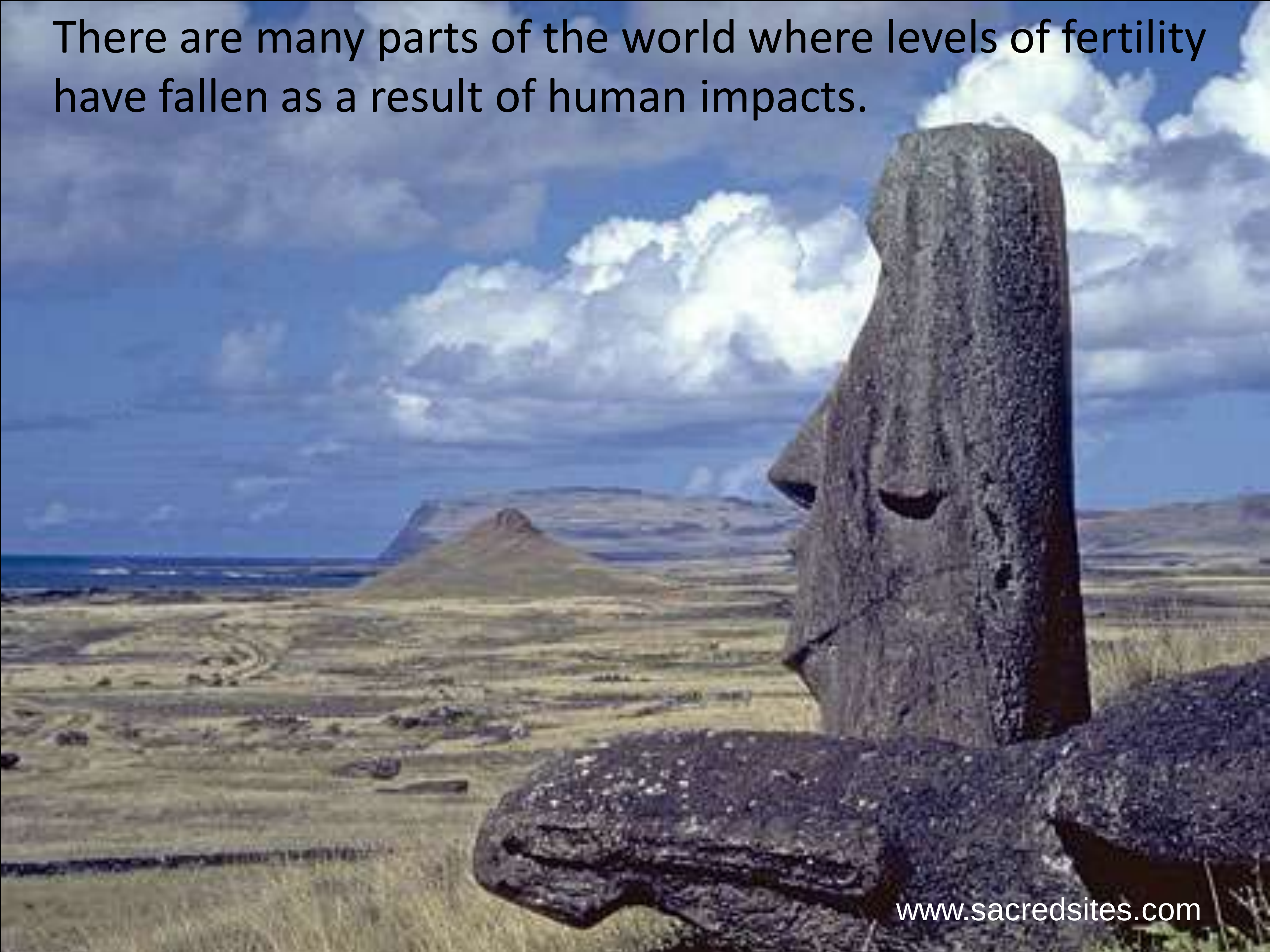
Anthropogenic 6kg
(Exported deer carcasses 1kg; smoke and ash if burned every 40 years, 5kg [based on loss of 200kg P with each fire])

Physical and chemical 4kg
(soil erosion and leaching 4kg, possibly very much more where soil poached)

Biological (wild) 3kg
(deer faeces in run-off 2kg when soils and vegetation thin; blown grass, leaves, etc. 1kg)

Ecosystem: possible net loss of >9kg P per km^2 per year?

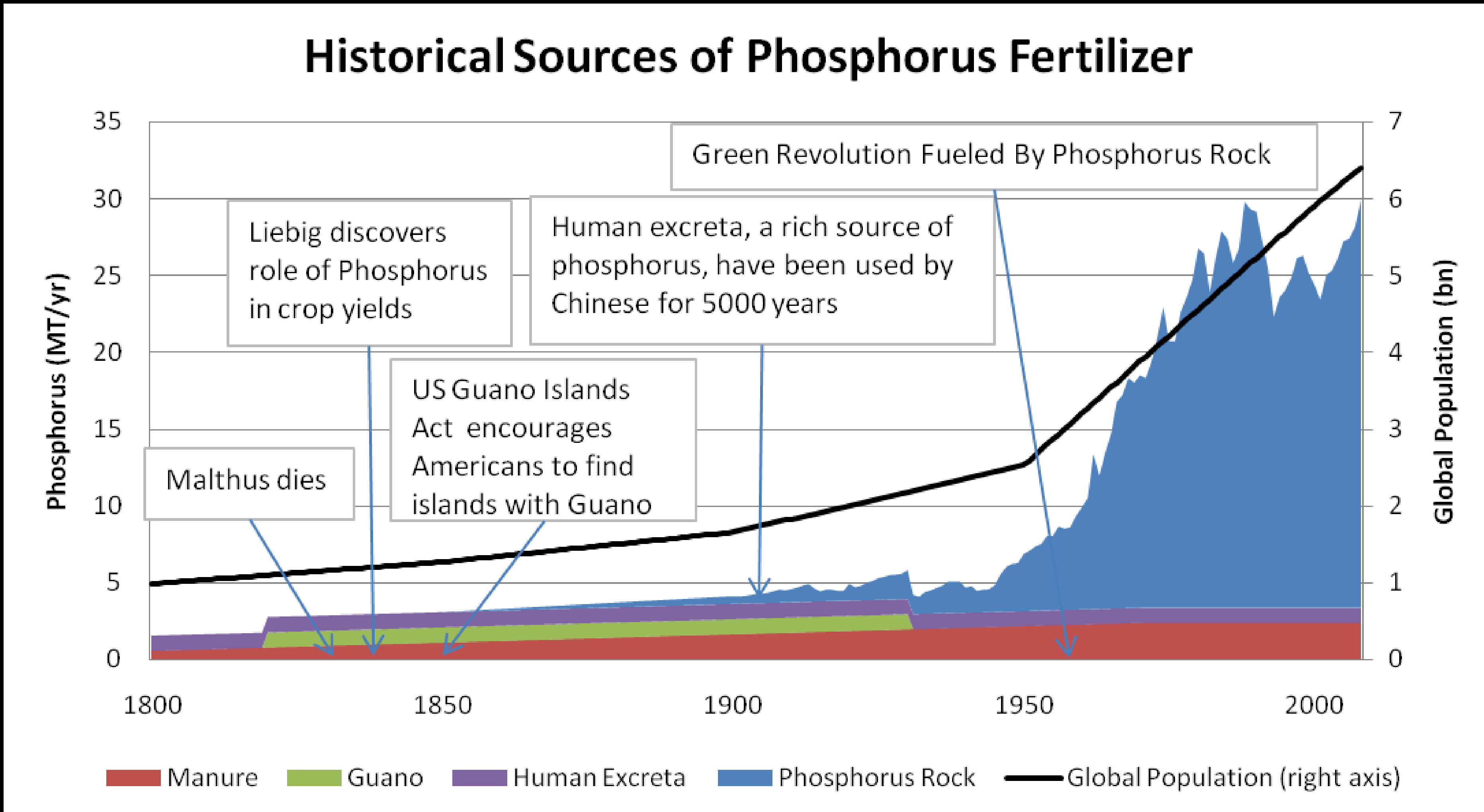
There are many parts of the world where levels of fertility have fallen as a result of human impacts.



www.sacredsites.com

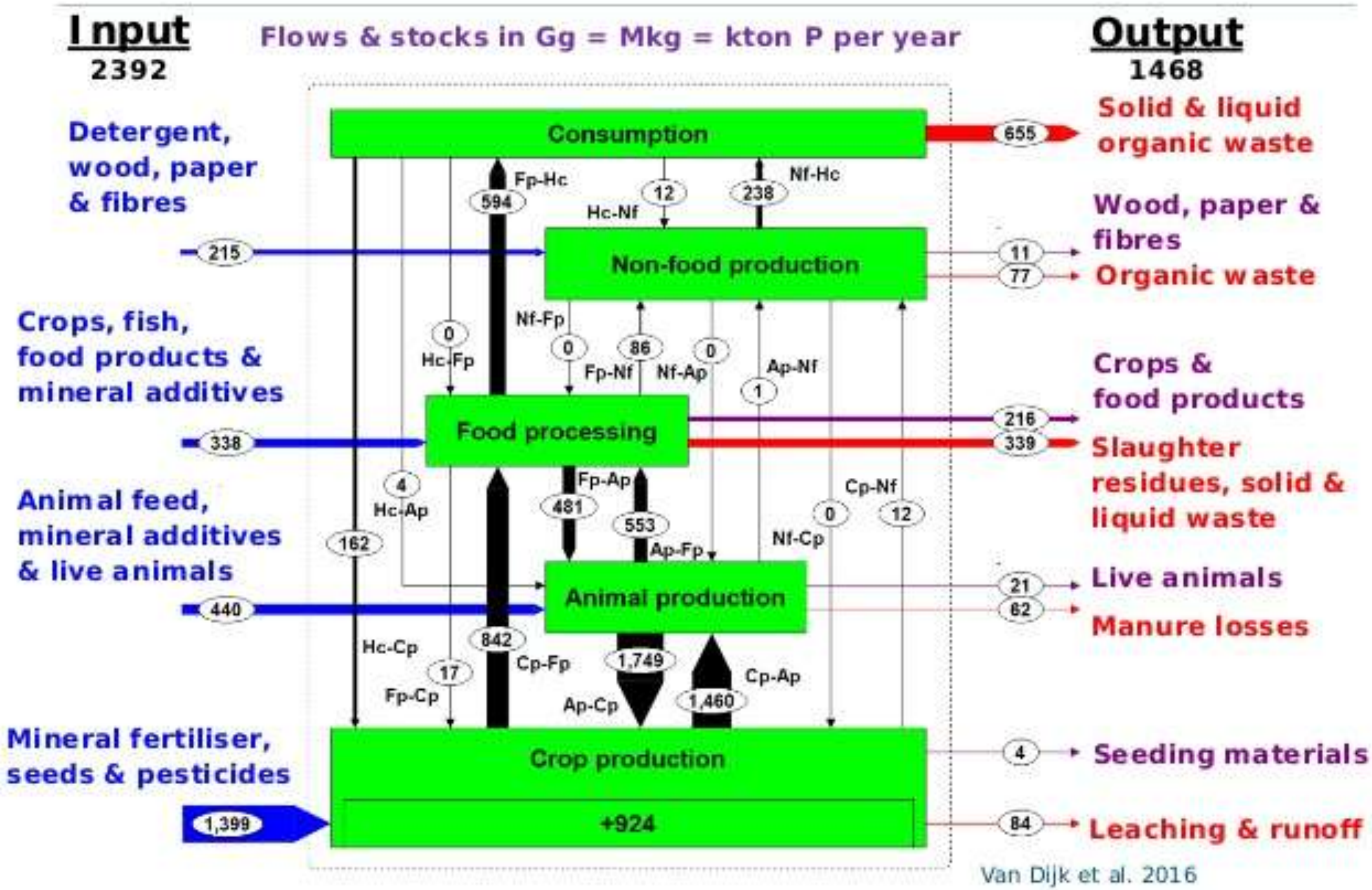
Deforested hills in Madagascar . . .

We may run short of phosphorus in future years.

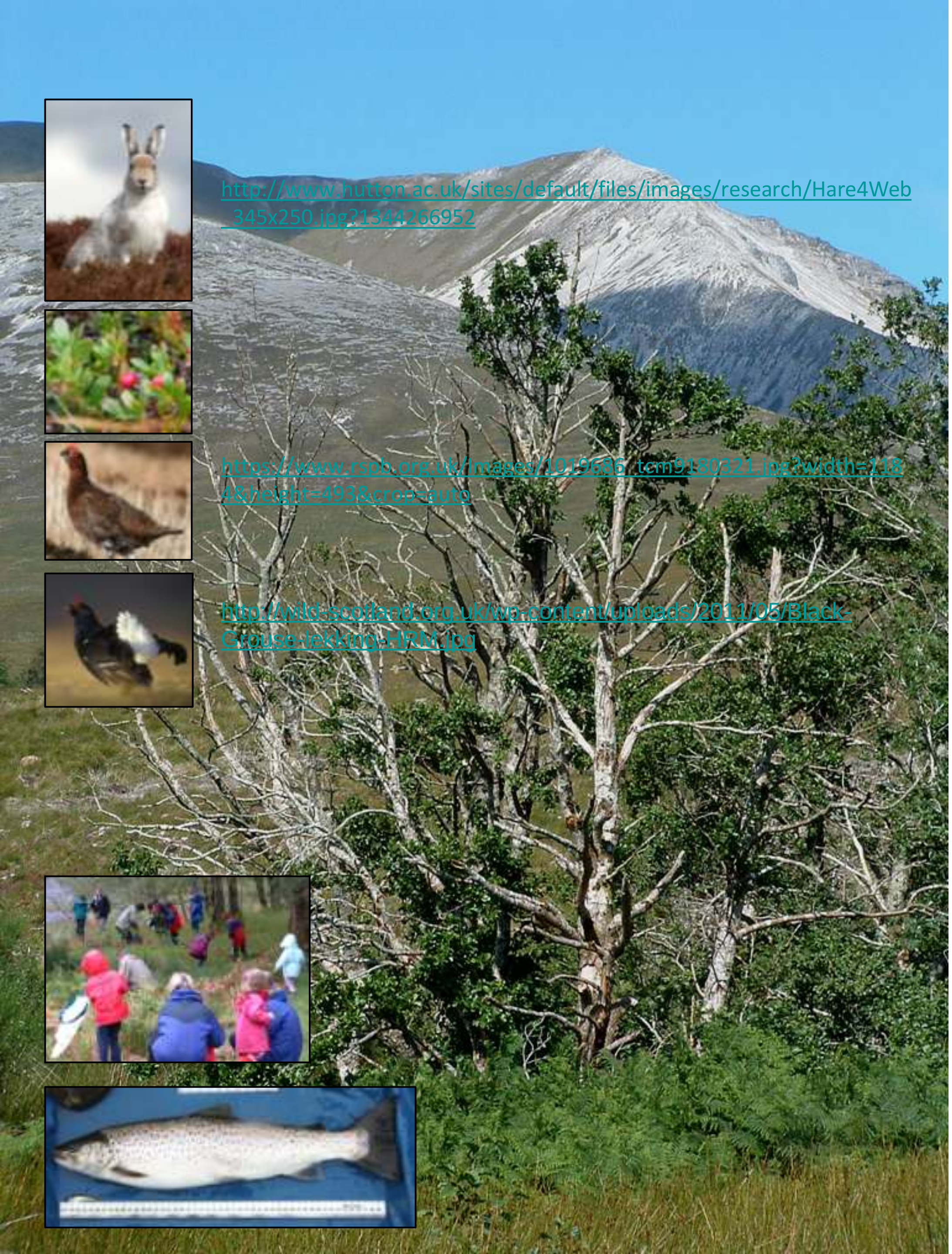


http://seekingalpha.com/article/182522-taking-stock-of-phosphorus-and-biofuels

Phosphorus use in the EU-27 in 2005



http://image.slidesharecdn.com/20160610cas-lmuphosphorusworkshopvandijkv2-160612085109/95/past-present-and-future-phosphorus-use-and-management-in-europe-12-638.jpg?cb=1465721867



Opportunities for new Wester Ross Biosphere?

United Nations Educational, Scientific and Cultural Organization

- ***Develop a clearer understanding of ecosystem nutrition;***
- ***Ecosystem fertility restoration and management studies;***
- ***Demonstration projects to learn and extend information about managing fertility.***
- ***'Think globally . . . (productive landscapes), . . . act locally'.***

Beinn Eighe NNR

Ecosystem nutrition in Wester Ross: conserving & replenishing phosphorus

A little fertiliser, fairly often (not a lot of fertiliser all at once) . . ?

A bit like feeding the birds . . ?

Larachantivore woodland (upper Gruinard) . . .

http://l7.alamy.com/zooms/db5ee27981cc47e59486d73529045ff4/bush-toilet-loo-with-a-view-s15x3n.jpg

Conclusions

•Juvenile salmon production depends upon food availability in most rivers in Wester Ross.

•Phosphorus is the limiting nutrient across much of Wester Ross.

•There has been a decline in the transfer of phosphorus into and across much of Wester Ross; **the landscape and biota are malnourished**.

•**Phosphorus budgeting is needed to rebuild ecosystem fertility at river catchment scales to revive wild salmon populations and other life.**

(big) Gruinard River headwaters

Sheneval bothy at the foot of An Teallach is popular with hill walkers (and salmon poachers!) . . .

Nearby soils are richer in earthworms and support a (?healthy) population of moles . . .

http://www.mountainbothies.org.uk/cust_images/bothy%20images/Shenavall---Alan-Bellis.jpg

These are oak trees!!

(big) Gruinard River headwaters

Sheneval bothy at the foot of An Teallach is popular with hill walkers (and salmon poachers!) . . .

Nearby soils are richer in earthworms and support a (?healthy) population of moles . . .

The stream is green and mossy . . .

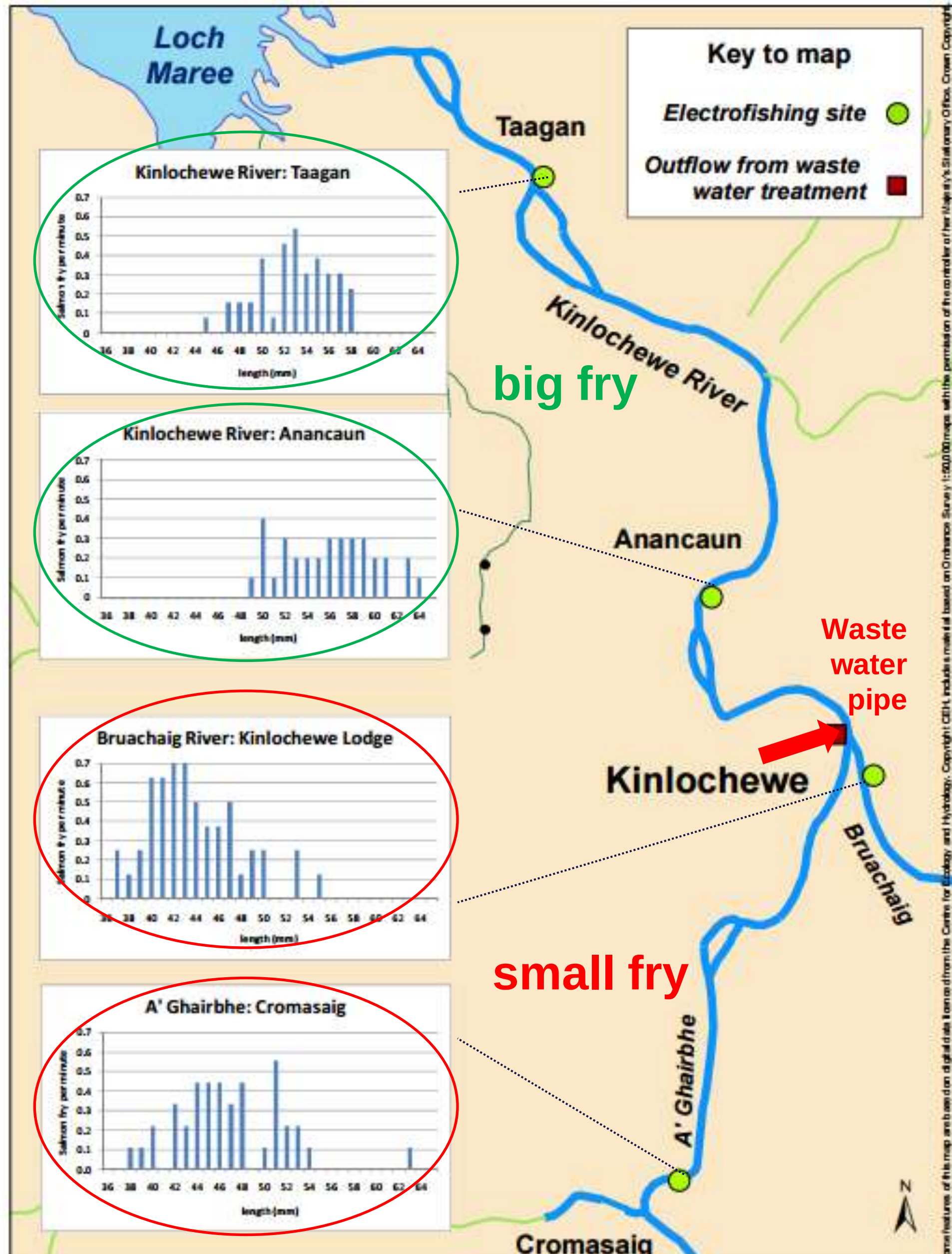
. . . and supports fat, healthy salmon parr . .

Kinlochewe River

Salmon fry grow faster below waste water pipe than above waste water pipe!

Kinlochewe waste water 27 Apr 2011

Figure 2.2 On 12th August 2009 salmon fry at sites in the Kinlochewe River below the waste water treatment work outflow were almost 1cm larger than those in the Bruachaig river just a short distance further upstream. Fry size varied between nearby sites and may be related to both density and to the amount of food available; a little extra nutrient may have led to faster growth!




Thank you
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Good for Ewe
http://www.goodforewe.org/
http://www.thevitruvianman.org/metaphor-on-a-wild-raspberry/