

Refertilising Scotland (part 2)

Peter D. Cunningham , info@wrft.org.uk

27 September 2010

- for wildlife
- for fisheries
- for people

Beinn Eighe N'N'R from Meall nan Tarmachan

Upland areas are not uniformly infertile . . .



Watching an eagle above Beinn Eighe NNR

Biodiversity hot spot, Beinn Eighe NNR



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

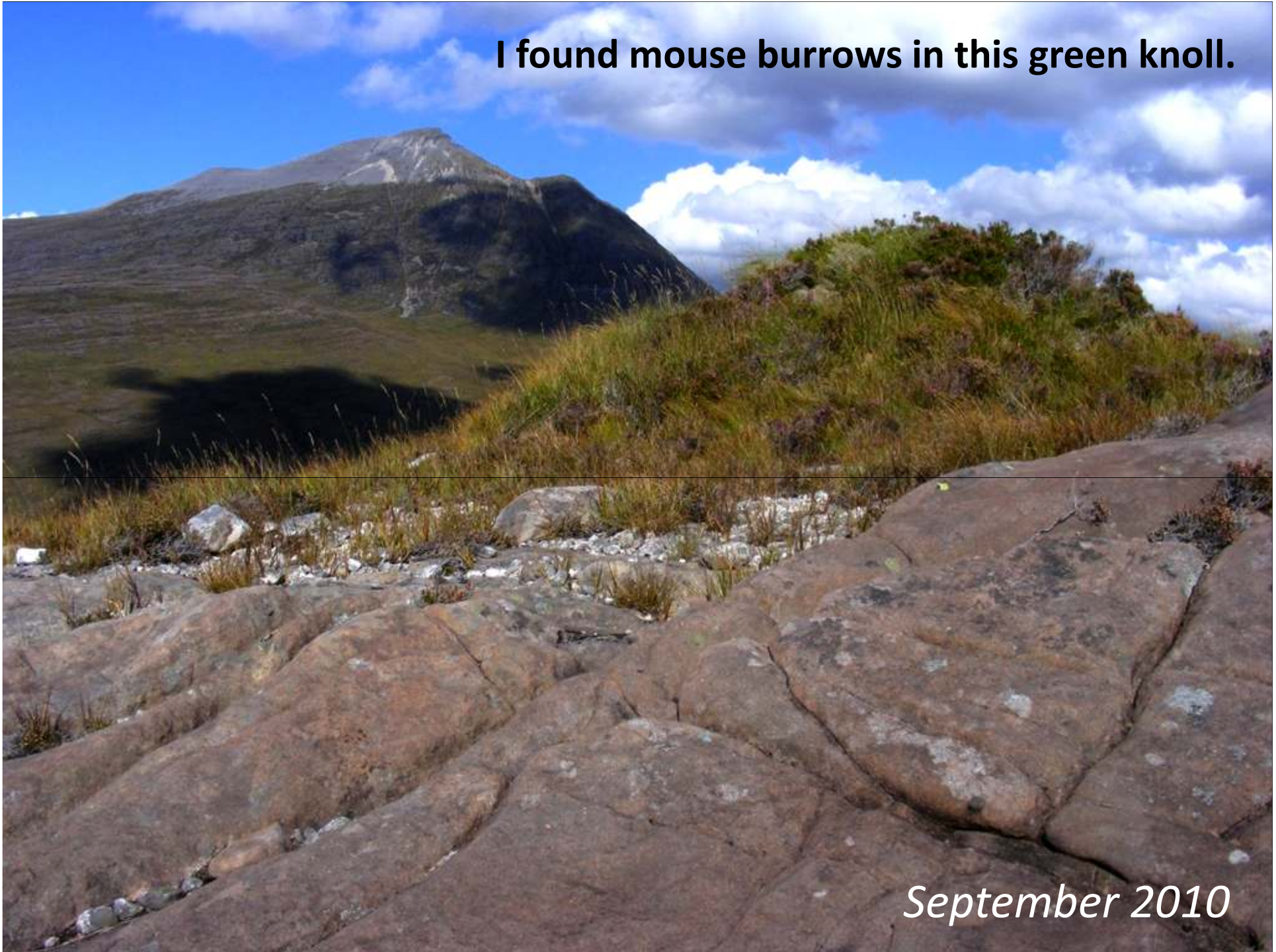


Raptor perch in Beinn Eighe NNR




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

I found mouse burrows in this green knoll.



September 2010

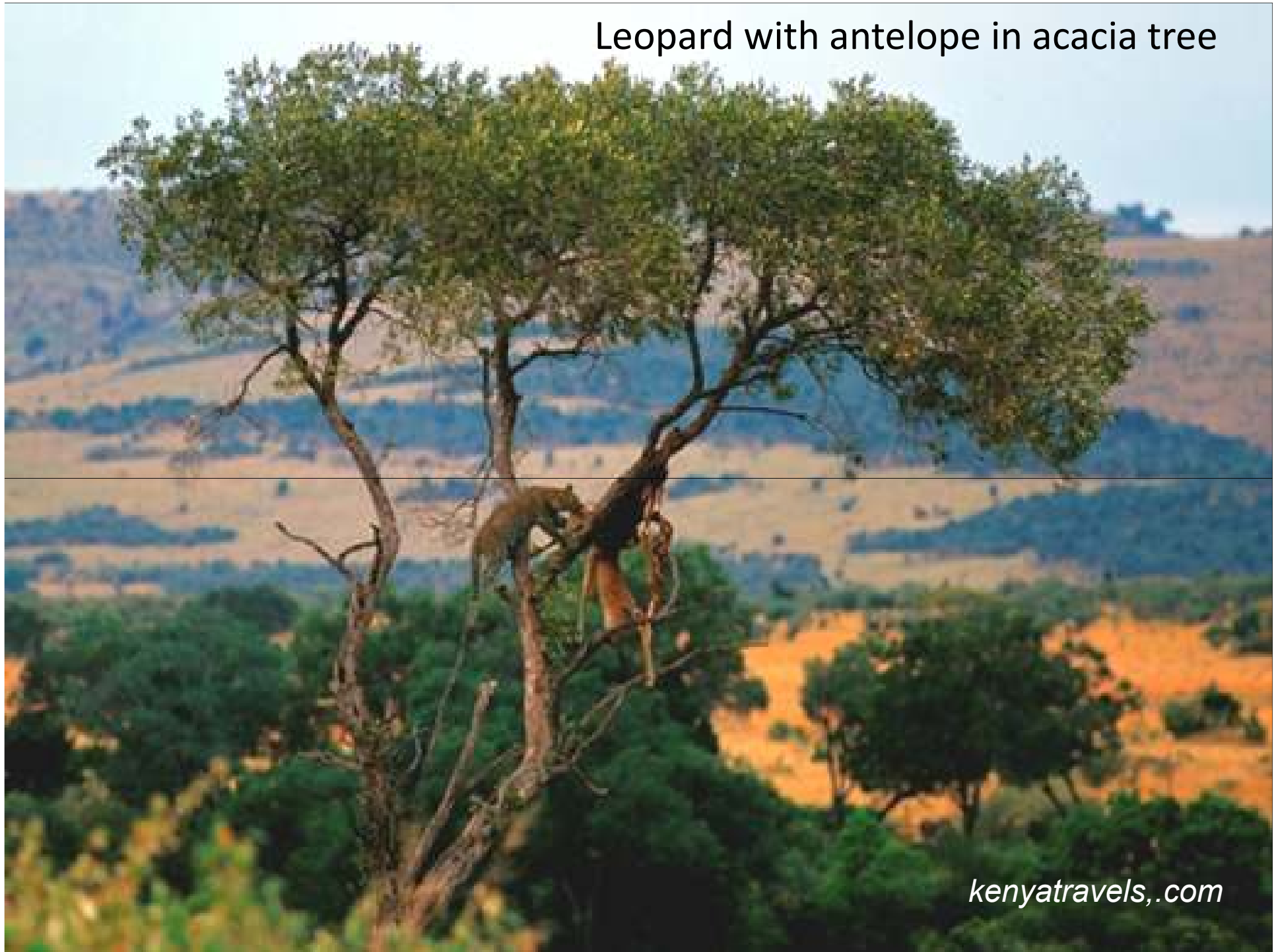
A woman with short brown hair and glasses, wearing a blue jacket, red gloves, and a blue scarf, stands in a field of tall, dry grass. She is looking down at a mossy hummock in the foreground. The hummock is covered in green moss and has several white sheep bones scattered on it. The background shows a vast, open landscape with more grass and some distant hills.

This green hummock near
Gairloch may be used by foxes . .
.note the sheep bones!

**Isolated oak tree, North Erradale
(where crows often perch)**



Leopard with antelope in acacia tree



kenyatravels.com

Happy cows?



Happy hazels?

Why is there a greener patch in the bog?



Bog near Redpoint (2002)



Where nutrients are recycled . . .

. . .from vegetation to sheep, and back to vegetation . . .

- *growth of plants - and insects - can be prolific*
- *more insects: more food for trout , salmon, birds . . .*

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



Fionn Loch islands, Little Gruinard catchment.



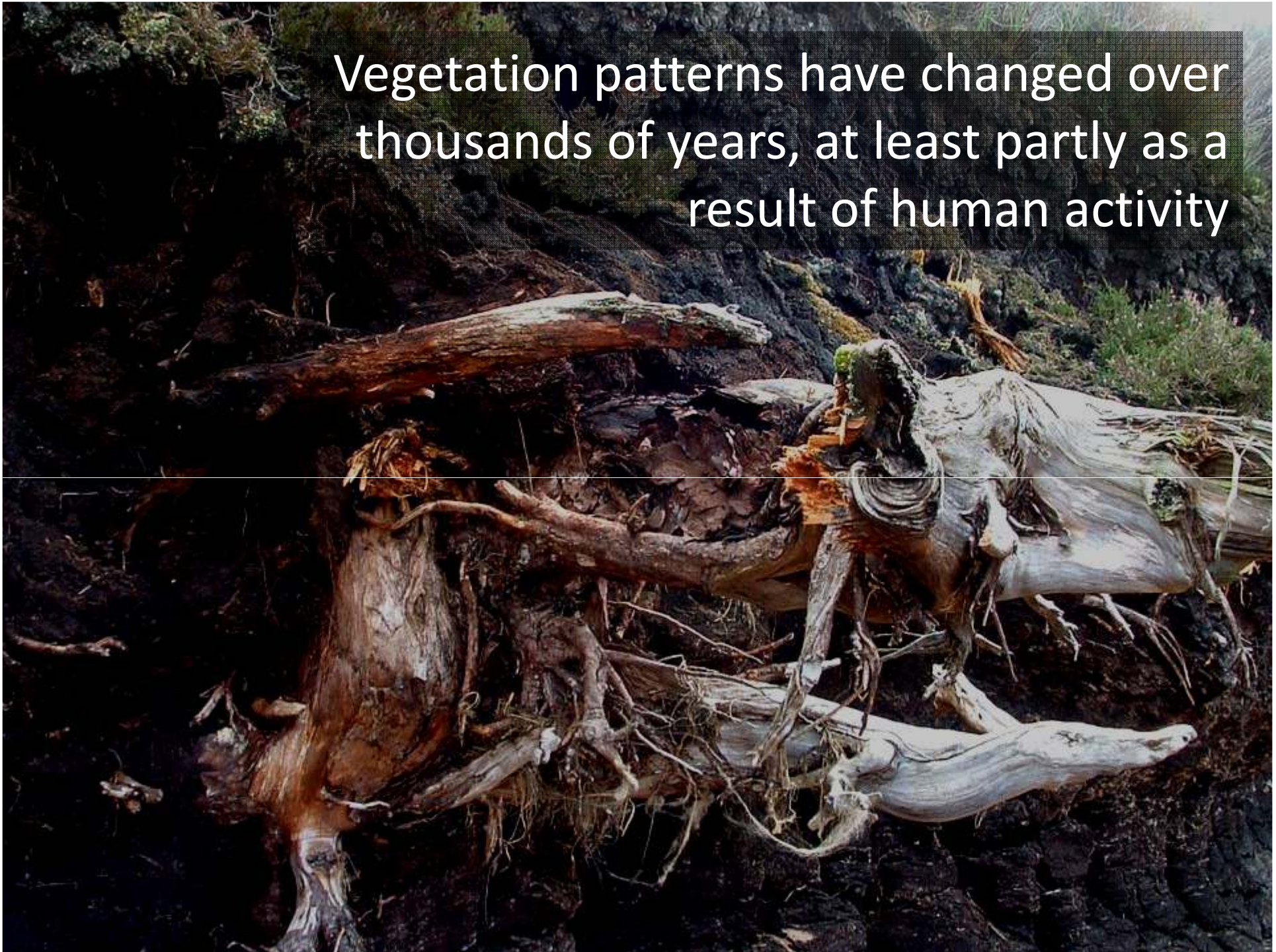
Have fertility levels changed as a result of land use and wildlife management practices?



How have fertility levels and patterns changed as a result of land use and wildlife management practices?



Vegetation patterns have changed over thousands of years, at least partly as a result of human activity



Human populations were higher in the past in some areas



Derelict cottage, Glen Torridon



September 2010

nettles

ARKive



© www.osfineges.com



Hillsides have been burnt to promote fresh growth.

Rainwater washes nutritious ash away.



Little Gruinard River, May 2010 (inside fenced enclosure)

Wildfire in 2007



A forest on a boulder



Human impacts affecting fertility (over 1,000s of years)

- extirpation of top predators (wolves, bear)
- destruction of forests
- burning vegetation
- heavy grazing pressure (cattle, sheep, deer)
- migration of people from Straths

= cultural oligotrophication ?

Soils, ecosystem fertility & salmon smolt production in Wester Ross

1. Much of **Wester Ross** is underlain by hard, insoluble Lewisian gneiss, Torridonian sandstone or Moine granulite, yielding very **little nutrients**.

2. **Soil fertility** is therefore dependent upon the retention and cycling of nutrients, particularly phosphate, through the **ecosystem**.

14. Increasingly **heavy rain leaches nutrients from soils** and washes away ash from fires. Spates erode away the richest riparian soils notably where alder trees have died back.

13. **Heather burning** is carried out to convert woody matter to ash, thereby releasing nutrients to promote the growth of grasses and other leafy matter for grazing deer or livestock.

5. Historically there were **bears and wolves**. Wolves eat deer, ingesting bone and recycling phosphates.

7. Look for **wee green knolls** in the peatlands where birds and mammals have enriched the soil: note the increased plant growth and biodiversity.

3. Unlike many rivers in the east of Scotland, there is **little human habitation** within the catchments of local rivers so little added nutrient from human sources.

4. **In the past** there were more **people** living in river catchment areas. Without modern sanitation, they **contributed to nutrient recycling**.

6. **Peat** has formed where sphagnum moss smothers the ground, acidifying the soil and preventing aerobic decomposition.

10. Given sufficient phosphate (e.g. bone meal in mammal faeces), **Alder trees** grow in symbiosis with symbiotic nitrogen-fixing bacteria, further enriching riparian soil fertility.

11. Most plants develop **mycorrhiza networks** with symbiotic fungi which deliver phosphate to plant roots in exchange for carbohydrate.

8. Similar green patches are found along river banks where otters defecate. In the autumn, these **otter 'spraint sites'** may contain salmon bones.

15. Growth of **periphyton** is faster where the streambed is stable and stream fertility is naturally high.

12. **Earthworms** help to recycle and retain organic matter and increase the porosity of riparian soils.

In some areas invasive **New Zealand flatworms** have reduced earthworm populations, displacing **moles** with adverse consequences for soils.

17. **Salmon parr** growth rates are highest where the food supply is richest. Over-winter survival and smolt production may depend upon the supply of mayfly and caddisfly larvae.

16. Flat-headed 'Heptageniid' **mayfly larvae** scrape periphyton from the streambed. Other mayfly and **caddisfly larvae** gather or filter organic detritus including leaf and periphyton fragments.

18. **Well-nourished smolts** are better prepared for life at sea than emaciated smolts.

9. **Adult salmon** deliver nutrients of marine origin to headwater streams especially if their carcasses are scavenged by other animals.

Break – any questions ?

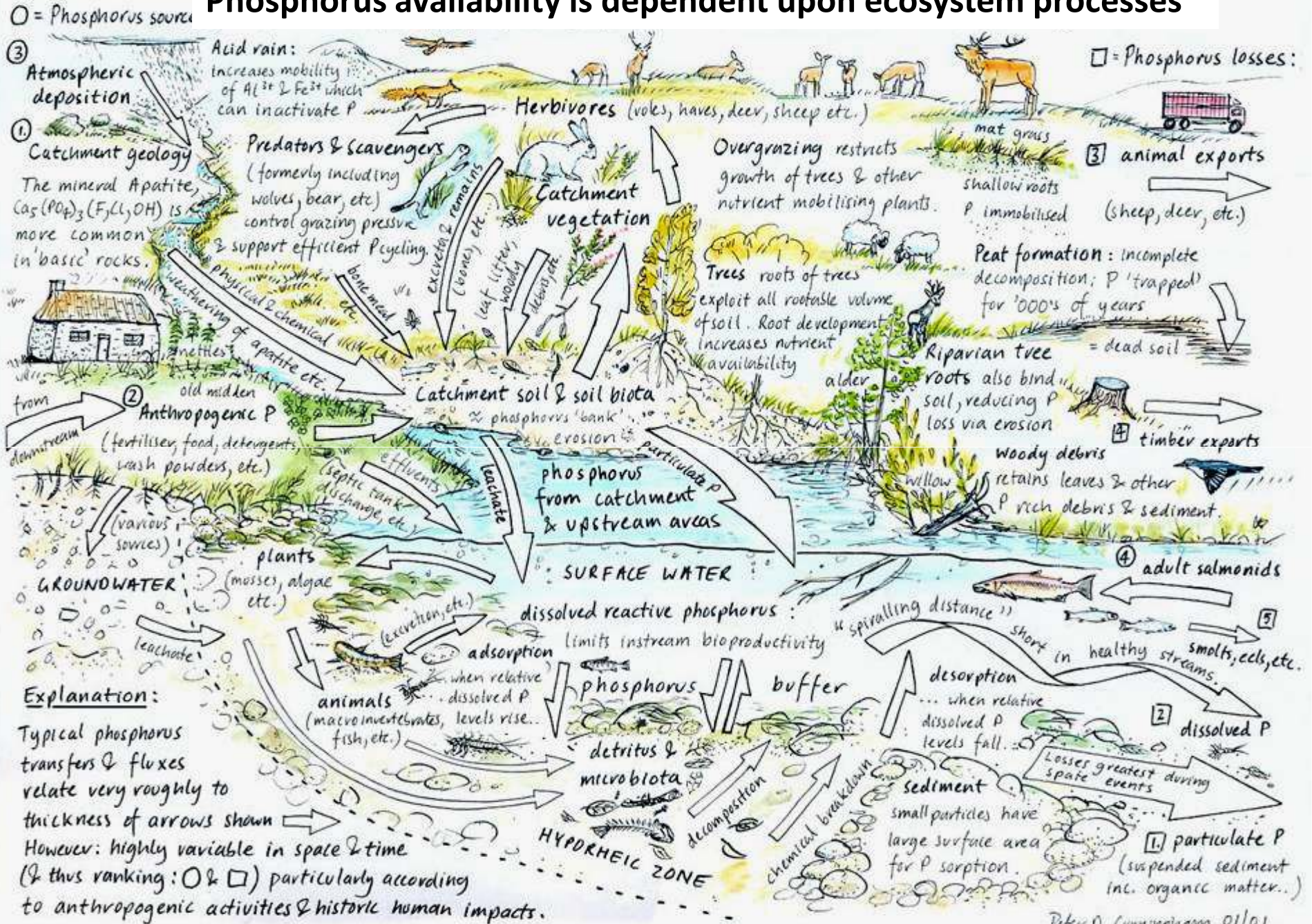


Biological productivity in Wester Ross is primarily limited by the availability of phosphorus, P

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



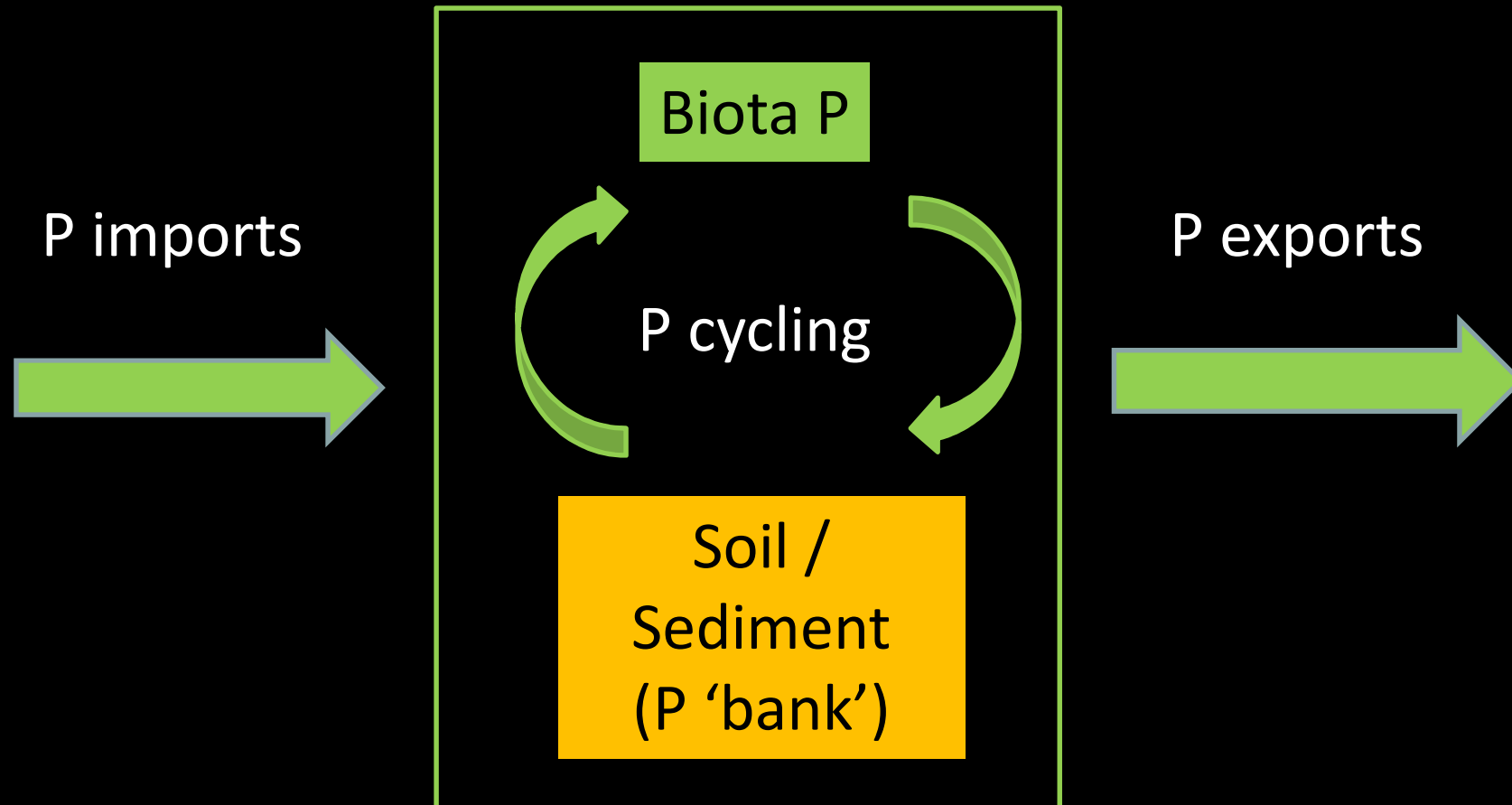
Phosphorus availability is dependent upon ecosystem processes



Some definitions:

- **Soil fertility:** the ability of a soil to supply plant nutrient
- **Nutrient flux:** rate at which nutrient passes through an ecosystem
- **Ecosystem fertility:** the ability of an ecosystem to circulate life sustaining nutrients to its component parts (?)

Simplified Phosphorus budget model:



Ecosystem

(can be what ever scale you choose)

Phosphorus budget

P imports



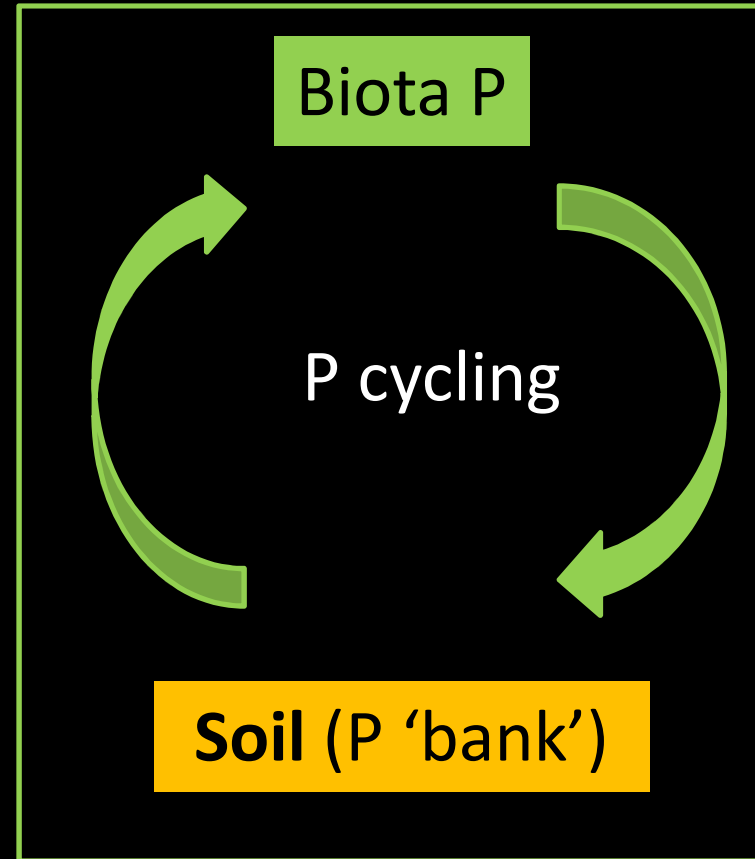
Anthropogenic
(food, fertiliser,
detergents, etc.)



Physical and chemical
(atmospheric deposition,
rock erosion)



Biological
(wild plant and animal
materials)



P exports



Anthropogenic
(livestock, crops,
timber, effluents, etc.)



Physical and chemical
(erosion and leaching)



Biological
(wild plant and animal
materials)

Ecosystem

Rainforest

Tropical Rainforest

P imports

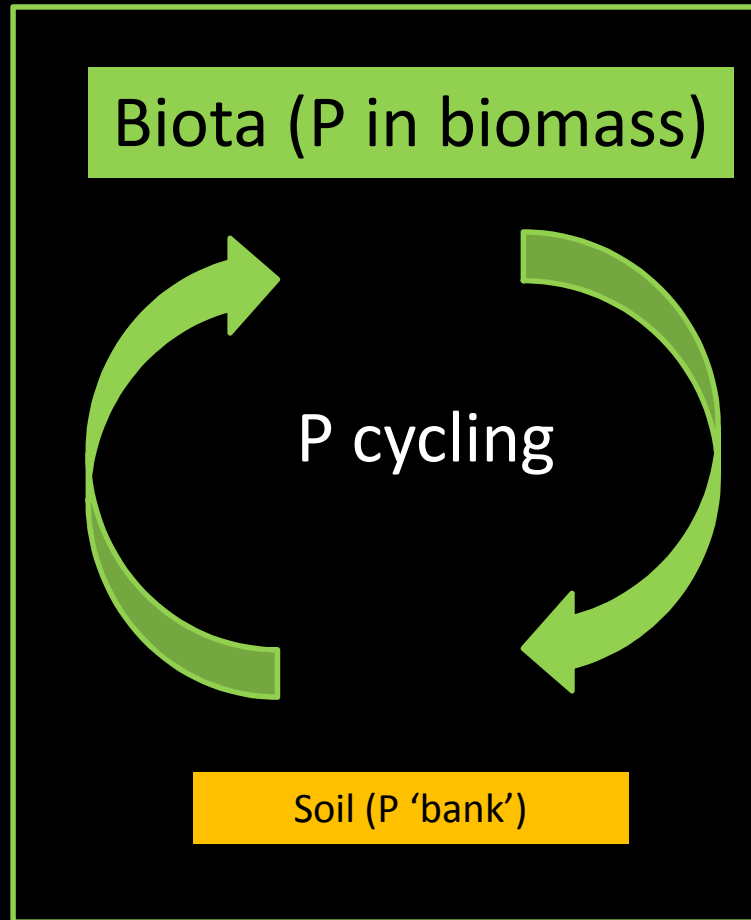
Anthropogenic



Physical and chemical
(atmospheric deposition,
rock erosion)



Biological
(wild plant and animal
materials)



P exports

Anthropogenic



Physical and chemical
(erosion and leaching)



Biological
(wild plant and animal
materials)

Ecosystem: highly
evolved & biodiverse

Cleared tropical Rainforest



Jungle clearance Sarawak

Cleared tropical rainforest (e.g. for oil palm)

P imports



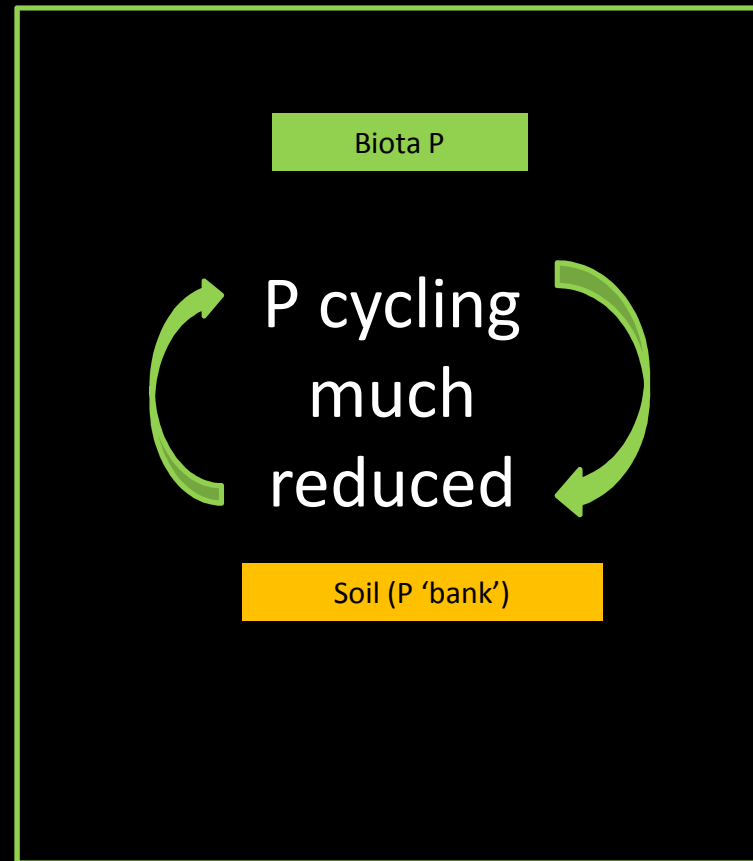
Anthropogenic
(food, fertiliser,
detergents, etc.)



Physical and chemical
(atmospheric deposition,
rock erosion)



Biological
(wild plant and animal
materials)



Ecosystem:

biodiversity collapses

P exports



Anthropogenic
(carcasses, crops,
timber, effluents, etc.)



Physical and chemical
(erosion and leaching)

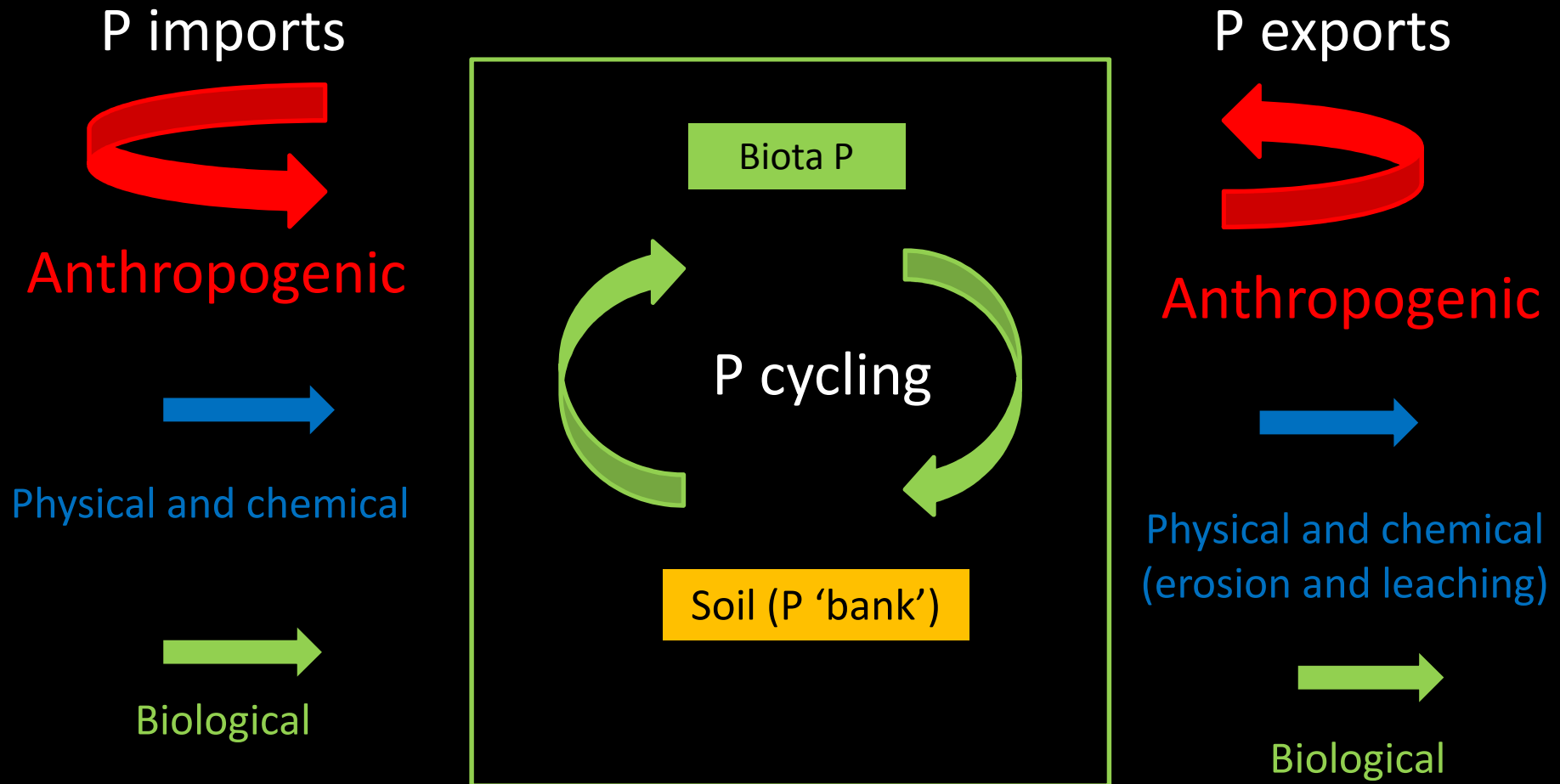


Biological
(wild plant and animal
materials)

Traditional agriculture



Traditional agricultural area



Agricultural Ecosystem: people are a part of the system

Nearly all crofts were cultivated 100 years ago,
using lime, manure and sea weed as fertiliser

Alltgrishan common grazings . . .

Melvaig crofts

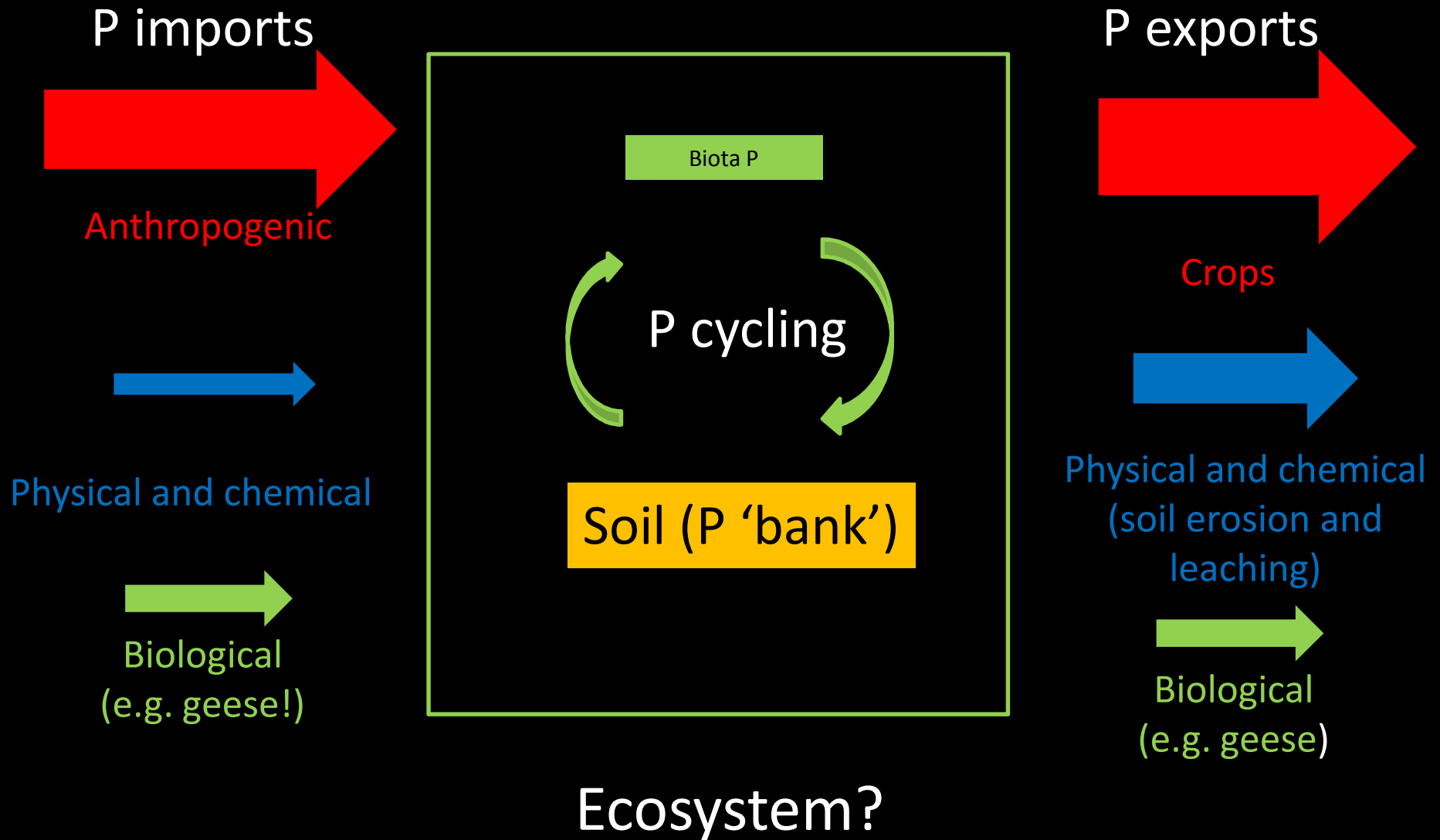
Although cattle and sheep are still exported each
year, little fertiliser has been used in recent years

Intensive agricultural area



Andy Hay (rspb-images.com)

Intensive agricultural area



Beinn Eighe National Nature Reserve





How 'natural'?



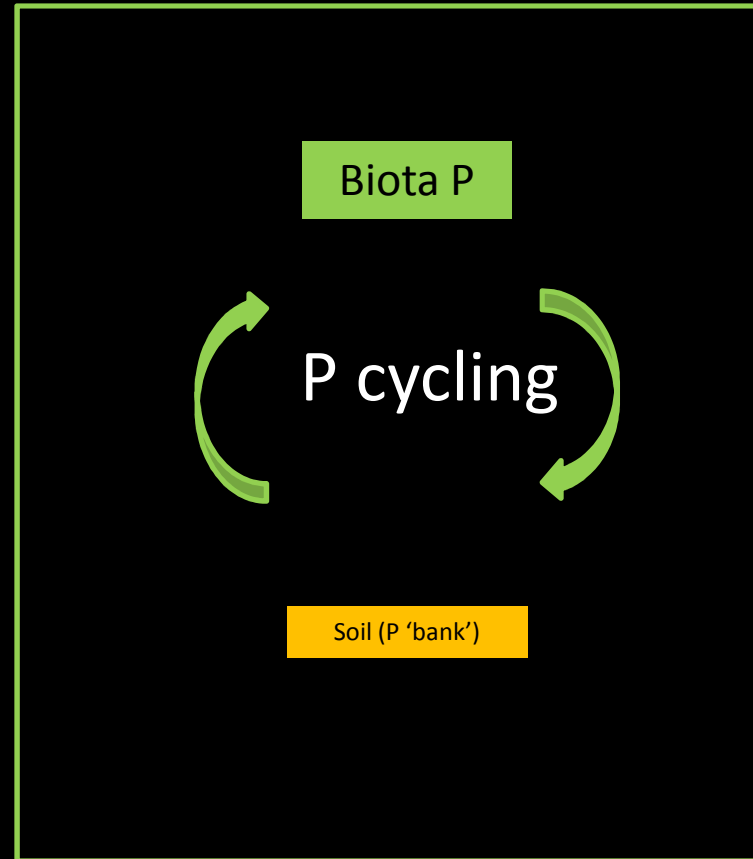
Beinn Eighe mountainside

P imports


Anthropogenic


Physical and chemical
(unyielding quartzite)


Biological



P exports

Anthropogenic


Physical and chemical


Biological

Ecosystem
impoversihed

Fertilisation trials were carried out on Beinn Eighe NNR in the 1950s by Donald McVean to find out how to enhance soil fertility and establish tree seedlings.



Fertilised area

Unfertilised area

Details are sketchy, but 50 yrs on, results can still be clearly seen.

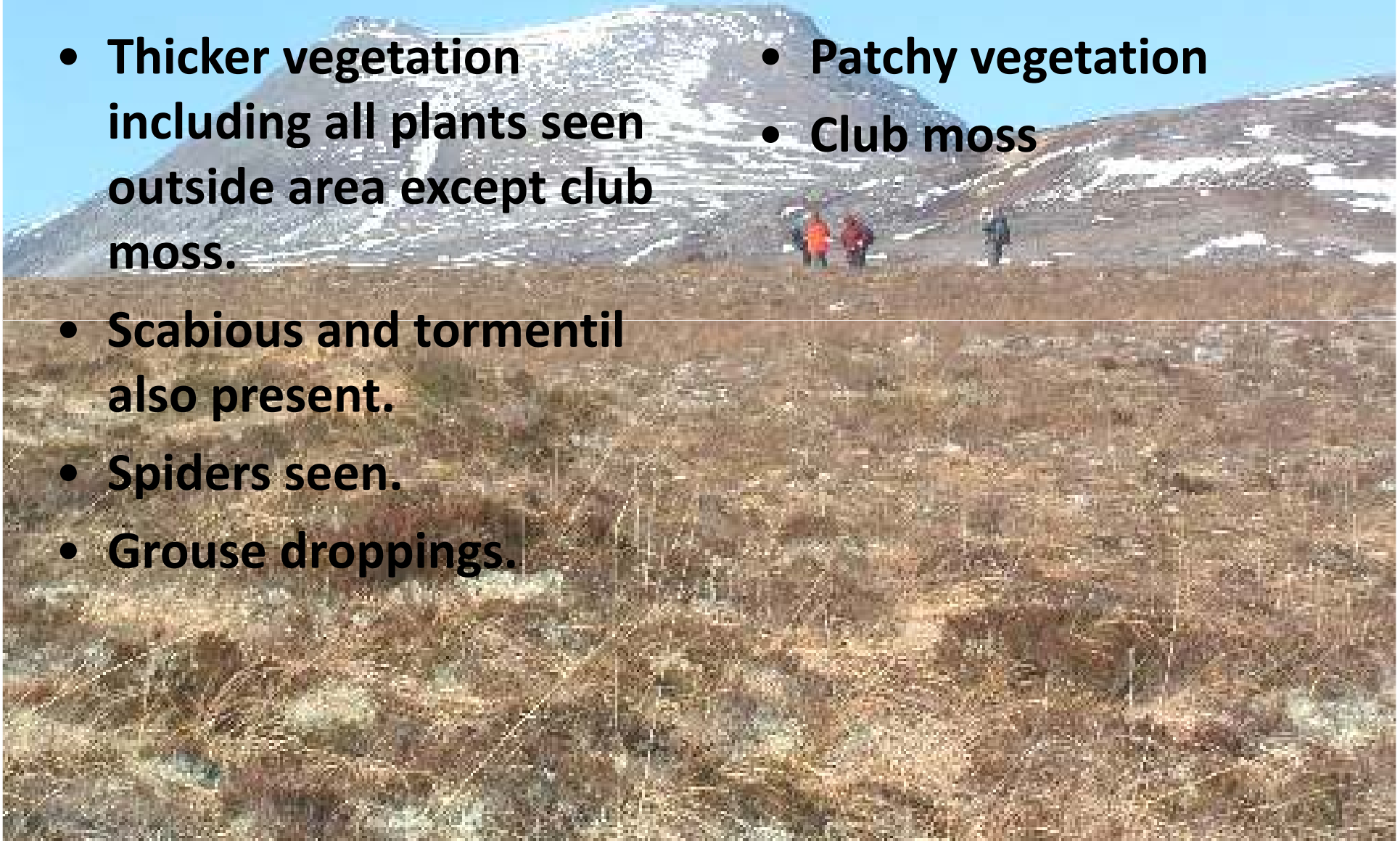
Looks like the trial was successful??

Inside area fertilised

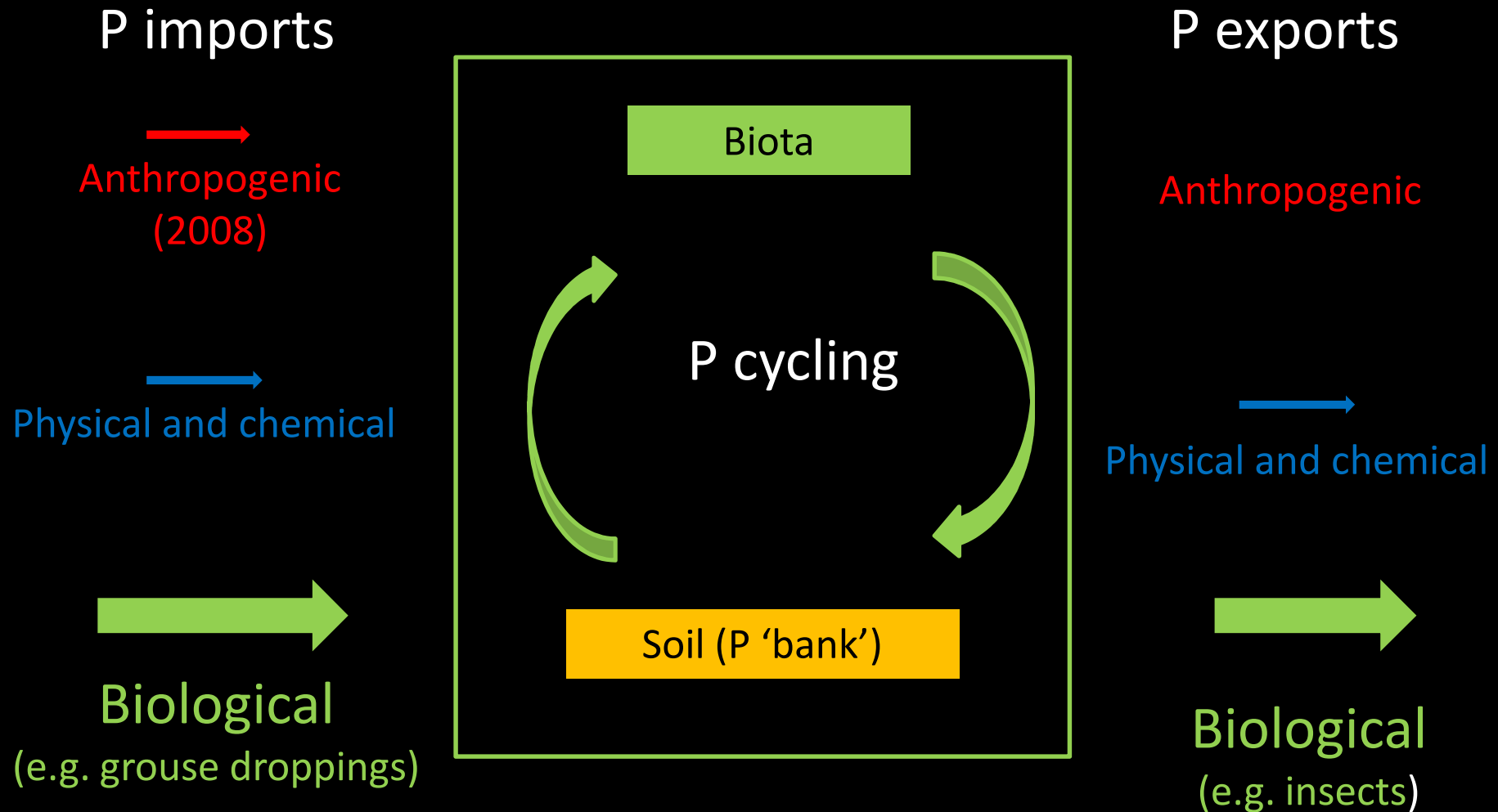
- 100% soil cover
- Thicker vegetation including all plants seen outside area except club moss.
- Scabious and tormentil also present.
- Spiders seen.
- Grouse droppings.

Outside area fertilised

- ~50% soil cover
- Patchy vegetation
- Club moss



Inside fertilised area (50+ years following fertiliser application)



Ecosystem enriched:
higher productivity and higher biodiversity . . .

Outside fertilised area

P imports



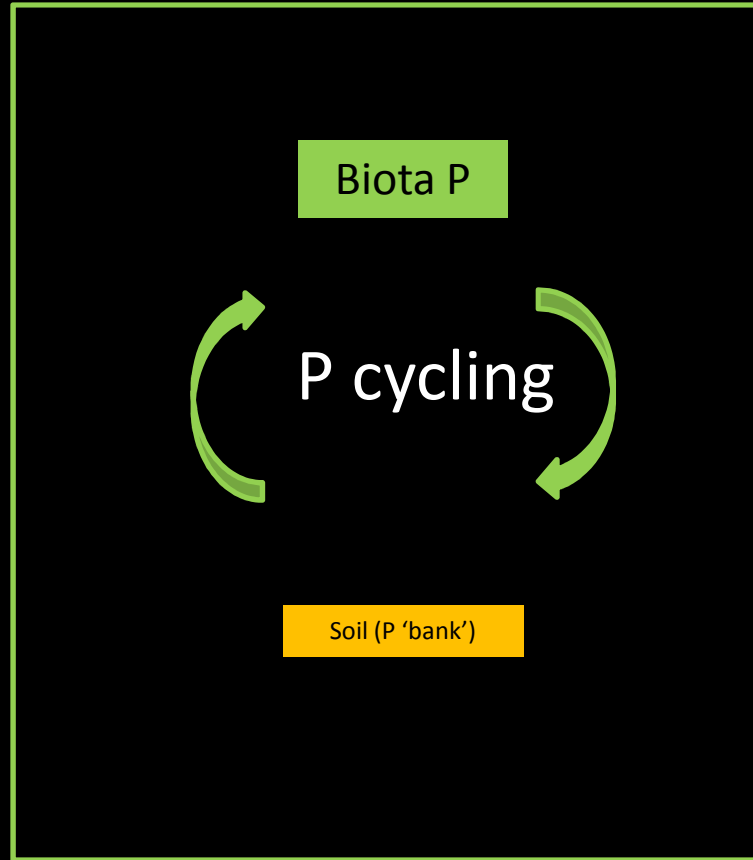
Anthropogenic



Physical and chemical
(unyielding quartzite)



Biological



P exports

Anthropogenic



Physical and chemical

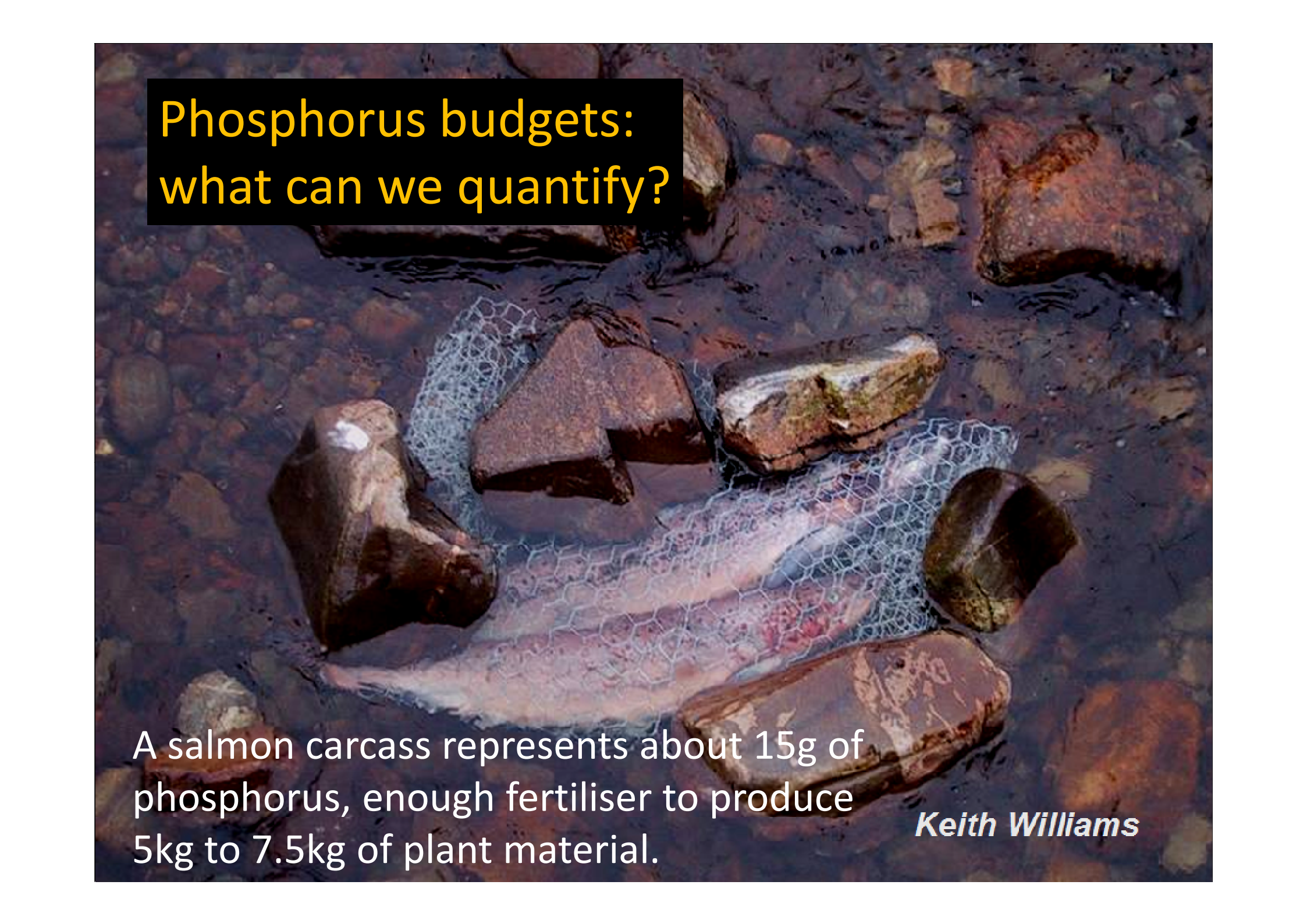


Biological

Ecosystem
impoversihed

. . . c. green knoll

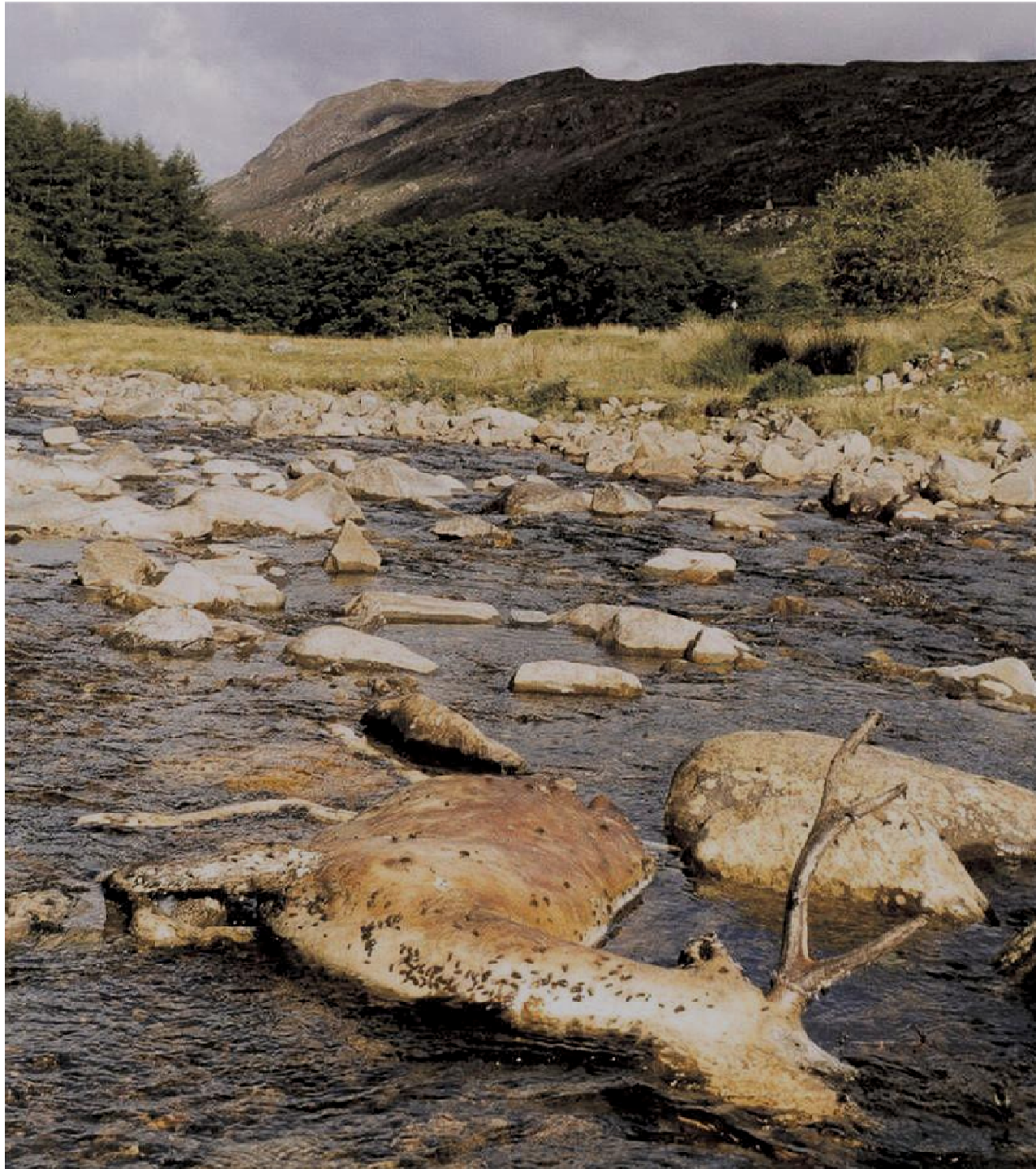


A photograph of a salmon carcass lying on a white mesh net in a stream, surrounded by dark rocks. The text is overlaid on the image.

Phosphorus budgets: what can we quantify?

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

Keith Williams



A deer carcass contains ~1 kg of phosphorus, mainly in bones.

Phosphorus budgets

200 salmon carcasses contain 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

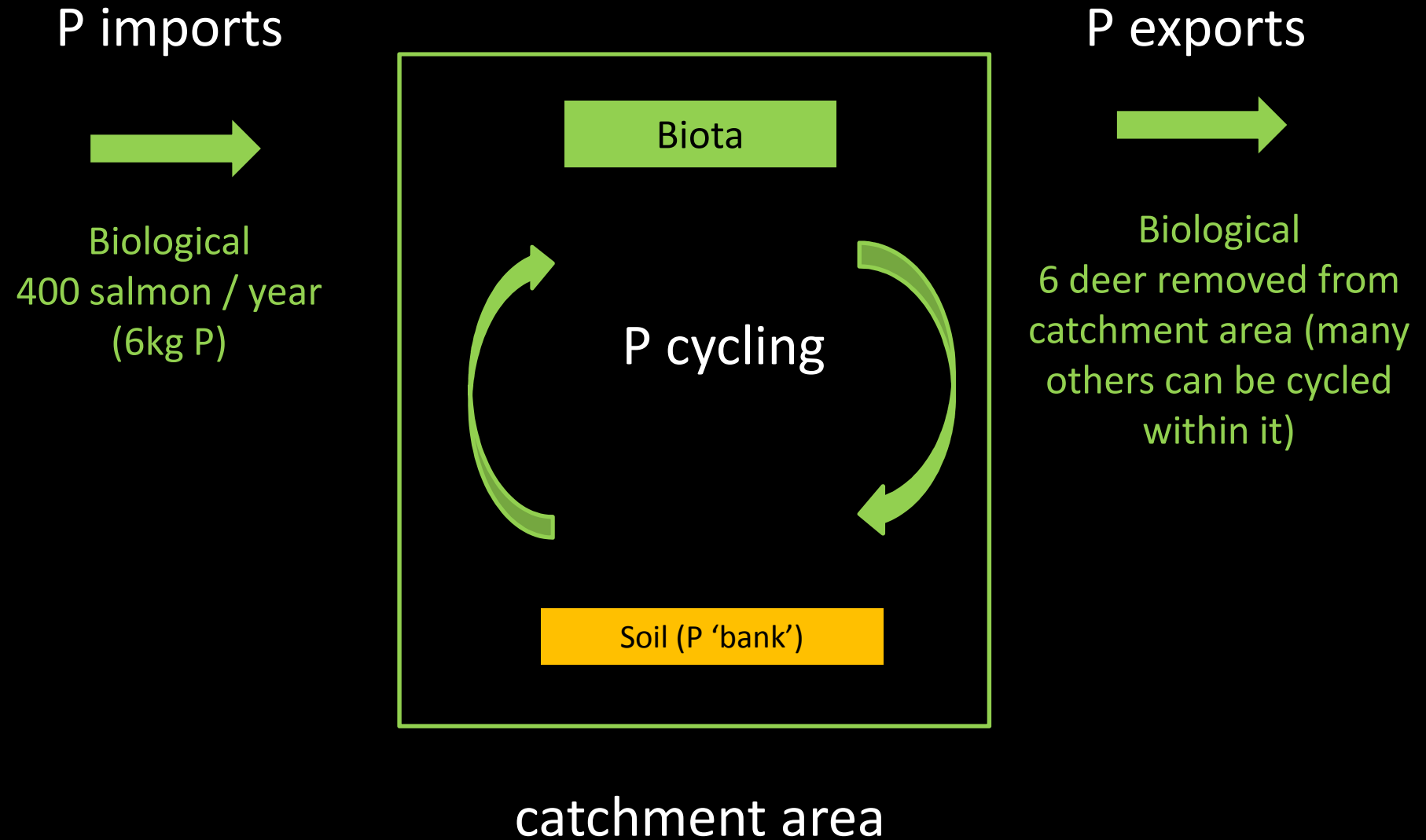
or



x 3

= ~ 3kg of
Phosphorus

'Biological' P budget model, e.g.



Break – any questions (or answers)?





What would happen
to deer populations
if they were not
culled?

Trees for Life:
Dundreggan

July, 2010

**No traces of highest carcasses
(search error or completely scavenged?)**



Only tufts of skin from middle carcasses



Picked skeleton of lower carcasse – knawed bones strewn around





Maggot infested remains of carcasses nearest path







How would wolves and bears affect carcass location and recycling of nutrients in more natural situation?



(Dundreggan boar: scrunch bones)

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

How many animals have been removed over past 100++ years?

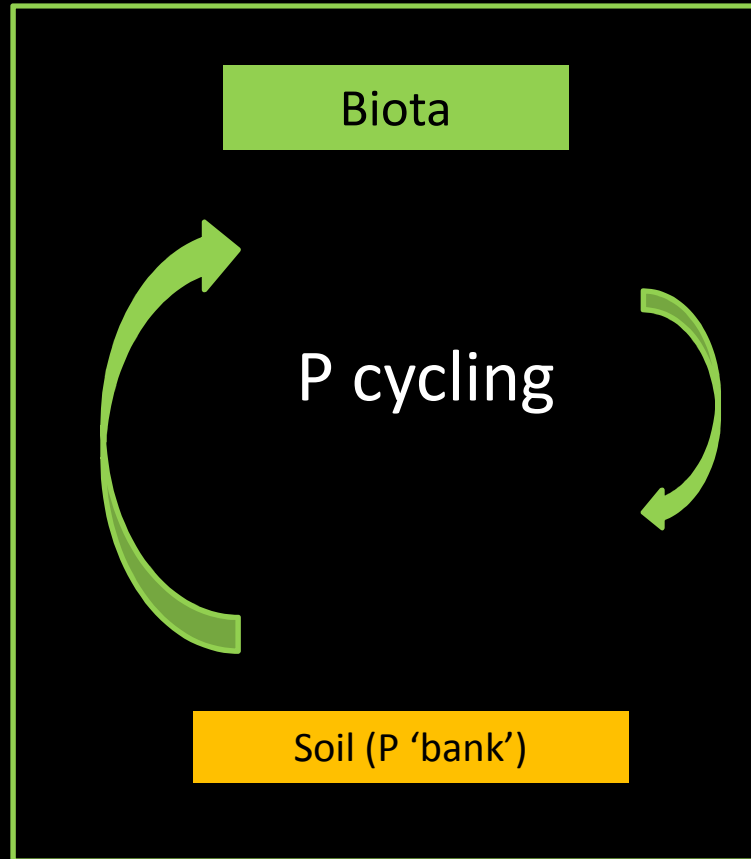
How much nutrient has been returned to the areas where the animals grazed?

imbalanced system

P imports



Biological
100 salmon / year
(6kg P)



P exports



Biological
20 deer removed from
catchment area (20kg P)

catchment area becomes
phosphorus depleted

Red Deer

Milner *et al* (2002): A Highland Deer herd and its Habitat

- **Carcasses left on hill.** . improve efficiency of cull, carrion feeding beetles; vertebrates: foxes, badgers, shrews, ravens, golden eagles, sea eagles and hooded grows.
- **Vegetation [after decomposition of carcass]** had significantly higher nitrogen ; additional nutrient input associated with whole carcass. . Leaving carcasses on hill may therefore benefit grazing animals by enhancing the nutrient content of forage . . . Mineral concentrations are likely to increase as bone material degrades and bones provide an important source of calcium and other minerals for deer.

Conclusions 1

- There is considerable variation in ecosystem fertility in space and time.
- Human impacts greatly affect ecosystem fertility both directly (e.g. application of fertiliser) and indirectly (e.g. extinction of top carnivores, export of livestock).
- Impacts can be positive and negative.

Conclusions 2

- Some parts of Scotland were more fertile, more biodiverse, and more productive in the past than they are at present. How much?

Recommendation

- A case can be made for ‘ecological fertilisation’: the gradual restoration of nutrients to areas from where nutrients have been lost, to restore soils, enhance biodiversity and biological productivity.
- Ecological fertilisation should mimic the natural patterns and rates of nutrient transfer that would have existed within the Scottish landscape in the past.

Revitalisation: restoring ecosystem fertility to support biodiversity and mankind.



Gairloch Estate: Balle Mor
native woodland restoration

Some estates have already developed enclosed woodlands to stabilise streams and enhance food availability.



WGS enclosure, Coulin Estate (headwaters of River Ewe)

**It's not just about fertilising soils to
grow trees . . .**

Ground Rock Phosphate fertiliser
applied initially at 125g / tree

Note grass growth



Application rates
should be carefully
considered . . .

Filamentous algal matt below WGS scheme,
Balgy catchment, Sept 2010





Opportunities at Beinne Eighe NNR:

- **Soil and fertility restoration**
- **Trophic (phosphorus) pathways**
- **Ecosystem restoration (or management)**
- **‘Think globally (productive landscapes), act locally’**
- **Demonstration area for local land and wildlife managers to maximise ‘natural’ productivity.**

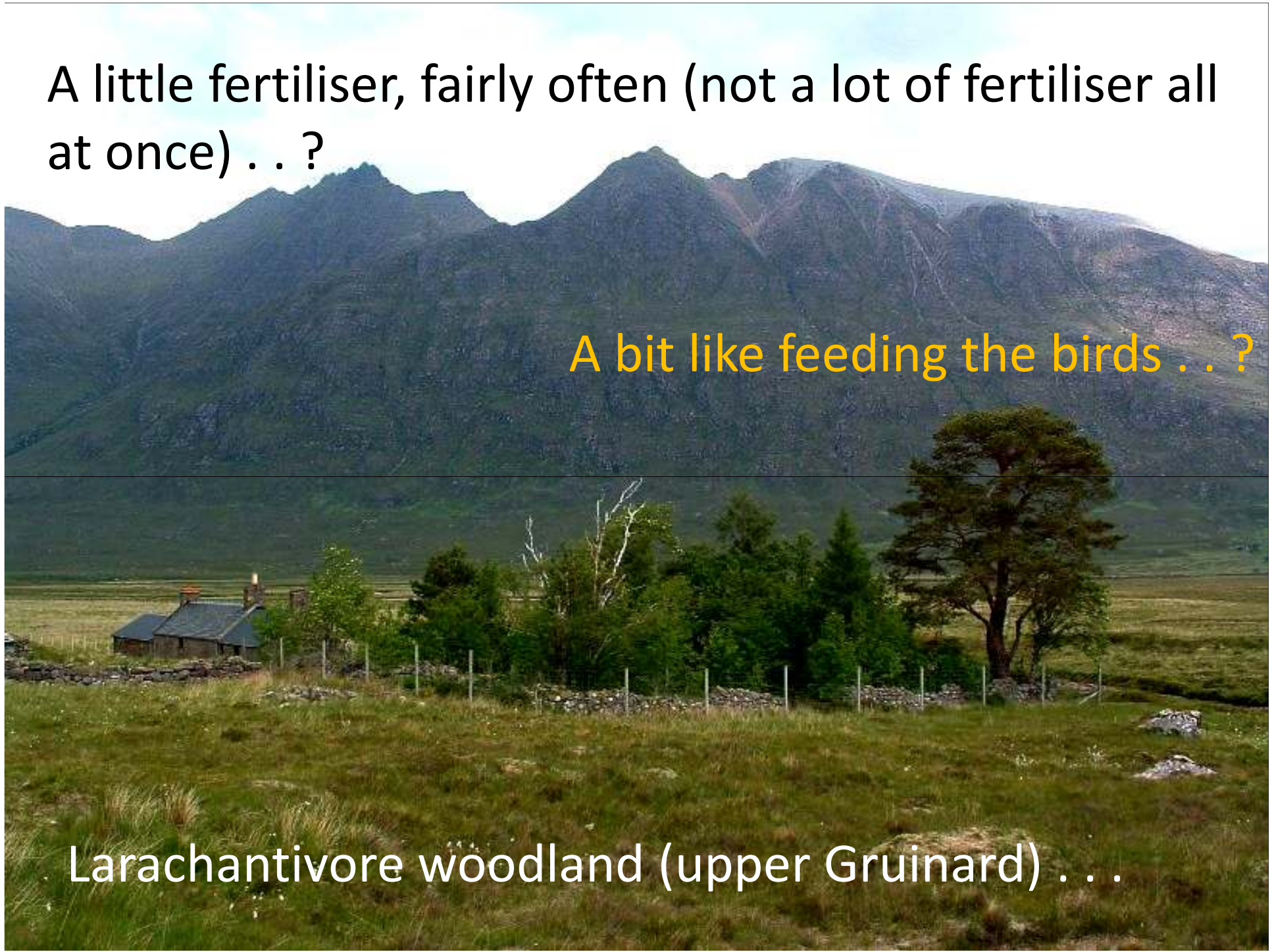
Beinn Eighe NNR and surrounding estates are ideally placed to make an important contribution to national and international efforts aimed at developing and demonstrating ways of reversing ecosystem-degradation processes currently progressing at alarming rates in many other parts of the world.

This is a challenge which we should invest in: levels of 'semi-natural' biological productivity over much of Scotland and elsewhere in the world could be, should be, and may need to be much higher.

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

A bit like feeding the birds . . . ?

Larachantivore woodland (upper Gruinard) . . .





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 . .

These are oak trees!!



Sheneval
bothy

'Ecological refertilisation'



Thank you