Morphological responses of powan to a conservation translocation.

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Powan (*Coregonus lavaretus*)

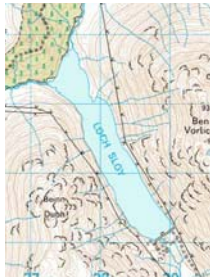
- Seven land-locked populations in Britain, remnants of an invasion after the last ice age.
  - Two native Scottish populations: Loch Lomond and Loch Eck.
    - Two refuge populations have been established from the Loch Lomond powan:
    - Loch Sloy and Carron Reservoir.

- Importance of conserving Scottish powan
  - Increasing pressures on Loch Lomond and Loch Eck
    - Recreational use of loch, eutrophication, introduced species.
  - Unlike populations in Europe, Powan are not exploited commercially, and so are ideal for ecological studies.
  - Powan in Scotland exist in distinctive fish assemblages.
    - Loch Lomond is species rich and contains a unusual form of the river lamprey that feeds in freshwater.

Aims

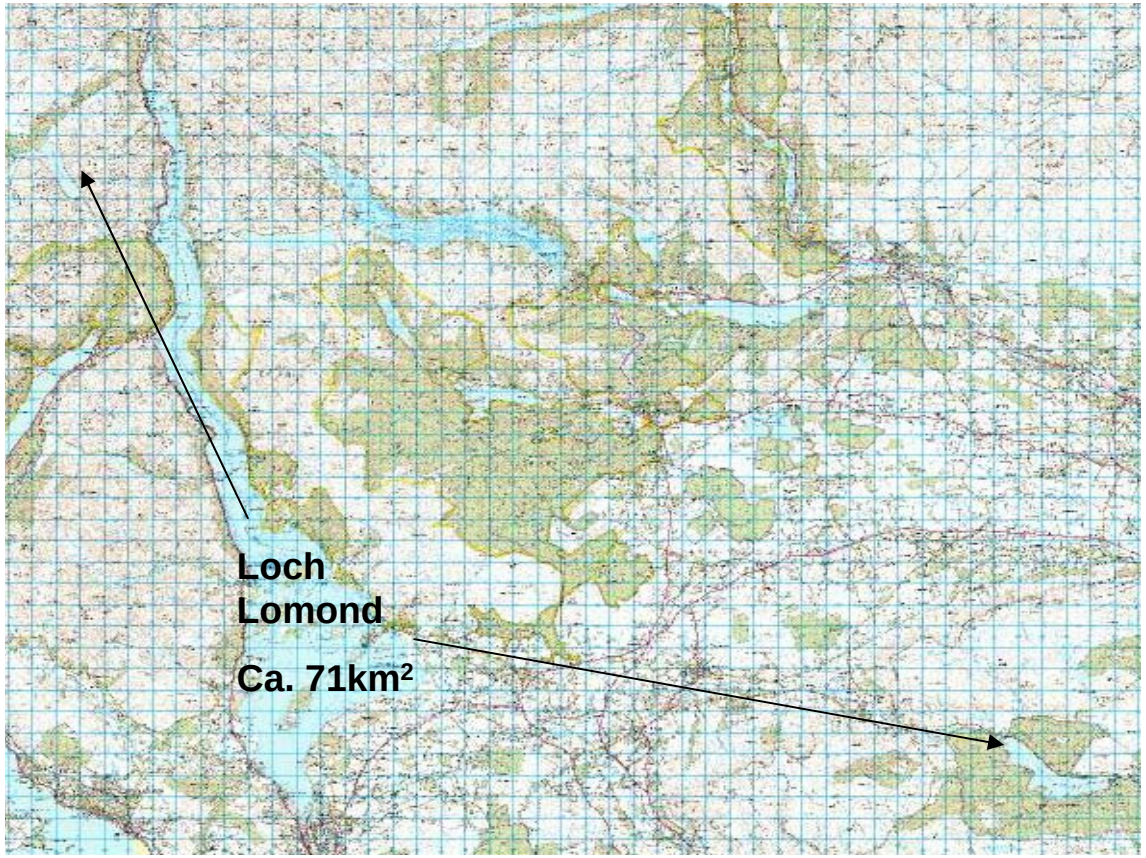
- Additional refuge populations are likely to be required for powan and closely related species in the UK
- Potential of responses to translocation to interfere with the aims of the conservation measure
  - To preserve the population as they are
  - Preserve/Increase genetic variability - local adaptation
  - However, if a refuge population becomes highly adapted - reintroduction or supplementation becomes difficult.
- What responses are found in translocated powan populations
  - Size and growth
  - Morphometrics
- Null hypotheses
  - There are no significant differences between:
    - Loch Lomond powan and Loch Sloy powan
    - Loch Lomond and Carron Reservoir powan
    - Loch Sloy and Carron Reservoir powan

Study sites



Loch Sloy

Ca. 1km²

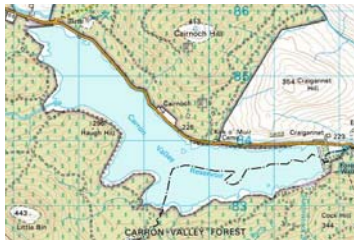


Loch Lomond

Ca. 71km²

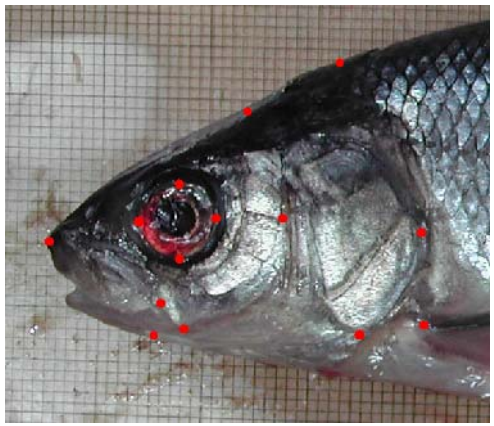
Carron Reservoir

Ca. 3km²



Methods

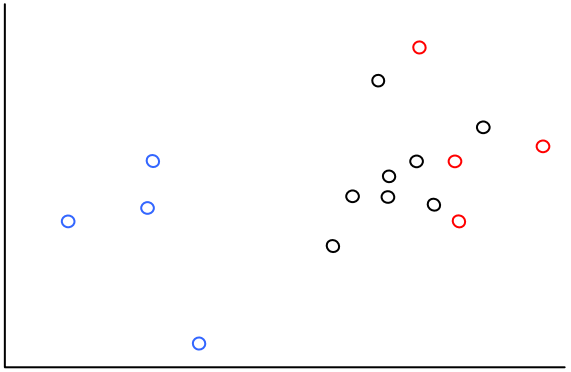
- Multi-mesh gill nets set overnight
- Winter 2005/06
  - Loch Lomond - 75 gill nets set from 9th Nov to 24th Jan
  - Loch Sloy - 7 gill nets set from 21st Dec to 28th Dec
  - Carron Reservoir - 10 gill nets set from 3rd Jan to 5th Jan



- Measurements taken from individuals
  - Fork length (Lf)
  - Weight (W)
  - Aged from scales
- Morphometrics
  - Digital photographs taken of the fish
  - Pictures of 40 individuals from each site chosen which showed good detail of the head.
  - 14 landmarks were chosen that could be identified in each picture
  - TPS software to analyse

Thin Plate Spline (TPS)

- TPS is a landmark based geometric technique.
  - Excludes the effect of size and so describes shape variation only
  - Shape remains integrated throughout the analysis – easier to visualise shape change

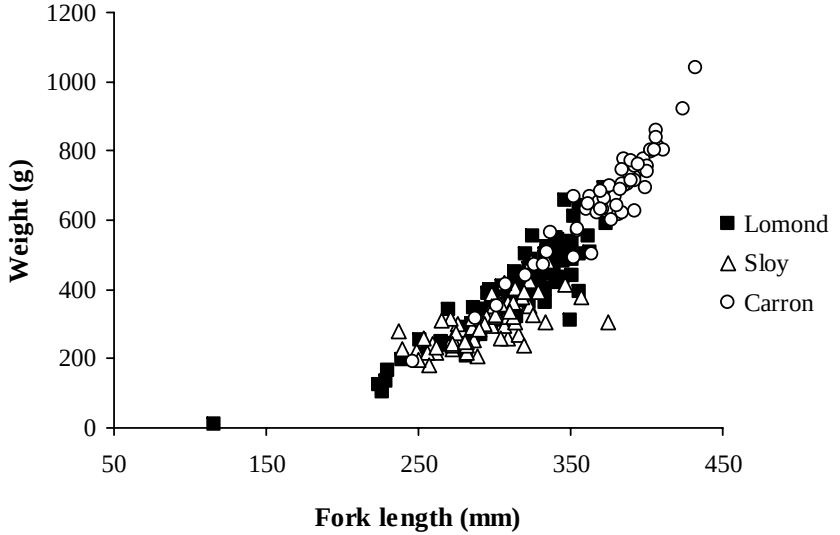


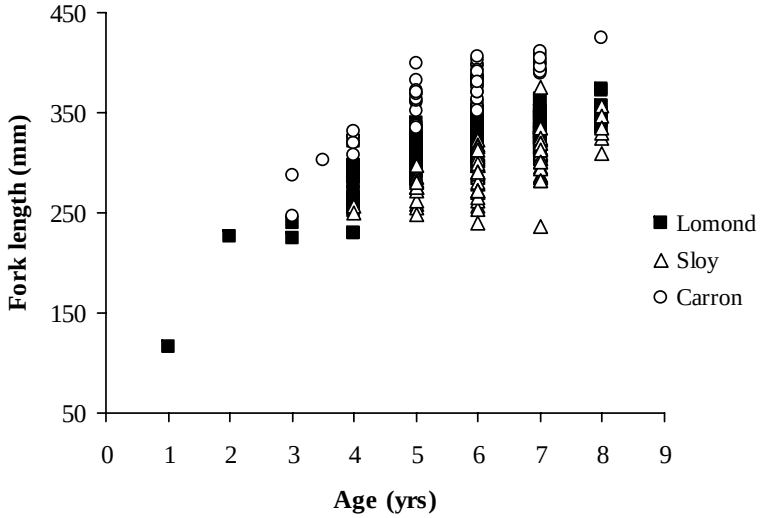
- Analysis using TPS software
  - Landmarks are converted to coordinates to describe each individual
  - Superimposition accounts for orientation
    - Two baseline coordinates are selected.
    - Procrustes fitting- shapes are all moved, scaled and rotated to give the least sum of squares
  - Partial warps describe the transformation from mean
  - Principle components analysis (PCA) produces hypothetical variables that account for as much variation in the data as possible.

Results – size and growth

- Significant differences (MANOVA, $p<0.001$) in Lf and W between all populations

Loch Sloy	p < 0.001	
Carron Reservoir	p < 0.001	p < 0.001
	Loch Lomond	Loch Sloy





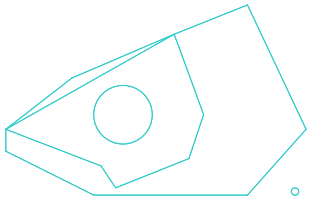
- The refuge populations have diverged in different directions from the parent population
  - Carron reservoir powan are larger and have the greatest growth rate.
  - Loch Sloy powan are the smaller and have the lowest growth rate.

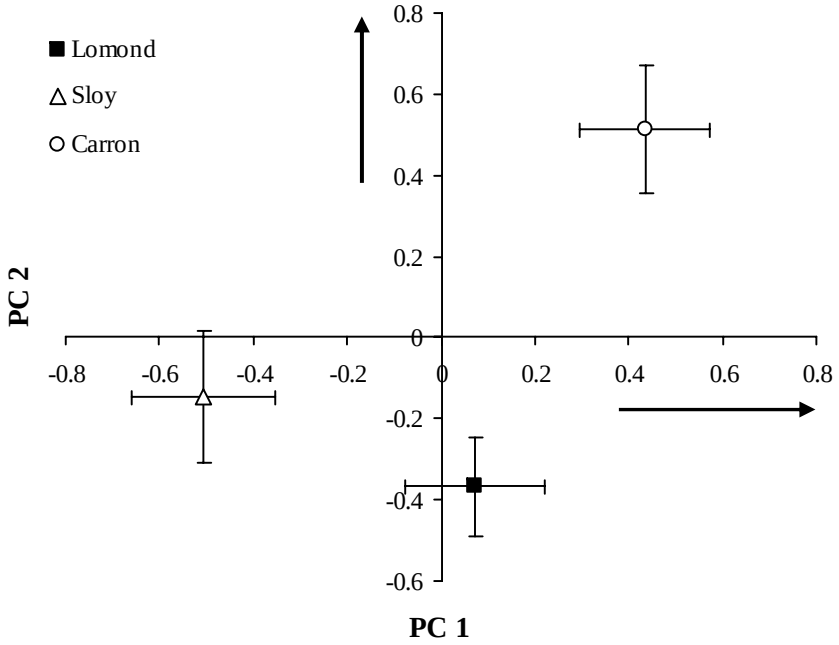
Results - morphometrics

- PC1
  - Explains 17% of variance in head coordinates
  - Differences in PC1 score are significantly different between populations (ANOVA, $F = 10.46$, $P<0.001$)
  - Post Hoc testing
    - Loch Lomond and Loch Sloy significant ($p<0.05$)
    - Loch Lomond and Carron Reservoir not significant ($p=0.25$)
    - Loch Sloy and Carron Reservoir significant ($p<0.001$)
- PC2
  - Explains 14% of variance in head coordinates
  - Differences in PC2 score are significantly different between populations (ANOVA, $F = 9.64$, $P<0.001$).
  - Post Hoc testing
    - Loch Lomond and Loch Sloy not significant ($p=0.88$)
    - Loch Lomond and Carron Reservoir significant ($p<0.001$)
    - Loch Sloy and Carron Reservoir significant ($p<0.01$)

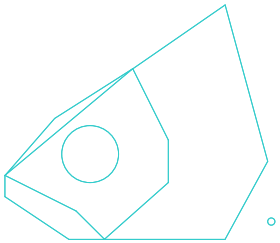
Results - morphometrics

- High PC2 score:
  - Longer head,
  - Most coordinates moving away from the snout
  - Pectoral fin base moves down





Loch Sloy	PC1: (p<0.05) PC2: NS	
Carron Reservoir	PC1: NS PC2: (p<0.001)	PC1: (p<0.001) PC2: (p<0.01)
	Loch Lomond	Loch Sloy



- High PC1 score:
  - Deeper head
  - Most coordinates mostly moving up
  - Eye more anterior, shorter mouth

Conclusions

- Lf and W
  - Significant differences between each population.
    - Large differences in size and growth are often reported when fish are introduced to a new area (Lindsey, 1981; Shields & Underhill, 1993).
  - Refuge populations have diverged in different directions
    - Loch Sloy powan are smaller and slower growing than Loch Lomond fish.
    - Carron Reservoir powan are larger and faster growing than Loch Lomond powan.
- Morphometrics
  - Significant shape differences between the populations
  - Head shape in refuge populations has diverged in different directions from that of the parent population
    - Lomond powan: shorter head, eye more anterior, and a smaller mouth.
    - Loch Sloy powan: shallower head, eye more posterior, and a larger mouth.
    - Carron Reservoir powan: deeper, longer head, eye more anterior, smaller mouth.

Conclusions

- Fish size and growth is known to vary depending on food availability and feeding opportunity (Kirchhofer, 1995).
  - Suggests there is some difference in food availability between these populations, and that powan from Loch Sloy do not have access to an optimal diet.
    - Possibly due to differences in nutrient status of these sites
    - Different availability of food species
    - Different levels of competition
- Morphology related to function
  - Head shape particularly related to acquiring and handling food.
    - Likely that food availability also plays a part in differences in head morphology
- Differences between sites
  - Physical- Size, Complexity, Depth, Shading, Water levels
  - Biological- Predation, Competition

Environmentally induced phenotypic plasticity can result in genetic divergence

Summary

- There appear to be some differences between populations that have occurred due to translocation.
  - Whitefish known to demonstrate phenotypic plasticity
  - Many differences are probably due to differences in feeding opportunities
- It is possible these phenotypic responses could cause a change in genetics
  - Therefore, more work is needed, particularly to discover whether there are genetic differences between these populations
- Further work:
  - Genetic work is in progress
  - Need to also do some laboratory common environment experiments

Thank you for listening.

Are there any questions?