# Practical Assessment methodologies for the evaluation and monitoring of *Margaritifera* habitats and their condition

Evelyn A. Moorkens

**Freshwater mussels: Search for resettlement habitats and evaluation of protection measures**

**Dresden 25th–27th March 2019**



Evelyn Moorkens
& Associates

# Questions questions questions questions.....

- "Half of scientific knowledge is asking the right question"

  Roger Bacon (1214-1292)

- "The art and science of asking questions is the source of all knowledge."

  Thomas Berger

- "The important thing is to never stop questioning."

  Albert Einstein

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?

?

# Standardisation

## International

English Version

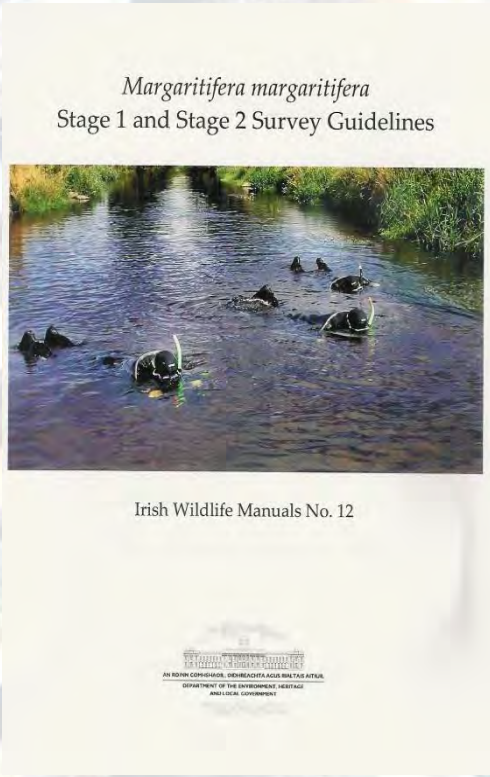
Water quality - Guidance standard on monitoring freshwater pearl mussel (Margaritifera margaritifera) populations and their environment

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Boon, P.J., Cooksley, S.L., Geist, J., Killeen, I.J., Moorkens, E.A. & Sime, I (2019) Developing a standard approach for monitoring freshwater pearl mussel (*Margaritifera margaritifera*) populations in European rivers. *Aquatic Conserv: Mar. Freshw. Ecosyst.*, https://doi.org/10.1002/aqc.3016.

## National




Balance - standard monitoring protocols and answering specific questions

# What are our questions?

## Questions relating to monitoring –

Using standard methods for surveillance, what is the current assessment of condition ?

Comparing standard surveillance survey results, what are the condition trends?

Using investigative monitoring methods, what is the reason for changes in condition since the last survey, or for ongoing trends?

But these questions cannot be considered in isolation, they must combine with longer term questions

# What are our questions?

Questions relating to monitoring –

Using standard methods for surveillance, what is the current assessment of condition ?

Comparing standard surveillance survey results, what are the condition trends?

Using investigative monitoring methods, what is the reason for changes in condition since the last survey, or for ongoing trends?

Questions relating to our understanding of each population – long term questions

How does (or did) each population achieve the conditions that allow for sustainable recruitment?

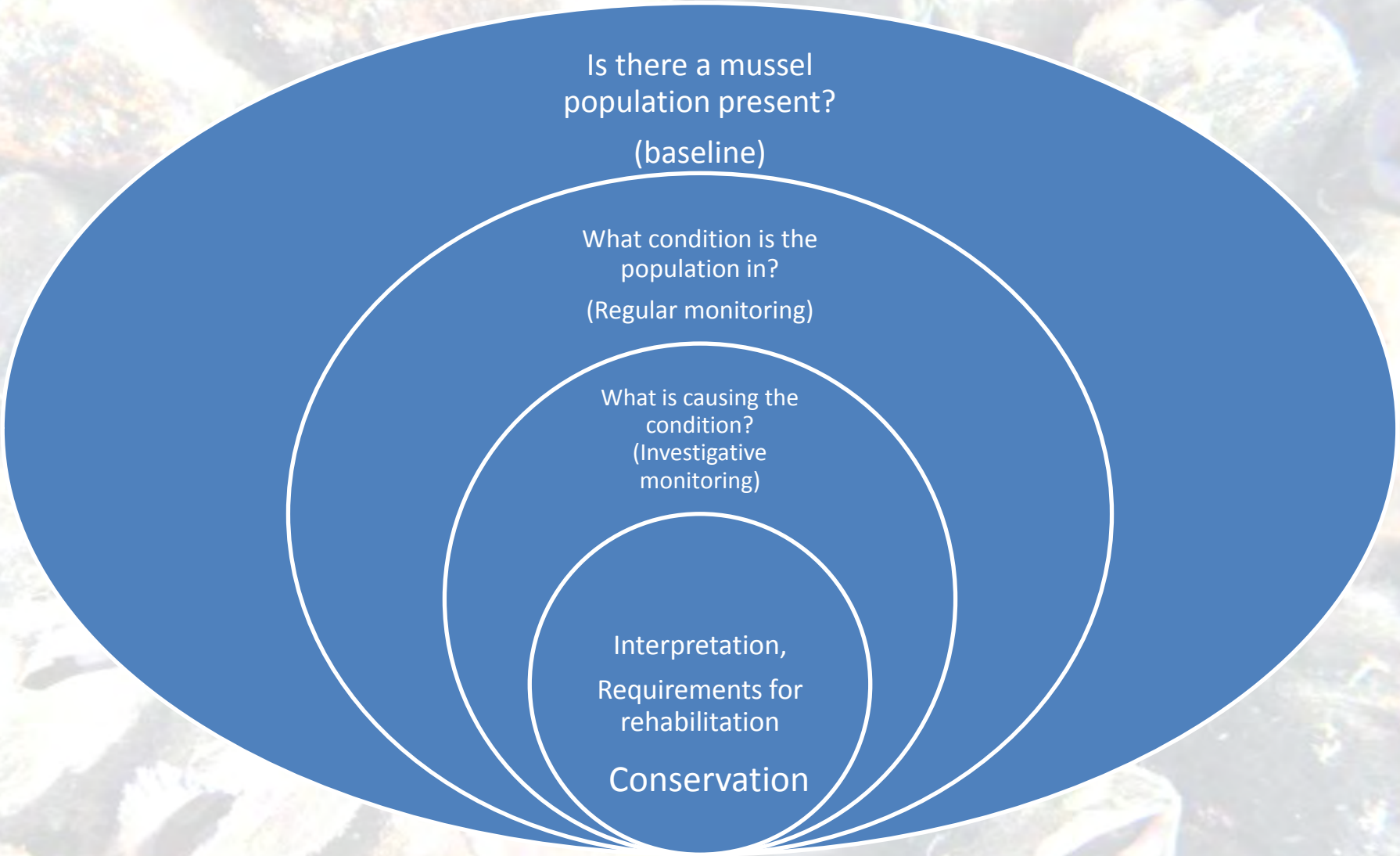
What are the realistic (or ideal) expectations for each population?

How far are we from achieving these expectations?

What measures should we take to achieve our objectives for each population?



Ongoing research




What is the problem? What is the cause? What is the solution?

# How do we know....

- What is the problem? → Condition of adult mussels poor?
- What is the cause? Lack of juvenile survival?
- What is the solution? What should we expect from this population?

Adult mussel numbers low?

# How do we know....

- What is the problem?
- What is the cause?
- What is the solution?

Episodic or one major event?

Chronic conditions?

River bed habitat?

River bed morphology?

Pressures?

# How do we know....

- What is the problem?
- What is the cause?
- What is the solution? →

Prioritisation of whole catchments for best populations

Prioritisation of stretches for small populations

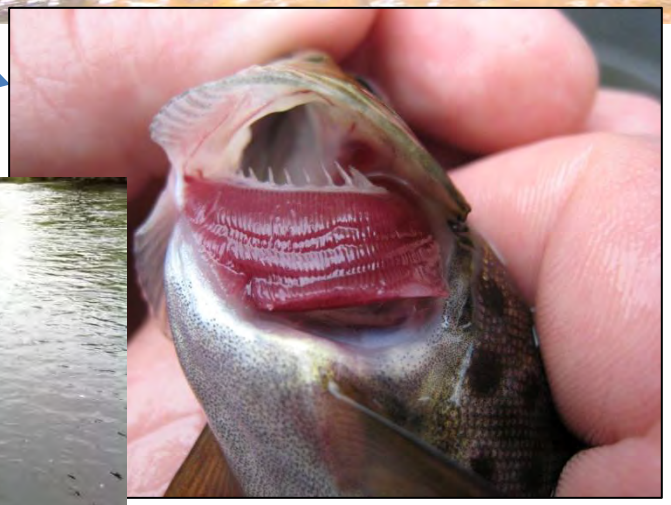
Conservation management including captive breeding for worst populations

# Progress our knowledge through:

- Baseline data
- Regular monitoring
- Less regular monitoring
- Investigative monitoring
- Informative investigations









National Standards Authority of Ireland (2017). Water Quality - Guidance Standard on Monitoring Freshwater Pearl Mussel (*Margaritifera margaritifera*) Populations and Their Environment. I.S. EN 16859:2017

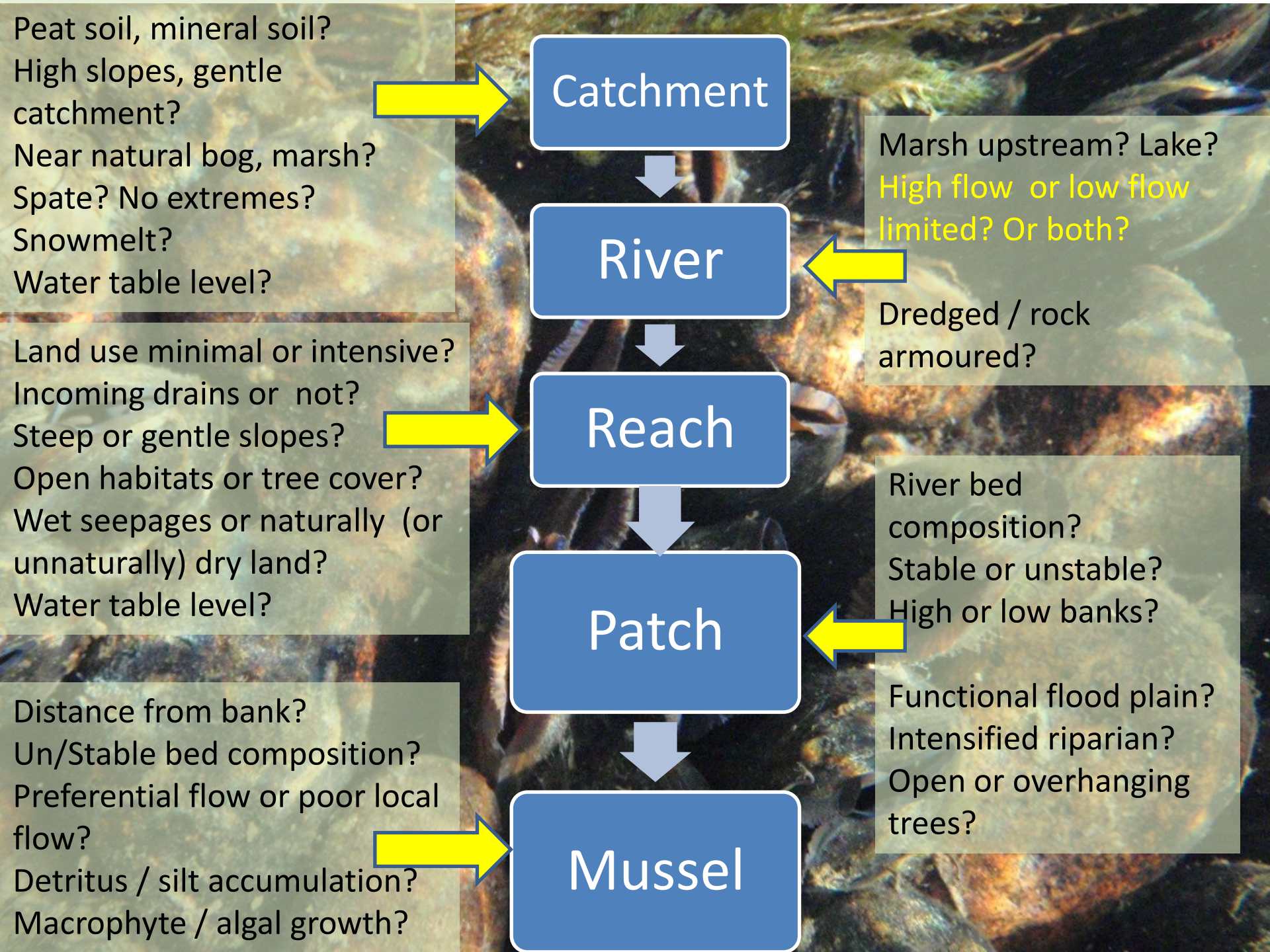
# Monitoring of population

Initial baseline monitoring
- Mussel distribution
- Population density
- Mussel age structure
- Juvenile densities
- Host fish density, glochidia
- Flow discharge baseline
- Physical habitat baseline
- Redox potential baseline
- Walkover / remote
- Pressures study
- Initiate monitoring transects / plots

Regular monitoring
- Mussel distribution checks
- Repeat monitoring transects / plots
- Age class demographic studies
- River bed redox
- River bed clast size
- Near bed velocity
- Assessment of algal / macrophyte cover

Investigative monitoring / investigations
- Water quality sampling
- Continuous monitoring sondes
- Mussel brooding level checks
- Fluvial audits
- Shear stress investigations
- Penetrometry
- Sedimentation rate studies
- Other pressure – dependent investigations
- Mussel stress levels
- Genetic differences
- Age v size analysis

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Peat soil, mineral soil?
High slopes, gentle catchment?
Near natural bog, marsh?
Spate? No extremes?
Snowmelt?
Water table level?
Catchment
Marsh upstream? Lake?
High flow or low flow limited? Or both?
River
Dredged / rock armoured?
Land use minimal or intensive?
Incoming drains or not?
Steep or gentle slopes?
Open habitats or tree cover?
Wet seepages or naturally (or unnaturally) dry land?
Water table level?
Reach
River bed composition?
Stable or unstable?
High or low banks?
Patch
Functional flood plain?
Intensified riparian?
Open or overhanging trees?
Distance from bank?
Un/Stable bed composition?
Preferential flow or poor local flow?
Detritus / silt accumulation?
Macrophyte / algal growth?
Mussel

# Catchment characterisation

- River and catchment size
- Geology
- Flow characteristics
- Geomorphology
- Level of naturalness
- Annual cycles
- River bank characters
- Terrestrial habitat characters

- Large, medium small
- Peat or mineral, sandy
- Even/ lake / marsh upstream
- Clast armouring / gravel beds
- Drained / intensified
- Snowmelt / temperature range
- Height of banks / tree shading
- Bog / forest / agriculture / urban
- Limited by high flows or low flows?

This helps to explain likely cause of flow, sediment and / or nutrient problems

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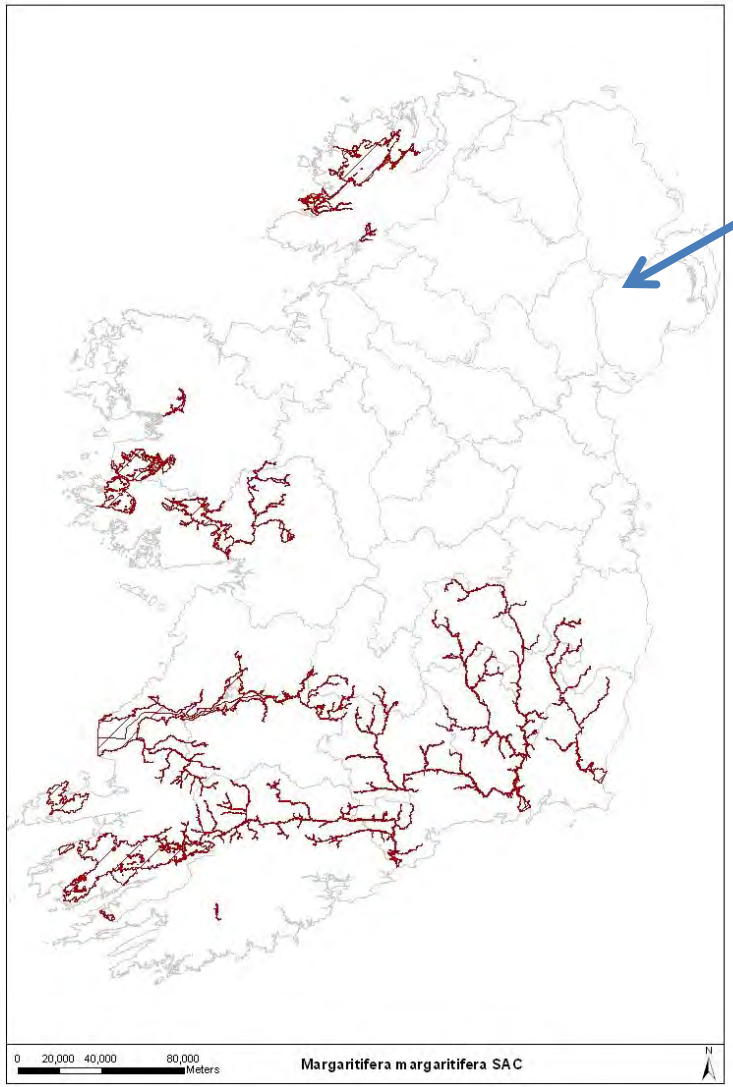
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# Population condition categories in Ireland

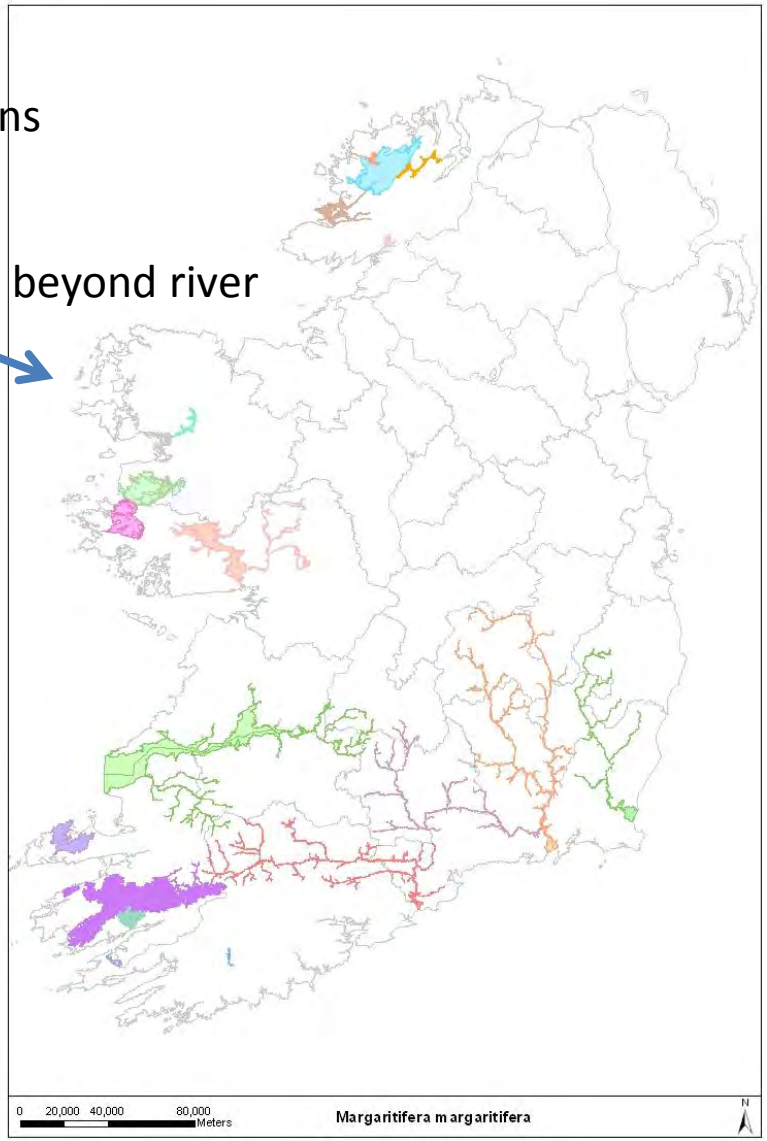
| A = Recruiting | B = Declining | C = Seriously impacted |
| --- | --- | --- |
| Western peat catchments, with large populations and average most recent recruitment <65mm = 12.86% | Western peat catchments, with large populations rapidly declining and average most recent recruitment <65mm = 3.67% | Eastern rivers with less peat, small populations and average recent recruitment <65mm 0.51% |

# Baseline distribution and distribution checks 2004-2018

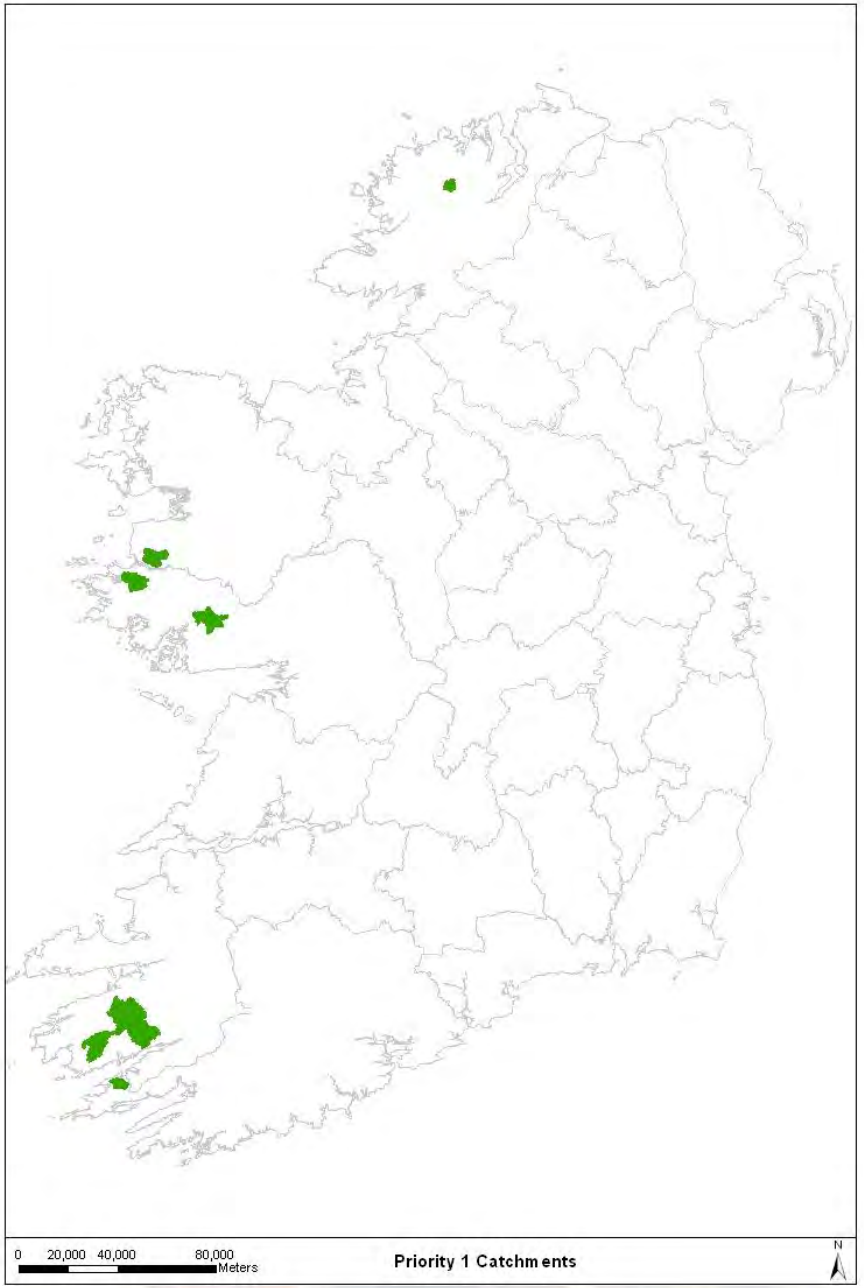



SAC populations

Extent of SAC beyond river



- Recruiting Rivers A:
  - 8 populations “Top 8”
  - 80% national pop
  - 8.5% total SAC catchment area







A = Recruiting







Wetter catchments have better flow velocities and more food at a local scale for juveniles (saturated land means that summer rain reaches the river)



# Wetlands help velocity levels at both riparian and at catchment level

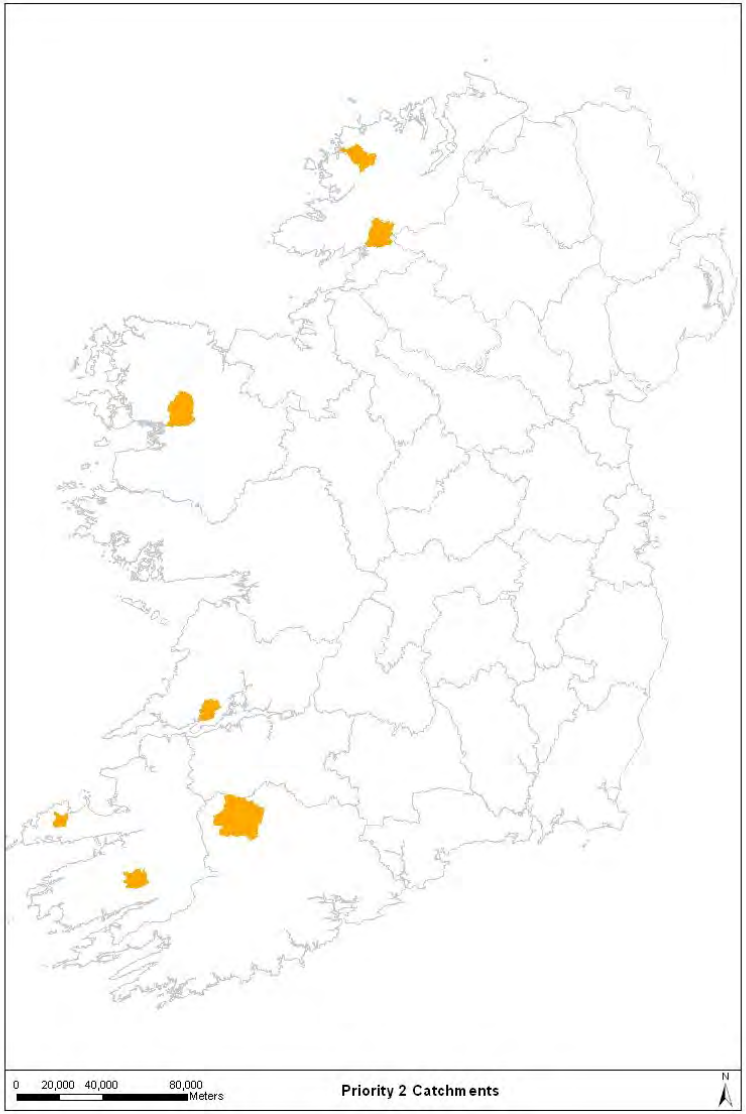


# Wetlands  protect flows and provide juvenile food source



- Priority Group 2:
  - 11 populations
  - 7.2% national pop
  - 24.6% total SAC catchment area





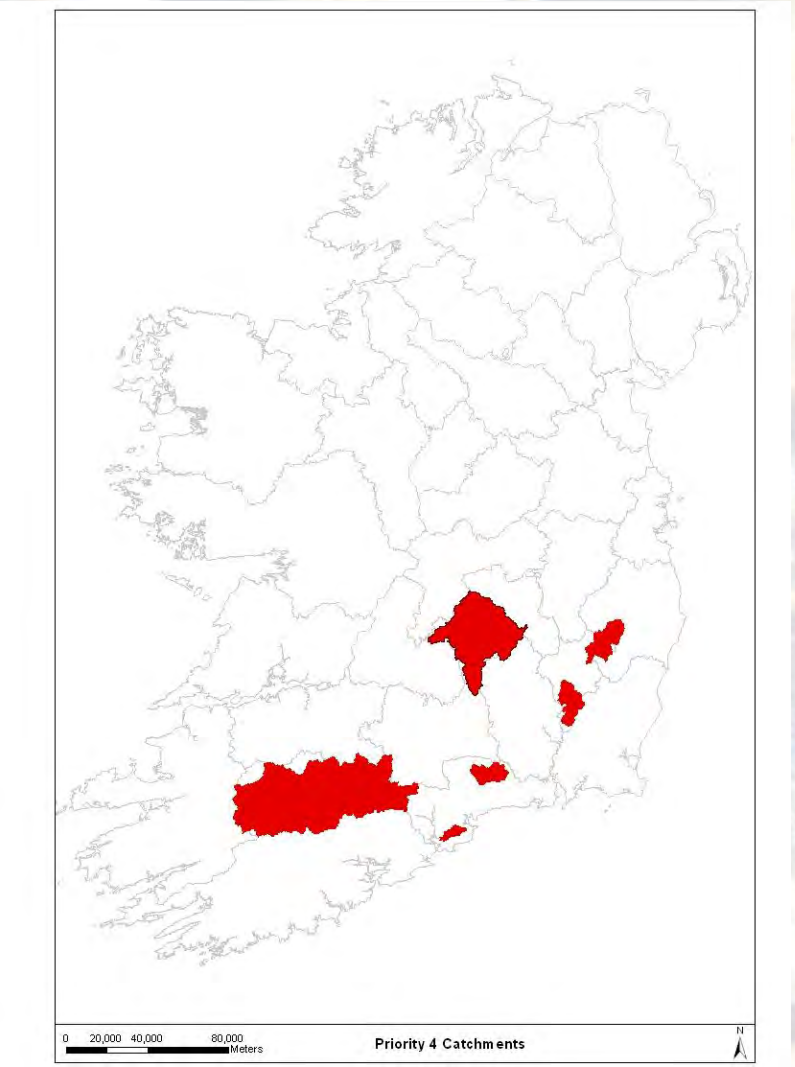








- Serious Decline C Rivers:
  - 7 populations
  - 0.35% national pop
  - 66.9% total SAC catchment area





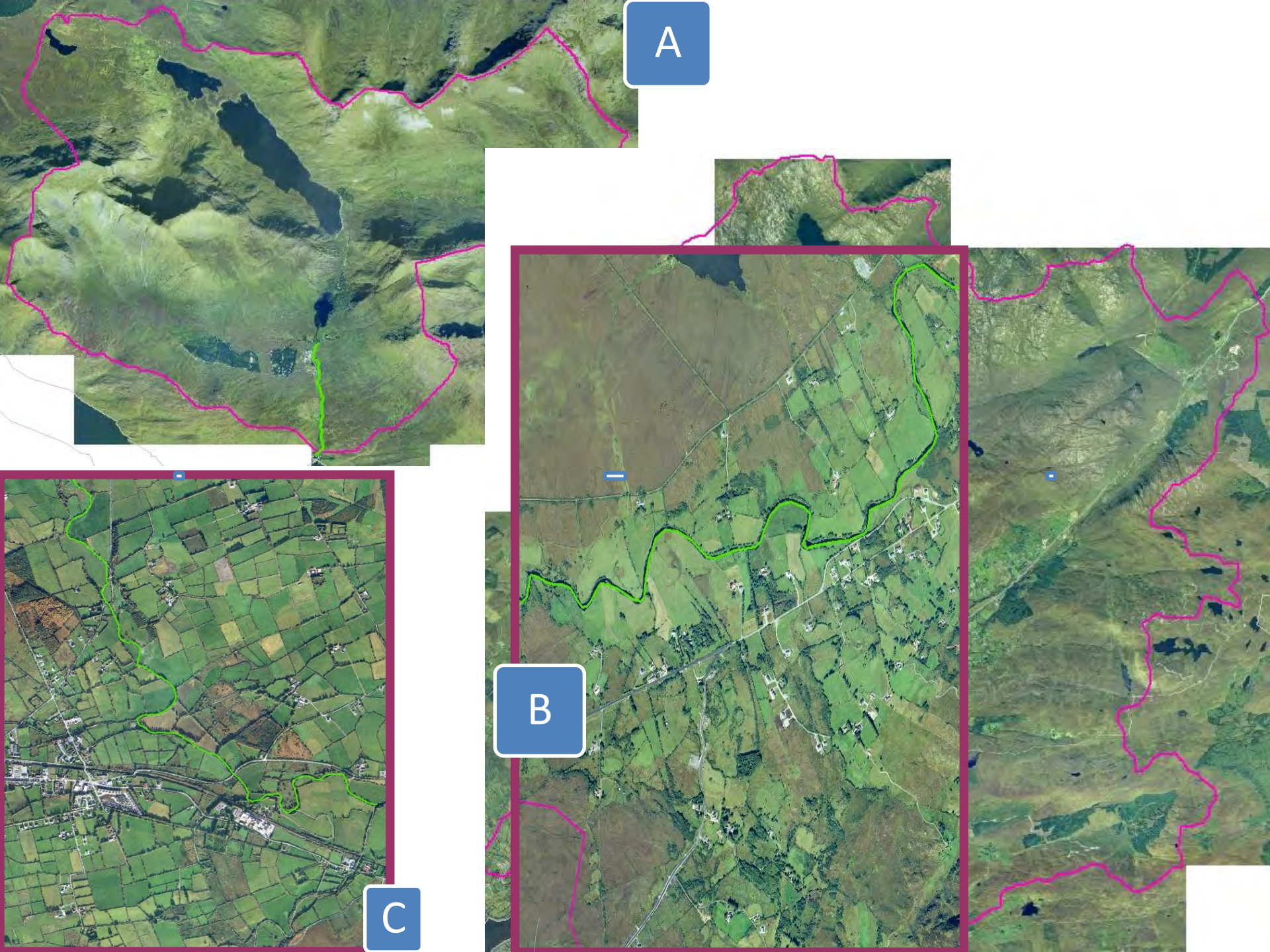











A
B
C

# Mussel population size / density

- Started in 2004 with wide range rapid studies / poor detail in information
- Set up perpendicular transects for
- monitoring purposes

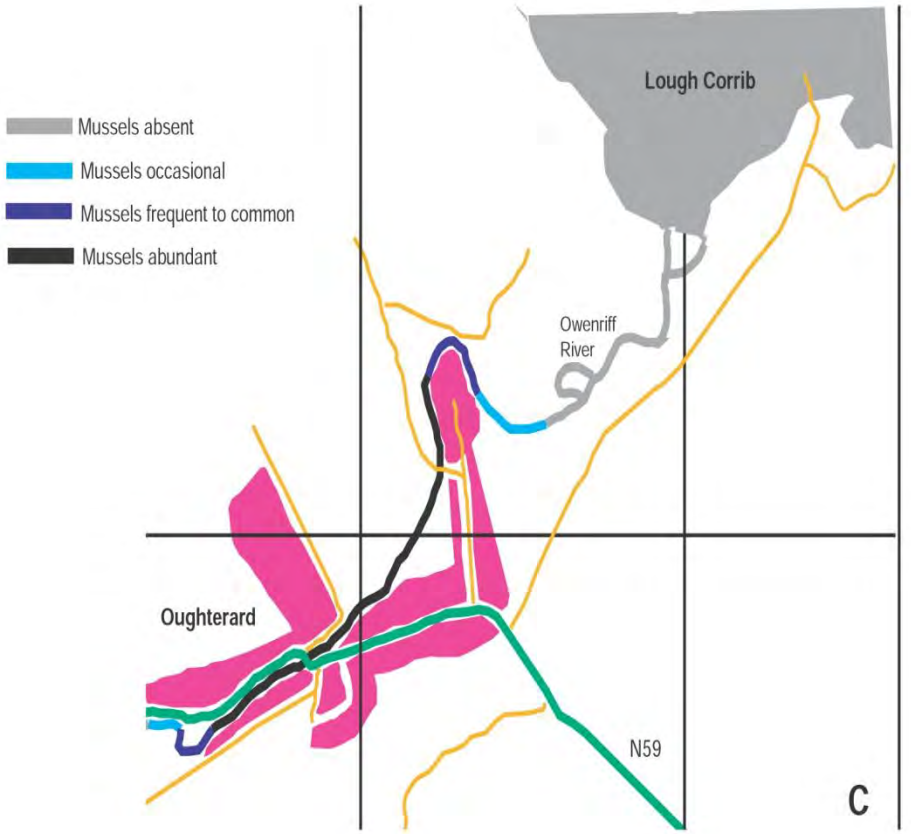
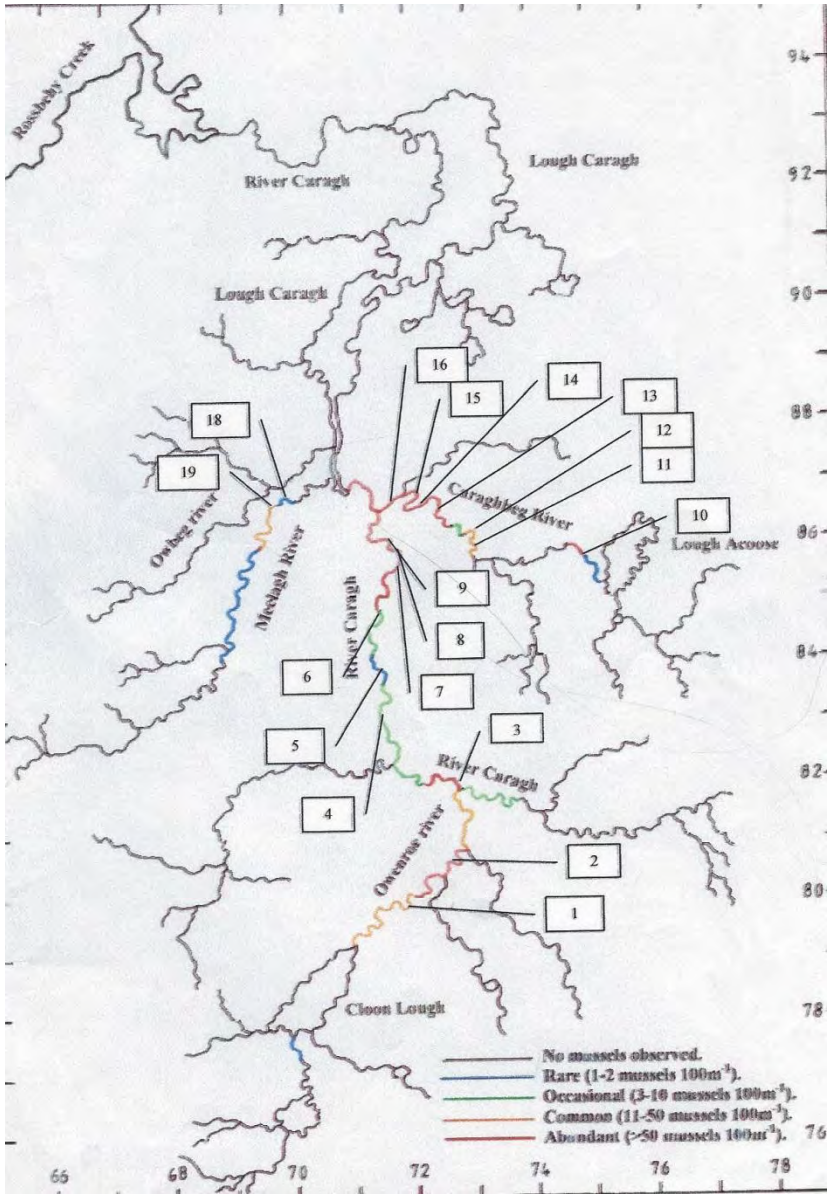



Figure 5: Mussel abundance in the downstream section of the Owenriff River

# Set up monitoring transects

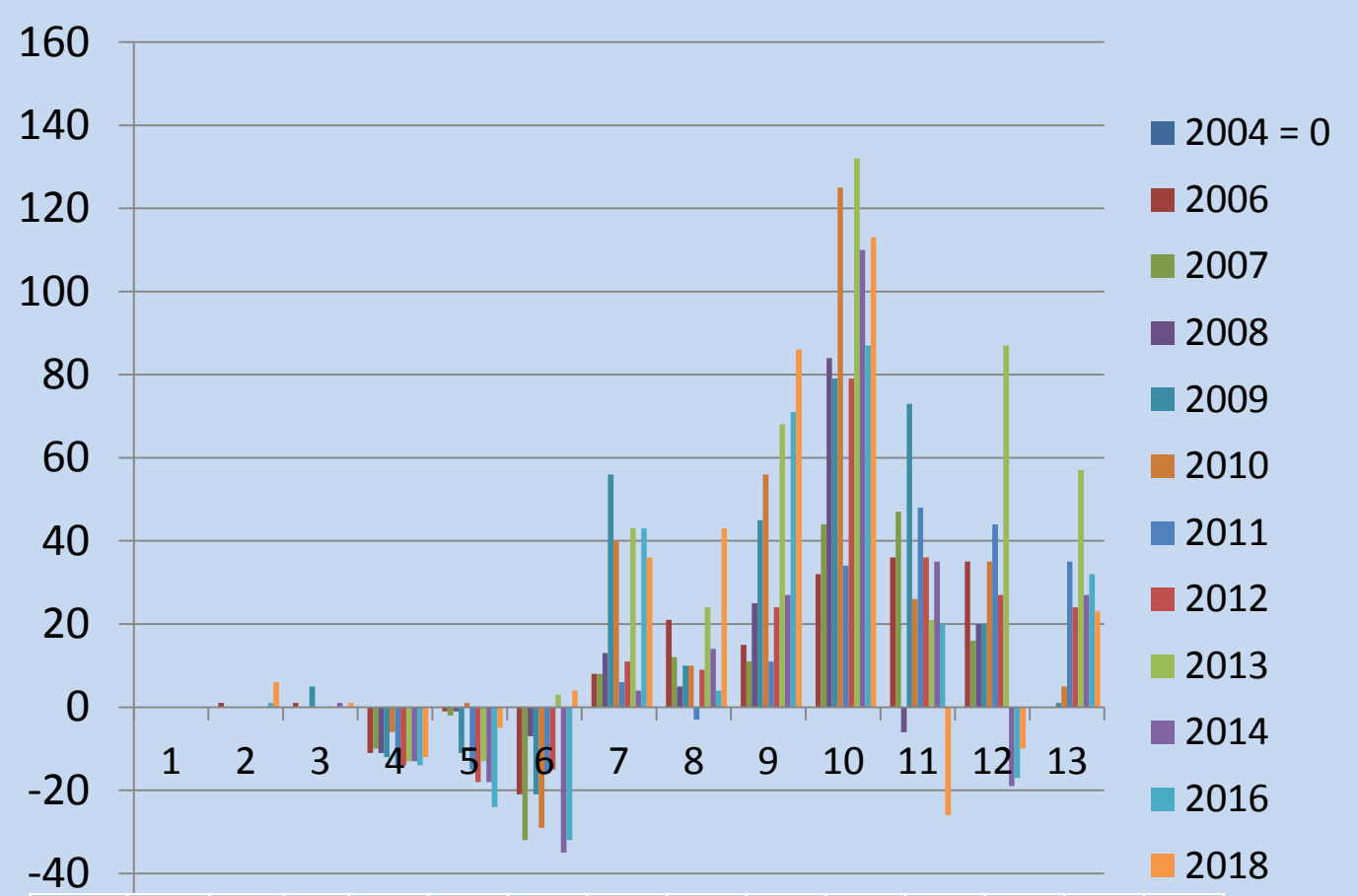




| Quadrat # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Substrate (% Cover)** | | | | | | | | | | | |
| Silt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sand | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gravel | 40 | 50 | 40 | 25 | 25 | 25 | 10 | 10 | 10 | 10 | 0 |
| Pebble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cobble | 50 | 50 | 40 | 75 | 75 | 25 | 50 | 50 | 30 | 30 | 0 |
| Boulders | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bedrock | 0 | 0 | 20 | 0 | 0 | 50 | 40 | 40 | 60 | 60 | 100 |
| **Aquatic Vegetation** (% Cover) | | | | | | | | | | | |
| Filamentous Algae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Myriophyllum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ranunculus* | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Fontinalis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Live mussels** | 6 (1) | 2 | 6 | 2 | 1 | 0 | 0 | 2 | 11 | 13 | 0 |

# Results of repeated transects: Recruiting

| Year | Total |
|---|---|
| 2004 | 245 |
| 2006 | 361 |
| 2007 | 339 |
| 2008 | 367 |
| 2009 | 490 |
| 2010 | 502 |
| 2011 | 375 |
| 2012 | 408 |
| 2013 | 654 |
| 2014 | 378 |
| 2016 | 416 |
| 2018 | 504 |




| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2004 | 0 | 0 | 0 | 14 | 26 | 63 | 29 | 12 | 21 | 14 | 47 | 19 | 0 | 0 |
| 2018 | 0 | 6 | 1 | 2 | 21 | 67 | 65 | 55 | 107 | 127 | 21 | 9 | 23 | 0 |

Possible trend: Movement towards Right (higher flow)

# Results of repeated transects: Declining

| Year | Total |
|---|---|
| 2006 | 144 |
| 2009 | 141 |
| 2014 | 108 |

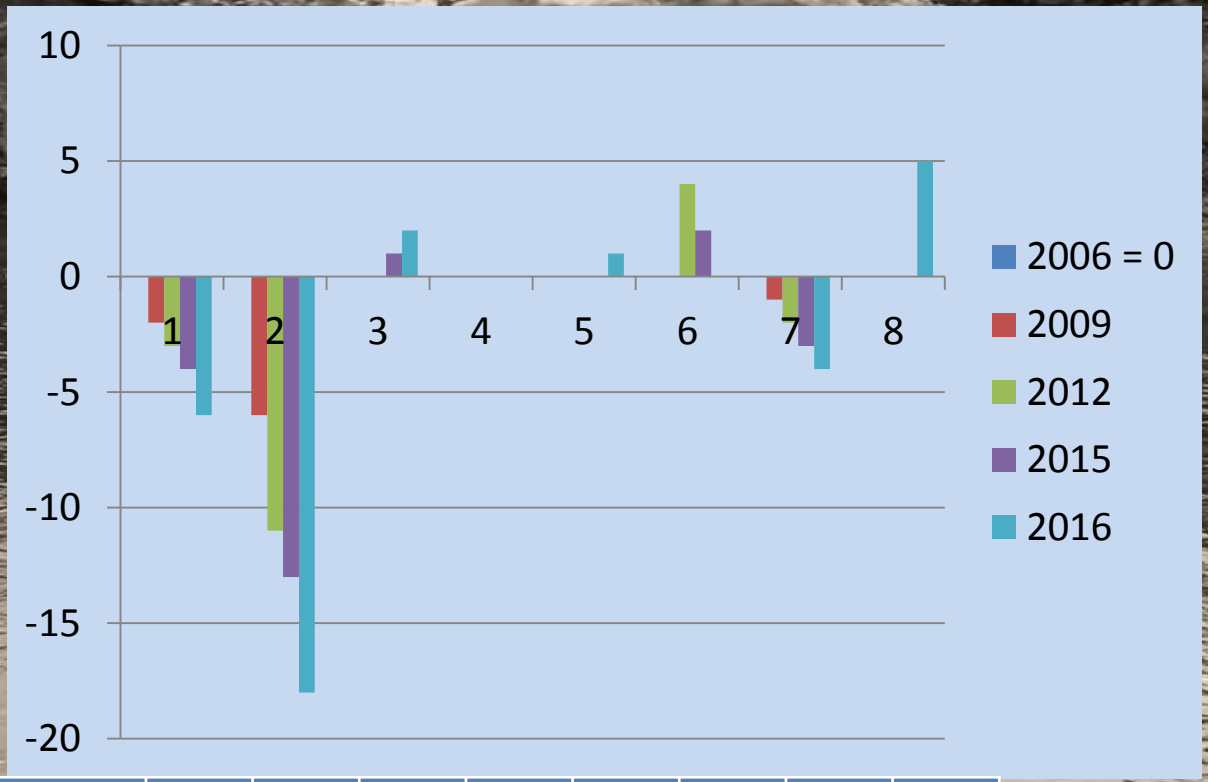



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 3 | 8 | 8 | 6 | 5 | 18 | 8 | 58 | 27 | 3 | 0 |
| 2014 | 11 | 3 | 6 | 1 | 2 | 15 | 10 | 17 | 38 | 2 | 3 |

Possible trend:
Decline and movement
Towards banks

# Results of repeated transects Severely impacted

| Year | Total |
|---|---|
| 2006 | 29 |
| 2009 | 20 |
| 2012 | 17 |
| 2015 | 12 |
| 2016 | 9 |




| 2006 | 6 | 18 | 0 | 0 | 0 | 0 | 5 | 0 |
|---|---|---|---|---|---|---|---|---|
| 2016 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 5 |

Possible trend: Movement towards right (higher flow) and extinction

# Is there a better methodology?

## Killeen & Moorkens (2014-2018)

## Juvenile Habitat Mapping

- Mapping across a wider area provides better understanding of river function
- Gets wider information on both adult mussels and juvenile habitat

Can use results to assess:

1) Population size
2) The most important reaches and patches
3) The level of recruitment
4) The main problems, whether habitat or condition
5) The rehabilitation priorities needed

# Parameter assessment categories

| Parameter | Habitat suitability | Habitat Condition | Method |
|---|---|---|---|
| Water depth (cm) | X | | Measuring stick |
| Wide clast size range? | X | | Visual category |
| Dominant clast size(s) | X | | Visual category |
| Sand to fine gravel? | X | | Yes / No |
| In lee of boulders? | X | | Yes / No |
| Compaction | X | X | Severe/ Moderate/ Slight / None |
| Silt cover | X | X | |
| Silt infiltration | X | X | |
| Detritus | X | X | |
| Algae | | X | |
| Floc | | X | |
| Scour | X | | |
| Macrophytes | | X | Silt accumulators = -ve<br>Mosses (*Fontinalis*) = +ve |
| Flow | X | X | Visual category |
| Mussels | X | | Count of visible mussels |
| Habitat suitability | X | | Good / potential / none |
| Habitat condition | | X | Good / moderate / bad |

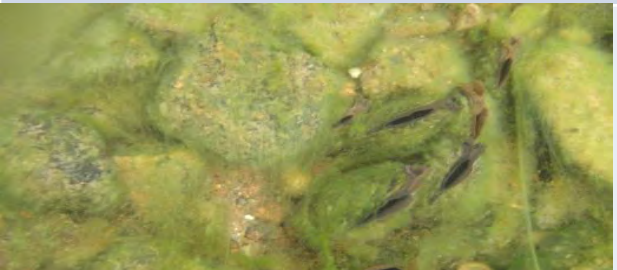
**Information is collected from 1 m x 1 m quadrats within transverse transects**
**To obtain sufficiently high resolution, transects are closely spaced (10 m),**
**and every 1 m quadrat on the transect is recorded**

# Nine habitat mapping combinations

| | Good habitat | Potential habitat | No habitat |
|---|---|---|---|
| Good condition | Good, good | Potential, good | None, good |
| Moderate condition | Good, moderate | Potential, moderate | None, moderate |
| Poor condition | Good, poor | Potential, poor | None, poor |





| Good habitat | Potential habitat | No habitat |
| --- | --- | --- |
| Good, good | Potential, good | None, good |
|  |  |  |
| Good, moderate | Potential, moderate | None, moderate |
|  |  |  |
| Good, poor | Potential, poor | None, poor |
|  |  |  |

# Habitat mapping examples

# Recruiting river:

Mussels

Habitat

Condition

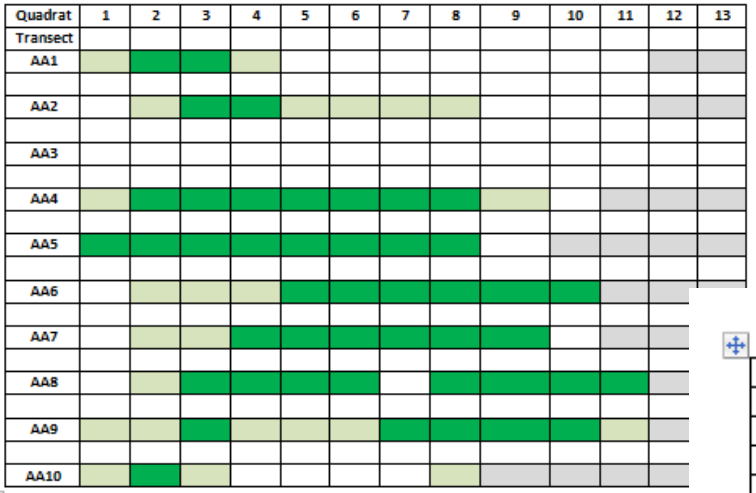
| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | | | | | | | | | | | | |
| BDB5 | 0 | 0 | 49 | 33 | 3 | 1 | 0 | 0 | 2 | 0 | 10 | 9 | 0 | 0 | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB4 | 0 | 0 | 0 | 0 | 20 | 35 | 38 | 7 | 7 | 0 | 0 | 11 | 31 | 2 | 0 | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB3 | 0 | 1 | 3 | 2 | 9 | 38 | 52 | 19 | 1 | 1 | 8 | 1 | 0 | 19 | 31 | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB2 | 0 | 0 | 0 | 0 | 0 | 45 | 81 | 93 | 82 | 22 | 10 | 8 | 8 | 28 | 41 | 17 | 4 | 0 | 0 |
| | | | | | | | | | | | | | | | | | | | |
| BDB1 | 0 | 0 | 0 | 0 | 18 | 95 | 219 | 129 | 34 | 39 | 30 | 47 | 28 | 38 | 48 | 44 | 18 | 6 | |

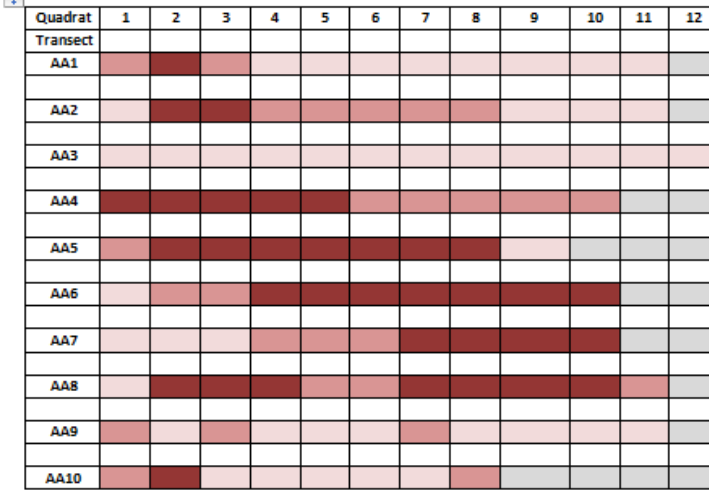
No potential juvenile habitat  Potential juvenile habitat  Good juvenile habitat

| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | | | | | | | | | | | | |
| BDB5 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB4 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB3 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB2 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB1 | | | | | | | | | | | | | | | | | | | |

Good condition  Moderate condition  Poor condition

| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | | | | | | | | | | | | |
| BDB5 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB4 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB3 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB2 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| BDB1 | | | | | | | | | | | | | | | | | | | |





# Declining river

Condition  and mussels reflect habitat
Mussels still widespread but fewer

| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | | | | | | |
| AA1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| AA2 | 0 | 1 | 14 | 1 | 1 | 3 | 4 | 0 | 0 | 0 | 0 | | |
| AA3 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AA4 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 2 | 0 | 0 | | | |
| AA5 | 2 | 9 | 5 | 2 | 2 | 1 | 2 | 12 | 9 | | | | |
| AA6 | 0 | 0 | 0 | 0 | 3 | 6 | 5 | 0 | 2 | 1 | | | |
| AA7 | 0 | 0 | 0 | 3 | 2 | 0 | 2 | 2 | 5 | 0 | | | |
| AA8 | 0 | 2 | 6 | 5 | 11 | 3 | 0 | 7 | 8 | 4 | 11 | | |
| AA9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 2 | 0 | | |
| AA10 | 11 | 19 | 0 | 0 | 0 | 2 | 0 | 1 | | | | | |

# Seriously impacted river

Good habitat patchy, not reflected by Condition or mussel locations,
Mussels restricted to high flow areas

| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | |
| CL1 | No | Good | Good | No | Pot | Good | Pot | Pot |
| CL2 | No | Pot | Good | Pot | Good | Pot | No | |
| CL3 | Pot | Pot | Good | Good | Good | Good | Pot | Pot |
| CL4 | No | Good | Good | Good | Pot | Pot | Good | |
| CL5 | Pot | Pot | Pot | No | Pot | No | | |
| CL6 | Pot | Good | Pot | Pot | Pot | Good | Good | Pot |
| CL7 | Pot | Pot | Pot | Good | Good | Good | Pot | No |
| CL8 | No | No | Pot | Pot | Pot | Good | Good | |
| CL9 | No | Pot | Pot | Pot | Pot | Good | | |
| CL10 | Pot | Good | Good | Good | Good | No | | |
| CL11 | Pot | Good | Good | Pot | Pot | Pot | No | |

| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | |
| CL1 | Poor | Poor | Poor | Poor | Mod | Mod | Mod | Poor |
| CL2 | Poor | Poor | Poor | Poor | Poor | Poor | Poor | |
| CL3 | Poor | Poor | Mod | Mod | Mod | Mod | Poor | Poor |
| CL4 | Poor | Poor | Poor | Poor | Poor | Poor | Mod | |
| CL5 | Poor | Poor | Poor | Poor | Poor | Poor | | |
| CL6 | Mod | Mod | Mod | Mod | Mod | Mod | Mod | Mod |
| CL7 | Poor | Poor | Poor | Poor | Poor | Mod | Poor | Poor |
| CL8 | Poor | Poor | Poor | Poor | Poor | Mod | Mod | |
| CL9 | Poor | Poor | Poor | Poor | Poor | Poor | | |
| CL10 | Poor | Poor | Poor | Poor | Poor | Poor | | |
| CL11 | Poor | Poor | Poor | Poor | Poor | Poor | Poor | |

| Quadrat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Transect | | | | | | | | |
| CL1 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 5 |
| CL2 | 1 | 2 | 1 | 0 | 1 | 0 | 1 | |
| CL3 | 1 | 0 | 1 | 2 | 0 | 1 | 0 | 0 |
| CL4 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | |
| CL5 | 4 | 0 | 0 | 0 | 0 | 0 | | |
| CL6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| CL7 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 |
| CL8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| CL9 | 0 | 0 | 0 | 0 | 0 | 1 | | |
| CL10 | 0 | 1 | 2 | 2 | 0 | 0 | | |
| CL11 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |

# Habitat mapping – how mussel populations decline

| | Number of quadrats | % Good juvenile habitat | %Good juvenile habitat in good condition | Average mussels per metre square |
|---|---|---|---|---|
| Recruiting rivers | 255 | 46% | 100% | 34 |
| Declining rivers | 221 | 44% | 43% | 10 |
| Seriously impacted | 258 | 27% | 29% | 0.26 |

Decline first in condition – then in loss of habitat in rivers that have a history of large populations

Useful tool to compare populations for condition assessment

Helps in our understanding of “index of impact”

# Size class demographic studies

- Population structure is assessed by measuring the lengths of mussels including those mussels buried within the substrate, based on 0.5m x 0.5m quadrats.
- Quadrats are undertaken based on 9 habitat mapping categories.
- The choice of demography quadrat location is very important as it is an invasive technique which causes considerable disturbance to the mussel beds. It should only be done in stable habitat.
- Great care has to be taken to ensure that all mussels are replaced in their correct positions and depth
- To avoid damage to the population, the number of quadrats examined should be minimal and adequately spaced apart.

# Size class demographic studies

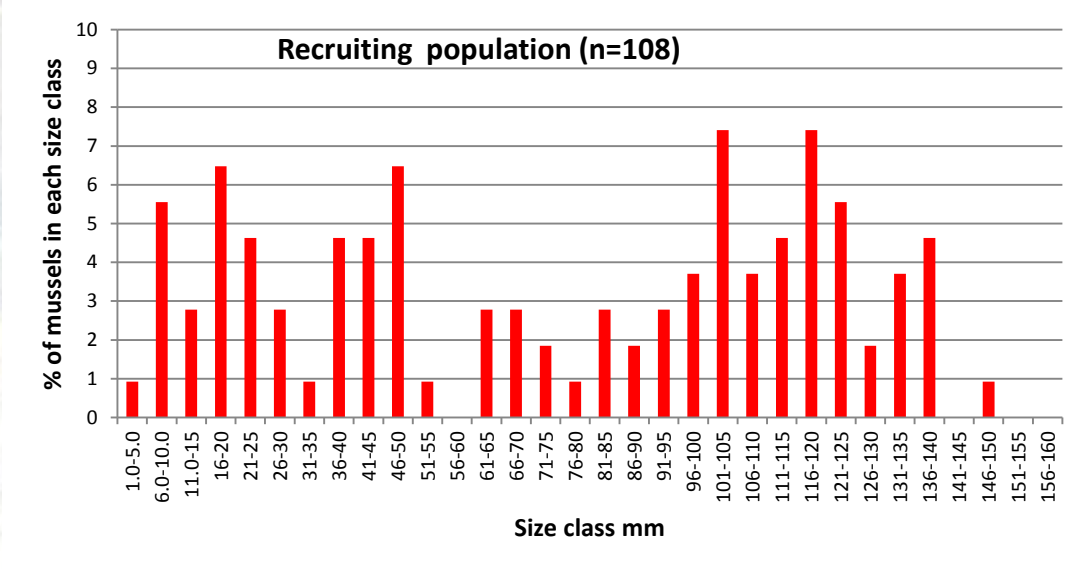


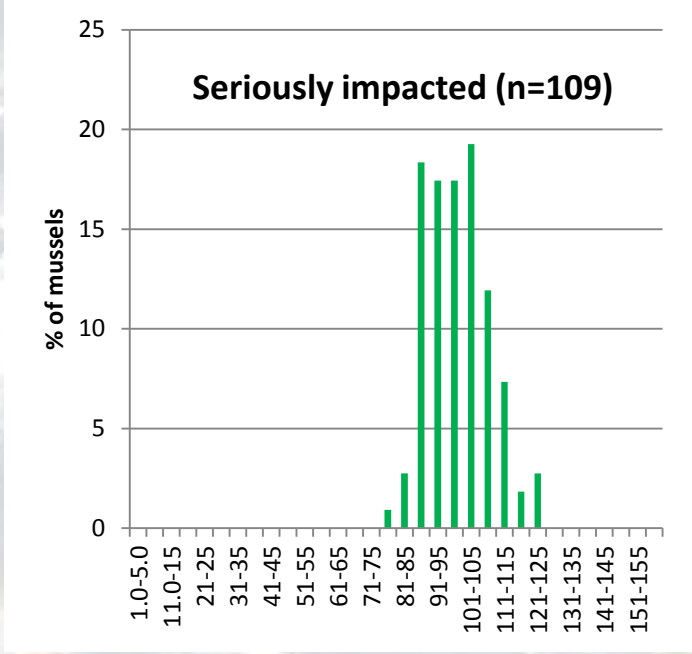


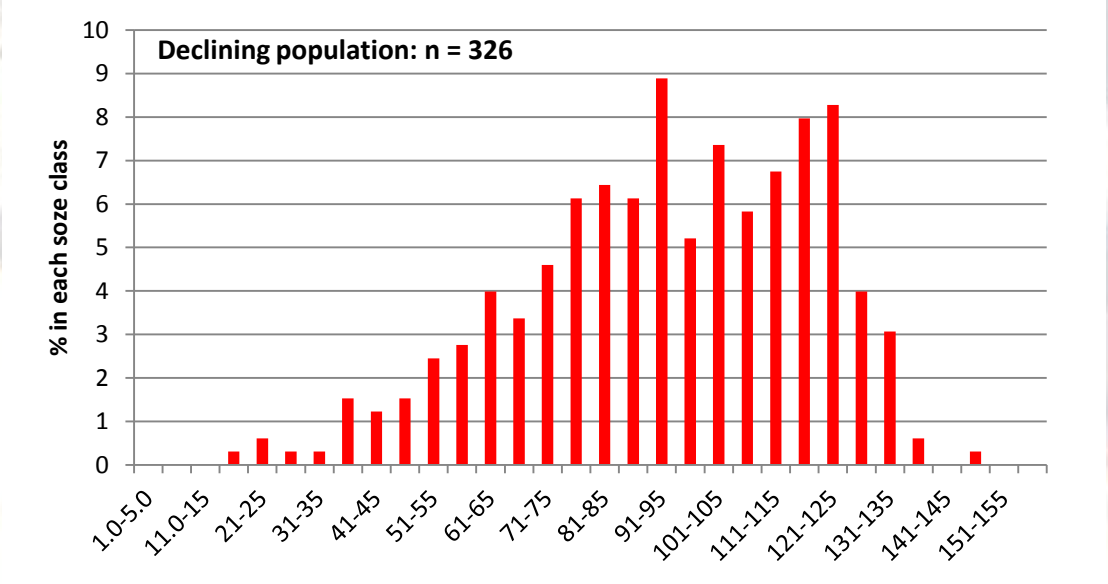




# Size class demographic studies

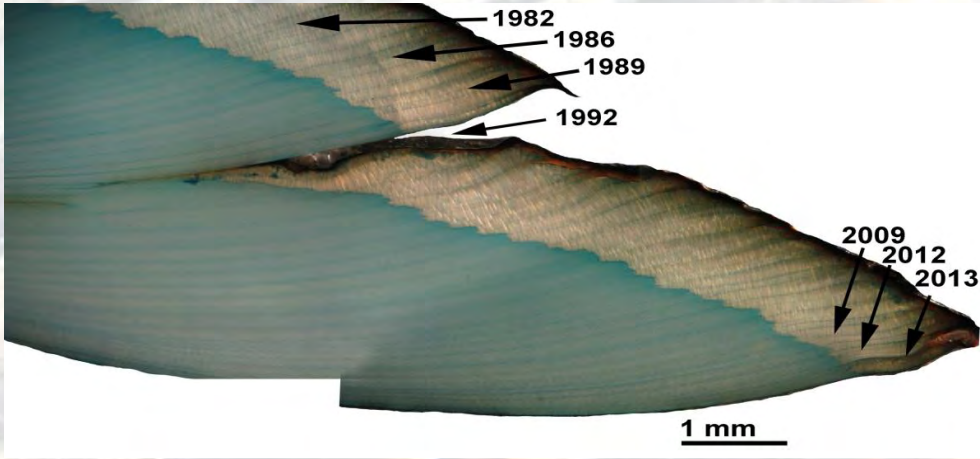


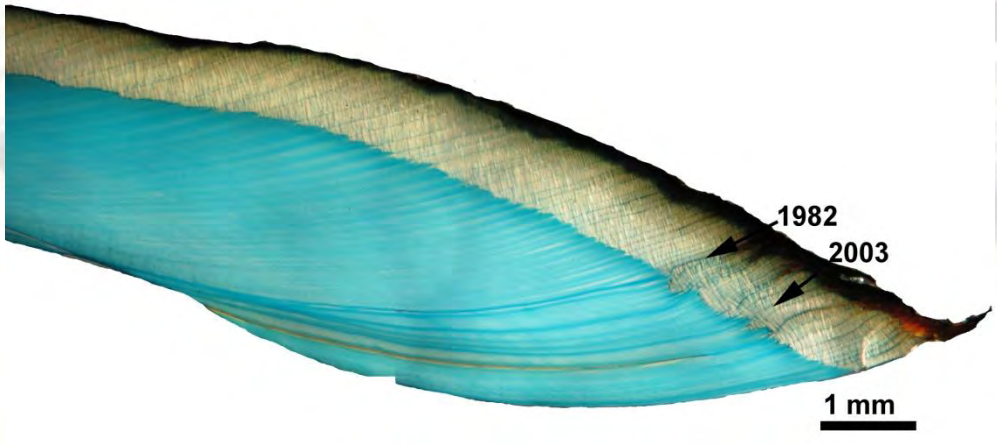



# Supplement demography data with age of mussels from shell analysis





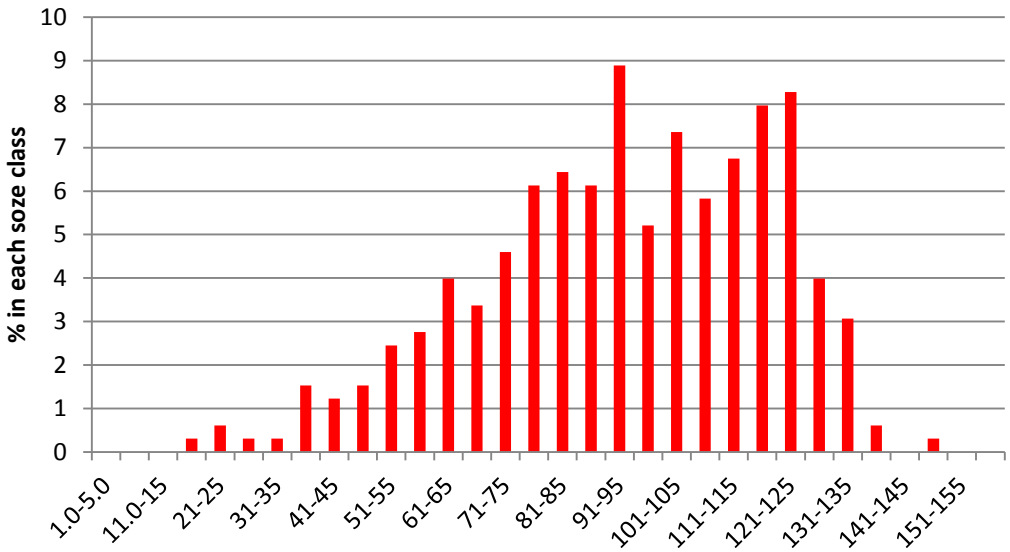



# Recruitment patterns from number of year classes found in ageing study and size classes in demographic studies

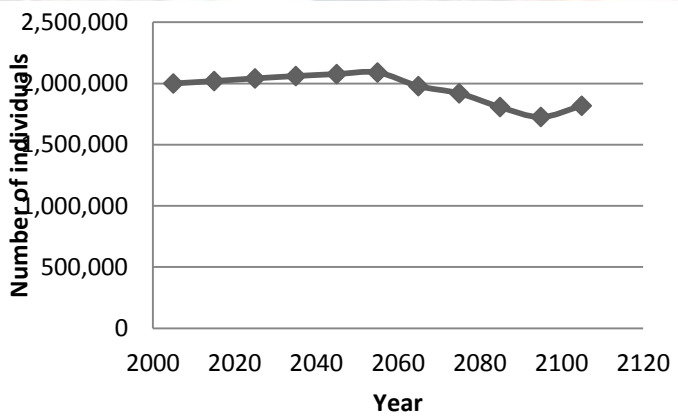
| River | 2010- | 2000-2010 | 1990-1999 | 1980-1989 | 1970-1979 | 1960-1969 | 1950-1959 | 1040-1940 | 1930-1939 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Annual | Annual | Patchy | Patchy | Annual | Annual | Annual | Annual | Annual |
| 2 | Patchy | Patchy | Annual | Annual | Annual | Annual | Annual | Annual | Annual |
| 3 | ≈ Zero | ≈ Zero | Patchy | Patchy | Annual | Annual | Annual | Annual | Annual |
| 4 | ≈ Zero | ≈ Zero | ≈ Zero | Patchy | Patchy | Patchy | Patchy | Patchy | Patchy |
| 5 | ≈ Zero | ≈ Zero | ≈ Zero | ≈ Zero | ≈ Zero | Patchy | Annual | Annual | Annual |
| 6 | ≈ Zero | ≈ Zero | ≈ Zero | ≈ Zero | ≈ Zero | ≈ Zero | Patchy | Annual | Annual |

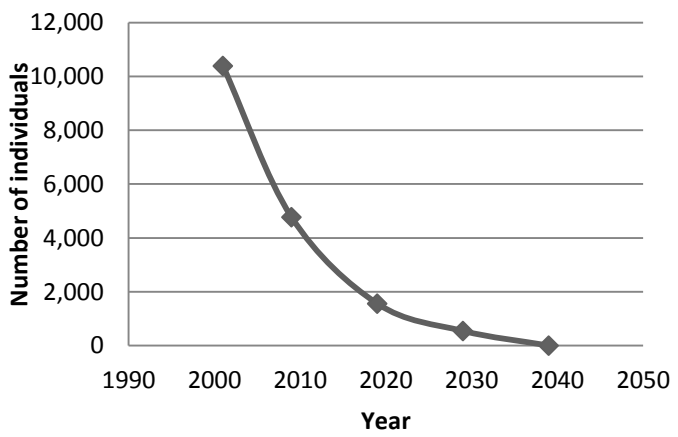
| | Good habitat | Potential habitat | No habitat |
|---|---|---|---|
| Good condition | Good, good | Potential, good | None, good |
| Moderate condition | Good, moderate | Potential, moderate | None, moderate |
| Poor condition | Good, poor | Potential, poor | None, poor |

+




=



# River bed redox

Geist and Auerswald, 2007

CEN: “critical for understanding”

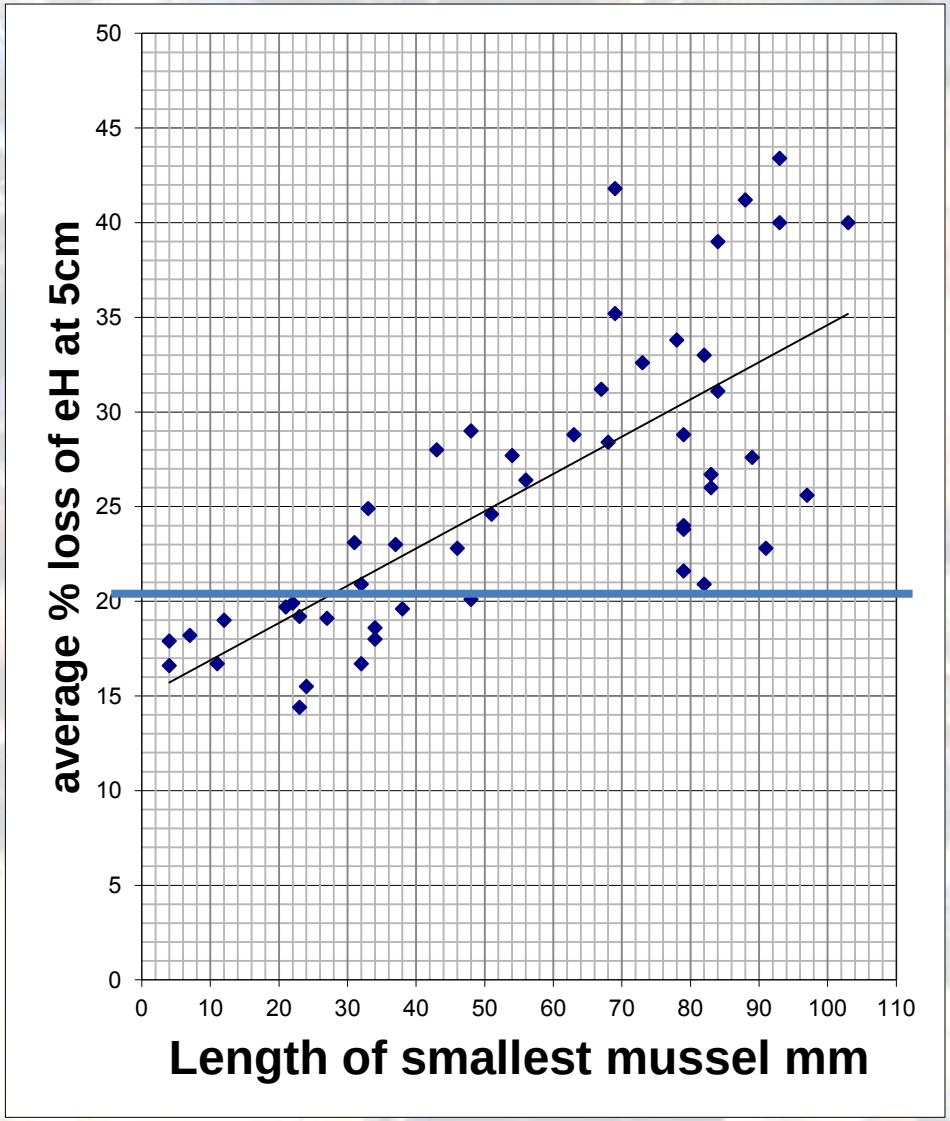
“Redox potential should indicate oxic conditions at all times, with temperature-corrected values < 300mV typically indicating anoxic conditions. There should be no pronounced difference (typically < 20 %) between open water and interstitial water at 5 cm depth”

4 readings per metre square across a transect

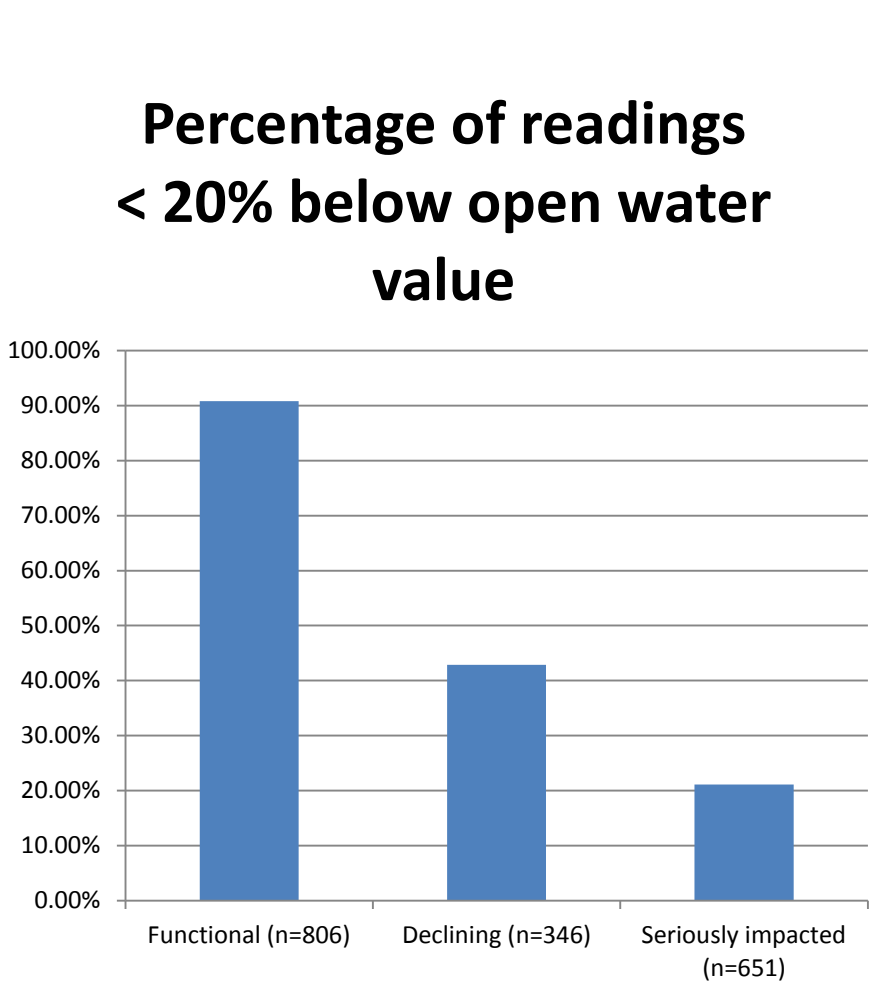


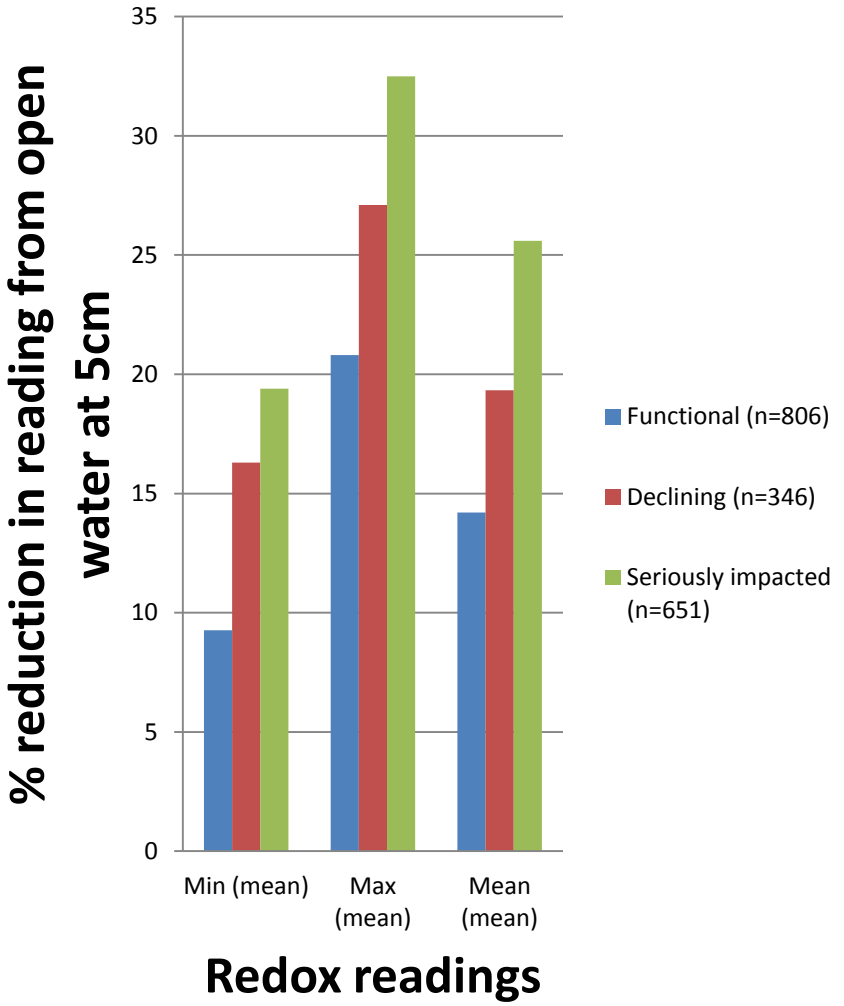
# River bed redox Average % eH loss at 5cm v smallest mussel

(25 populations)

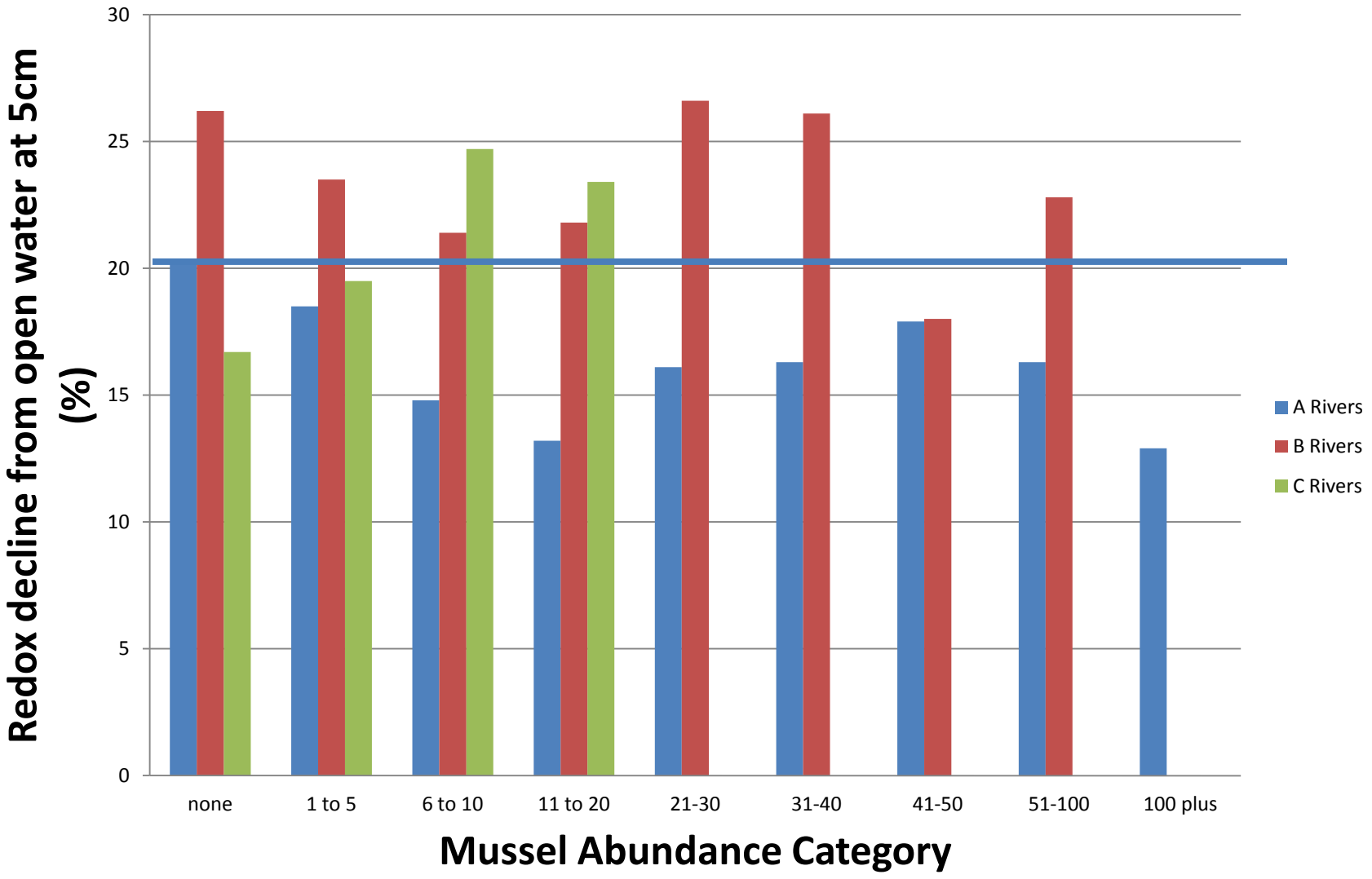


# Redox means from different river conditions



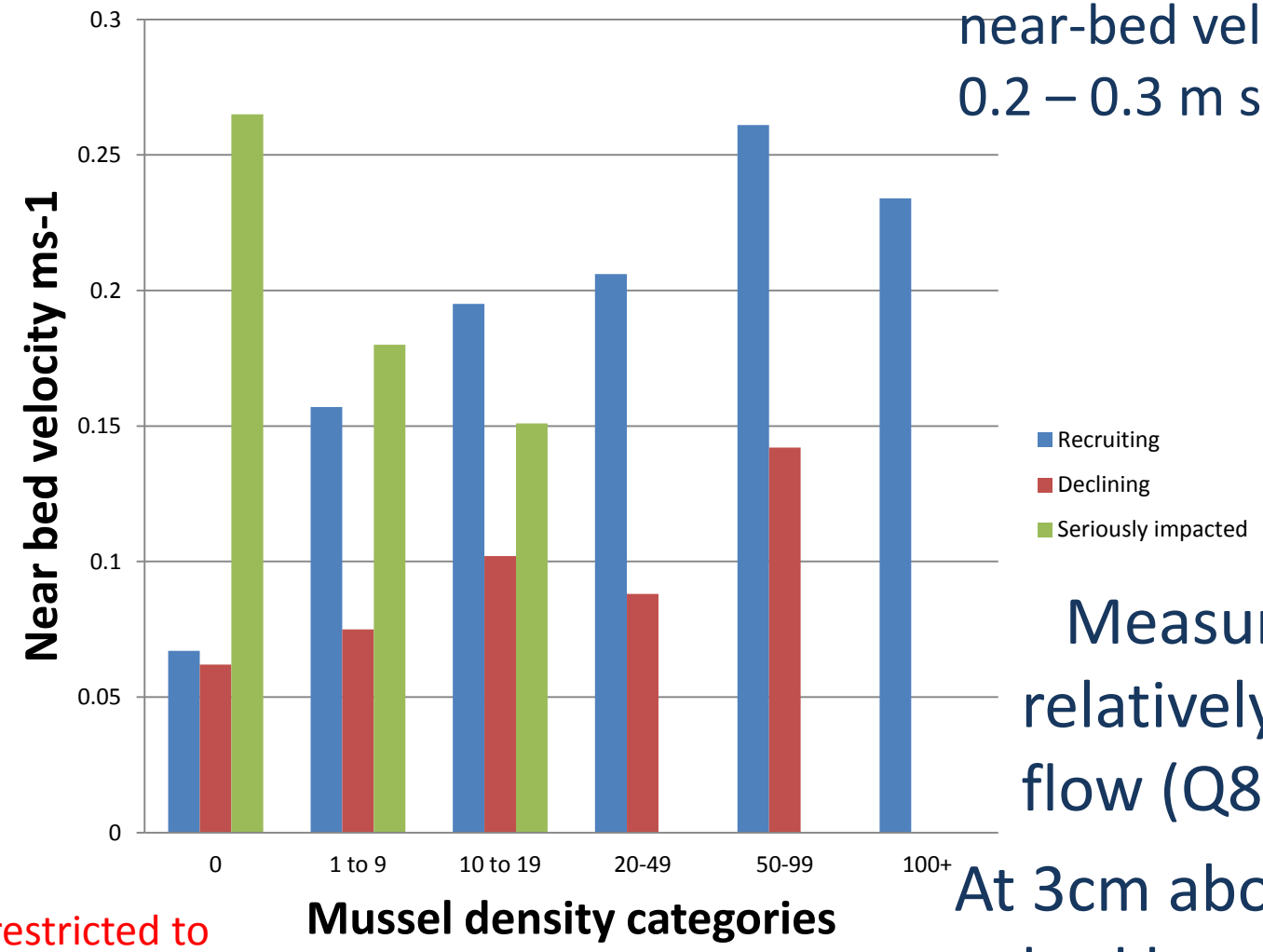
# Redox by mussel abundance




Why do declining rivers have better numbers but worse redox than very poor populations?

# Near bed velocity

Optimal habitat has near-bed velocity of 0.2 – 0.3 m $s^{-1}$.




Measured at relatively low flow (Q85 +)

At 3cm above bed level

Note: mussels restricted to fastest flow areas in poorest populations

# Investigative Monitoring: Fish hosts – densities, glochidial checks

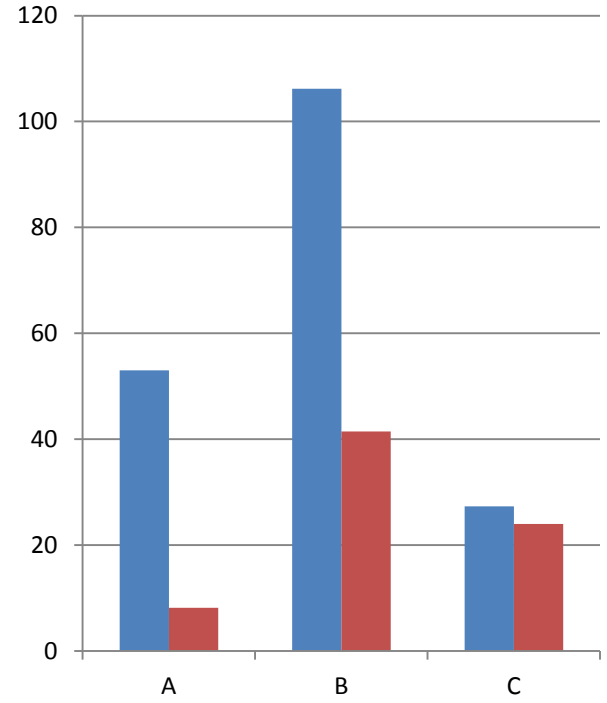
Johnston & Moorkens, 2018

- Surveyed 29 *Margaritifera* populations across three surveys (2009, 2012 & 2017)

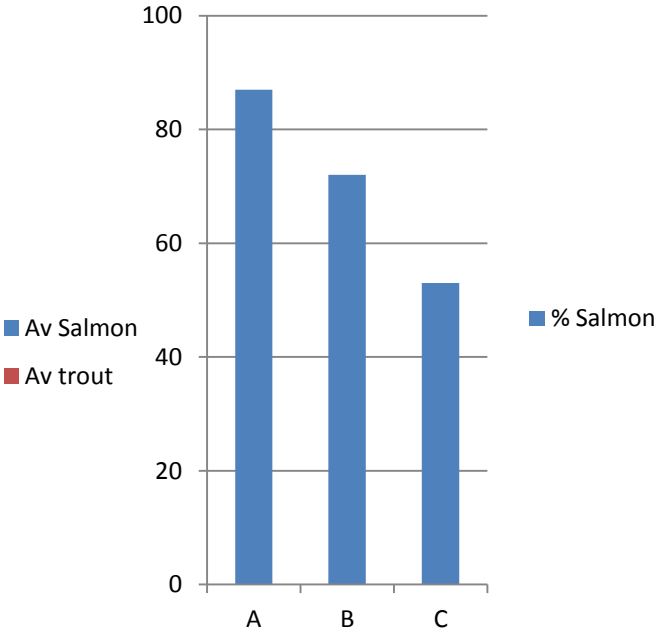
- Salmon were present in 93% rivers and were the majority species in 79%

- Trout were present in 97% of rivers but were the majority species in 17%

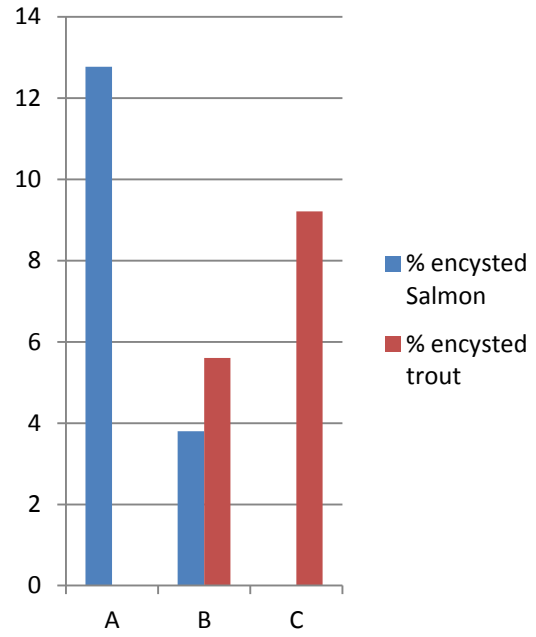
| A Recruiting | B Declining | C Severely impacted |
|---|---|---|
| Western peat catchments, with large populations and average most recent recruitment <65mm = 12.86% | Western peat catchments, with declining populations and average most recent recruitment <65mm = 0.67% | Eastern rivers with less peat, small populations and average recent recruitment <65mm 0.51% |




Average number per site



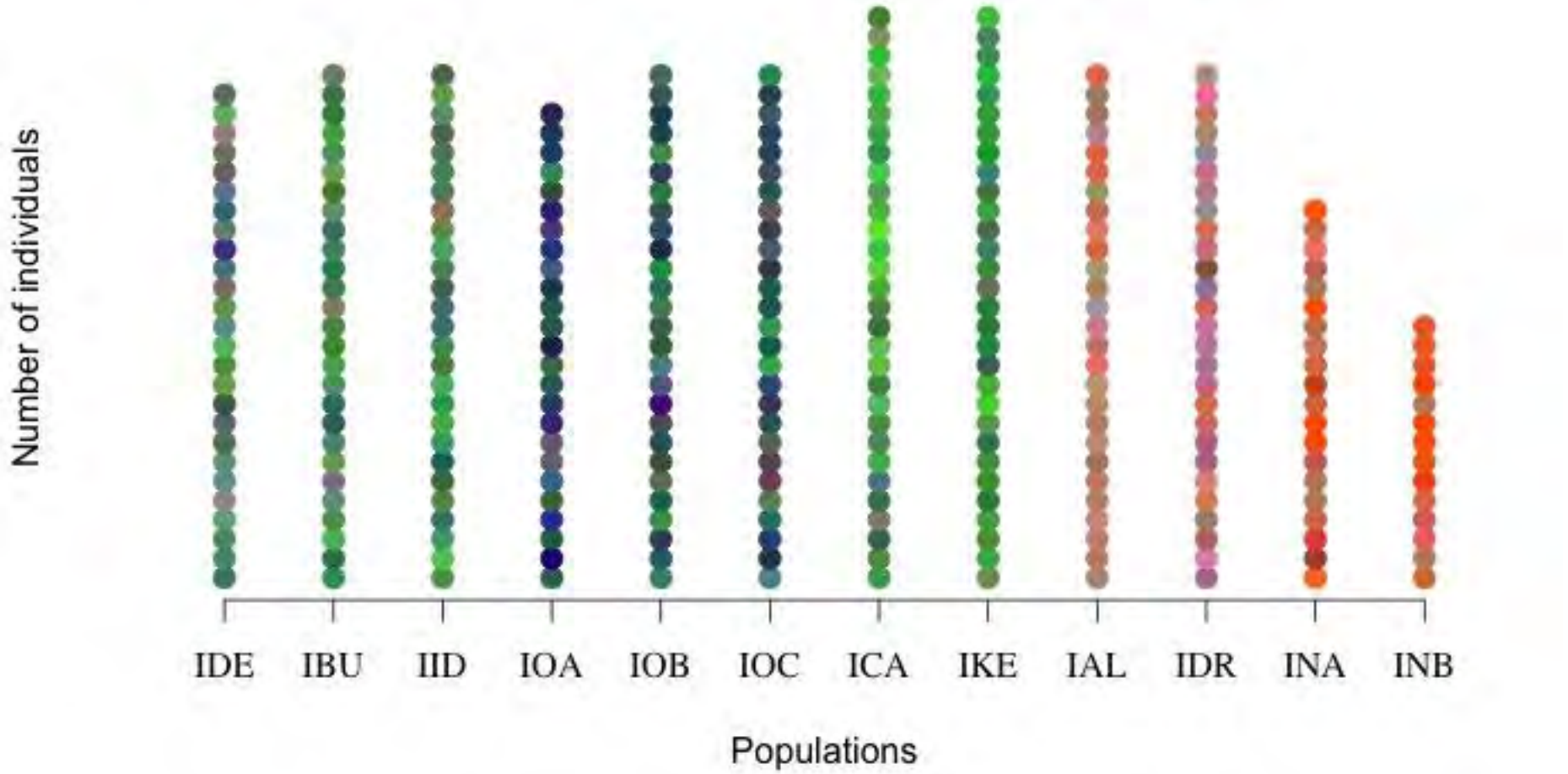

% salmon per site




% encystment per site

# Investigative Monitoring: Genetics

Geist, J., Moorkens, E., Killeen, I., Feind, S., Stoeckle, B., O'Connor, Á. & Kuehn, R. (2018). *Aquatic Conserv: Mar Freshw Ecosyst*. **28:** 923-933.



# Investigative Monitoring: Stress Testing

Moorkens E. A., & Killeen I. J. *(2018)*. *Tentacle* **26**: 3-4.



Dataset of instances of pollution events

Repeat surveys of chronic conditions

Correlations with female brooding levels

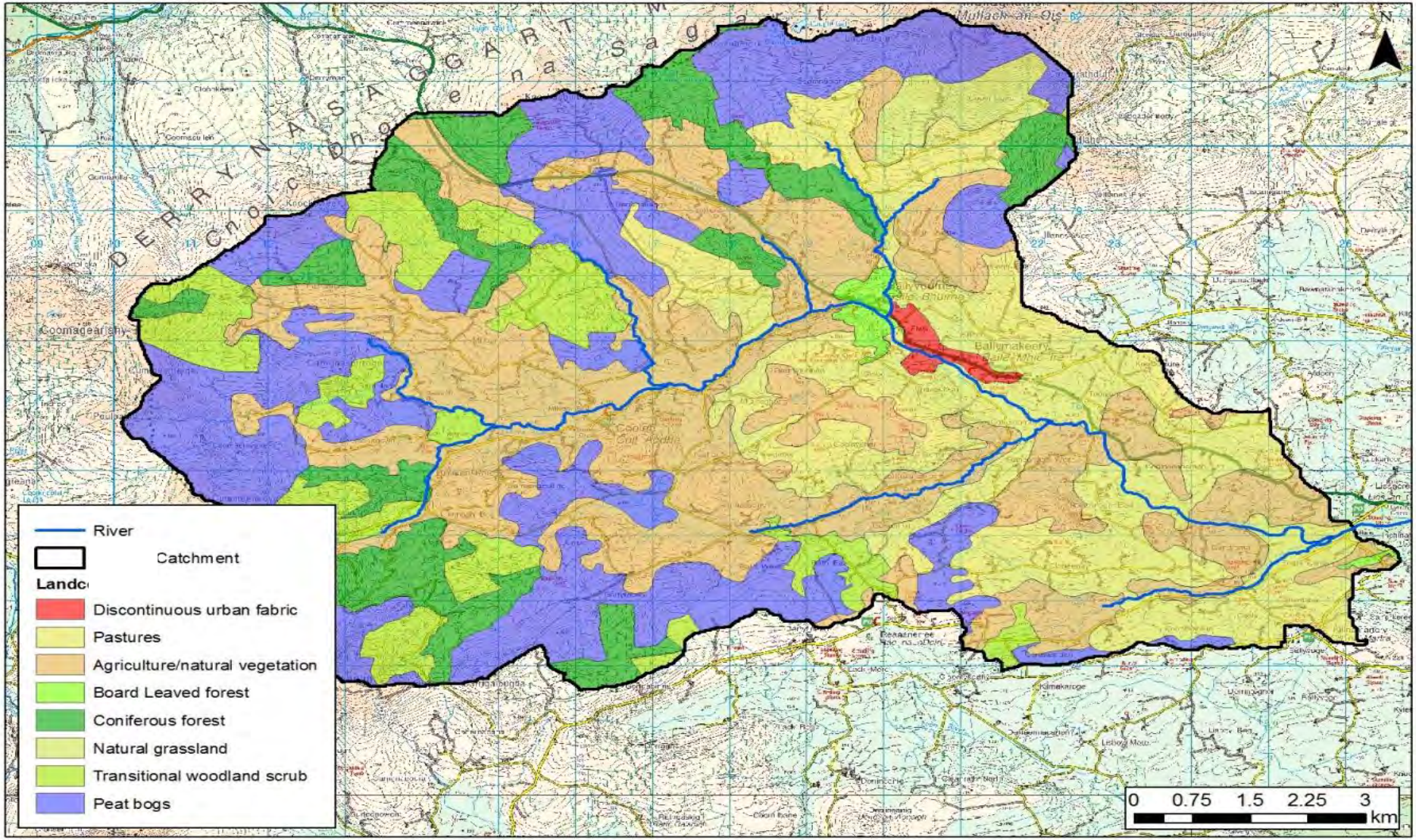
# Augmenting populations with captive reared juveniles



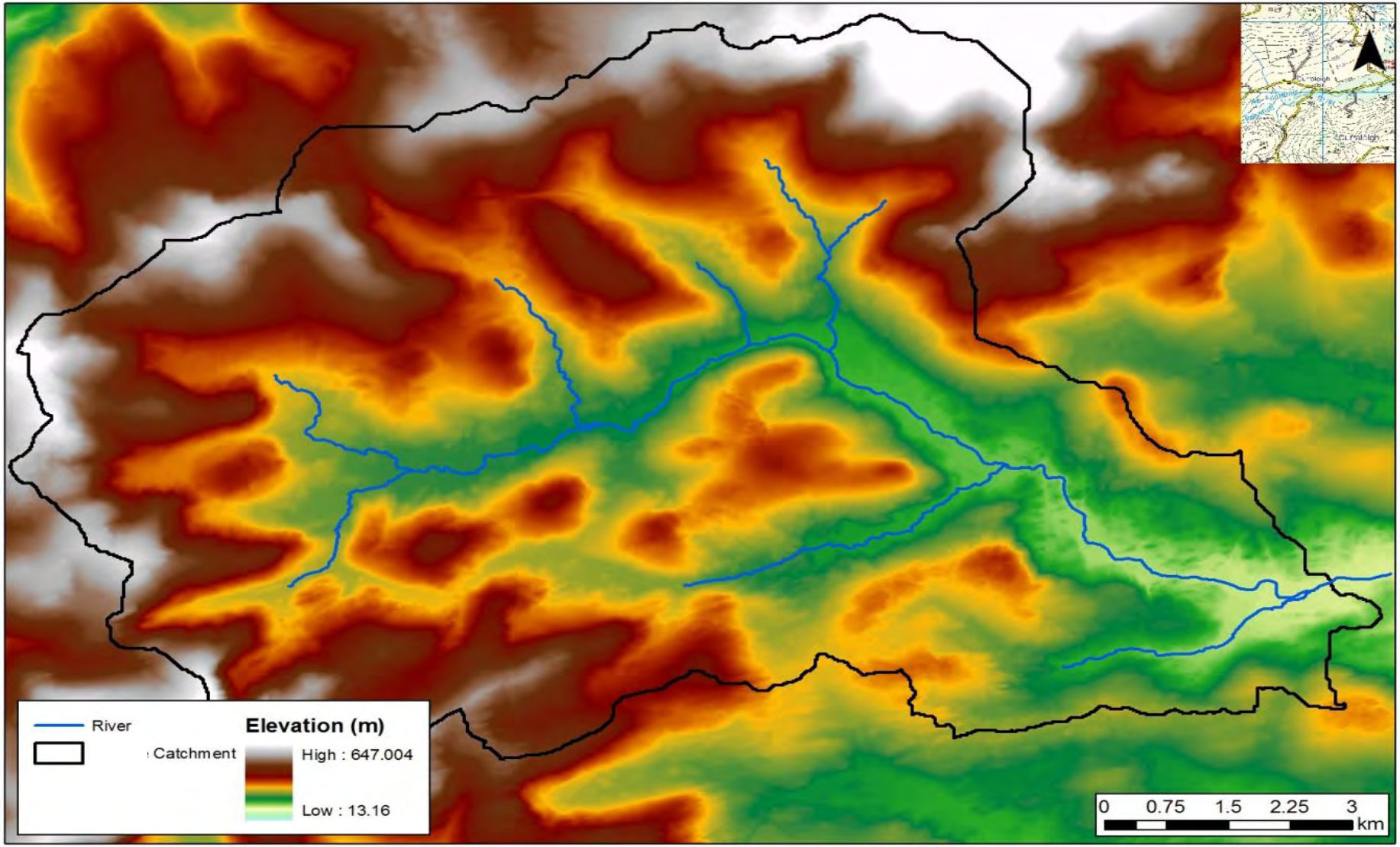
# Augmenting populations with captive reared juveniles

- Remote studies
- High flow walkover survey
- Low flow juvenile habitat survey

# Remote studies - Look for more natural land use



# DTM and LiDAR (DSM) inform areas that are likely to be too steep and which terrains are more appropriate



# Gradient analysis

As a rule of thumb FPM occurs in Ireland where elevations are below the 200m contour

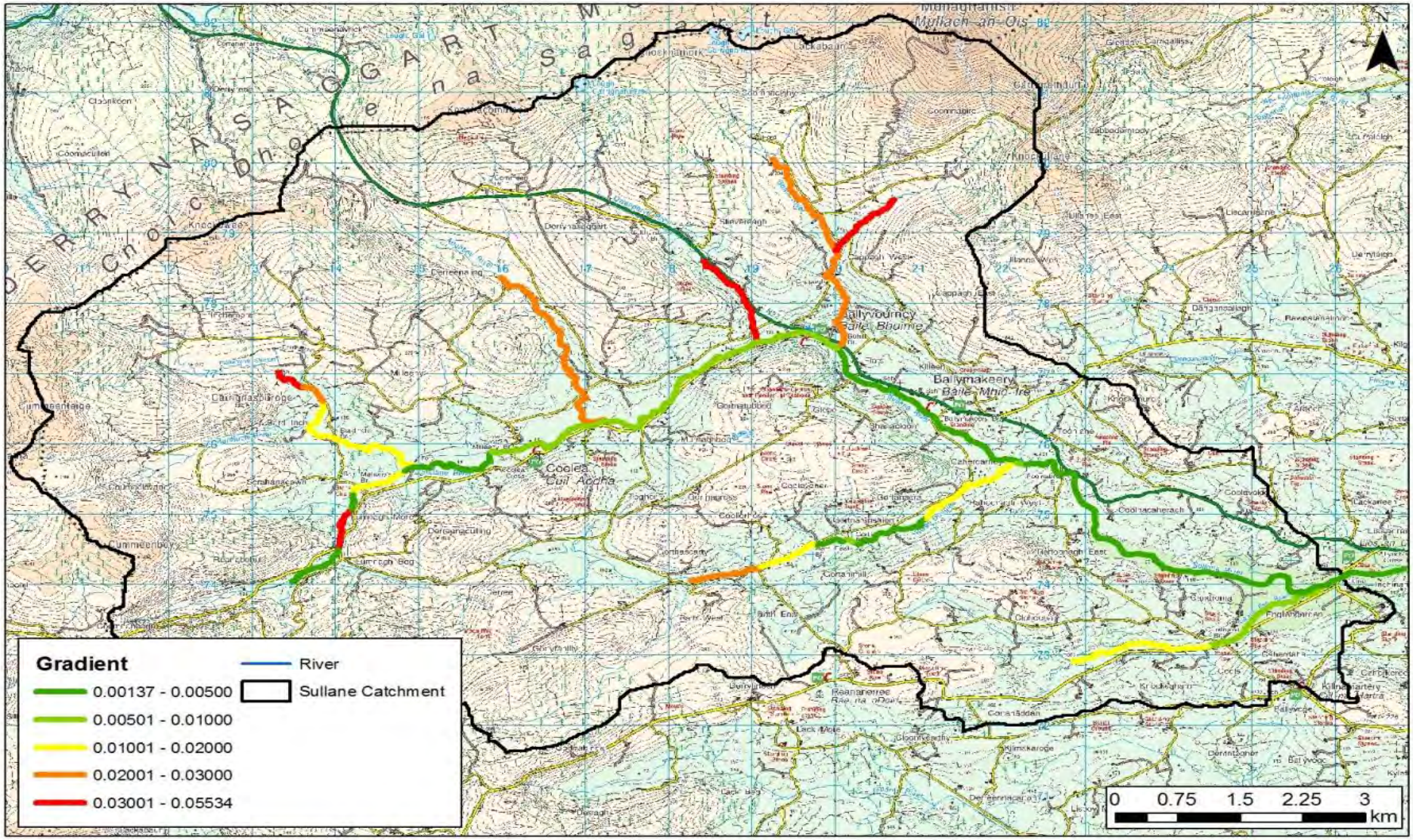
Further analysis based on the 10:85 method

Contour levels are taken at the 10% and 85% mark along each individual reach and the difference in elevation between the two points is divided by the distance

Positive areas (dark green) = 0.00137-0.005

(light green) = 0.00501-0.100

# More detailed gradient profile to narrow down areas for high and low flow surveys



# Surveys for juvenile habitat - High flow survey (walkover survey)



Good flood plain function – river bed not scoured – bring forward to low flow survey

# High flow survey
## (walkover survey)



River restricted during high flow – discount - too scoured for juvenile survival

# Low flow survey specifically for juvenile translocation(instream survey)



River bed substrate and condition poor



River bed substrate and condition good

# Low flow survey specifically for juvenile translocation(instream survey)

%redox loss Mean, Min, Max (methods based on Geist & Auerswald, 2007) (<20% decline at 5cm)

Near Bed Velocity (Methods based on Moorkens & Killeen, 2014) (0.2 – 0.3m/s at Q85)

River bed habitat mapping

(Methods based on Killeen & Moorkens, 2018) (Good habitat in good condition)



River bed substrate and condition poor



River bed substrate and condition good

# Sample of results

| | %redox loss Mean | Rank | % redox loss min | Rank | % redox loss max | Rank | NBV | Rank |
|---|---|---|---|---|---|---|---|---|
| A2 | 16 | 5.5 | 15 | 7 | 17 | 4 | 0.0955 | 9 |
| A3 | 19 | 8 | 15 | 7 | 20 | 7.5 | 0.1453 | 7 |
| A4 | 18 | 7 | 15 | 7 | 20 | 7.5 | 0.2046 | 4 |
| A5 | 16 | 5.5 | 13 | 5 | 18 | 5 | 0.2497 | 2 |
| A6 | 13 | 4 | 8 | 1.5 | 19 | 6 | 0.1762 | 5 |
| A7 | 11 | 1 | 8 | 1.5 | 13 | 1.5 | 0.3944 | 1 |
| A8 | 11.5 | 2 | 10.5 | 4 | 13 | 1.5 | 0.2236 | 3 |
| A9 | 12 | 3 | 10 | 3 | 15 | 3 | 0.1584 | 6 |

Rankings based on redox and velocity

| Site | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|
| Mussels | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 2.5 | 2.5 | 1 |
| Dominant clast | 4.5 | 4.5 | 1 | 10 | 4.5 | 10 | 10 | 10 |
| Silt infiltrated | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| Scour | 5 | 5 | 5 | 10 | 5 | 5 | 5 | 5 |
| Compaction | 7.5 | 3 | 3 | 3 | 3 | 7.5 | 7.5 | 11 |
| Filamentous algae | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 |
| Diatom abundance | 7 | 7 | 7 | 1.5 | 7 | 7 | 7 | 7 |
| Macrophytes | 11 | 8 | 8 | 4 | 8 | 4 | 4 | 4 |
| Bryophytes | 9 | 9 | 9 | 9 | 9 | 3 | 3 | 9 |
| Juvenile habitat suitability | 6 | 2 | 2 | 6 | 2 | 6 | 6 | 6 |
| Juvenile habitat condition | 9.5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Juvenile food seepage | 8.5 | 8.5 | 8.5 | 8.5 | 2.5 | 2.5 | 2.5 | 2.5 |

Rankings based on habitat mapping

# Overall rankings

| Site | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | B1 | B2 | C1 | C2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sum of parameter rankings** | 122 | 106 | 95.5 | 92 | 86 | 70.5 | 75 | 93.5 | 148.5 | 143 | 141 | 149 |
| **Overall rank** | 8 | 7 | 4 | 6 | 3 | 1 | 2 | 5 | 11 | 9 | 10 | 12 |

The study concluded that even the best sites in Reaches B and C would be inappropriate sites for juvenile augmentation, but Reach A has good potential for translocation of juveniles.

It was recommended that the best sites at Reach A (A6, A7 and A8) should be used in Year 1.

# Conclusions – Most useful monitoring?

## Regular monitoring

Juvenile habitat mapping and condition monitoring including repeat transects

Associated with mapped areas: age class demographic studies by habitat/condition category

River bed redox

Near bed velocity

Assessment of algal / macrophyte cover

## Investigative monitoring / investigations

Stress and mussel brooding level checks

Genetic differences

High flow walkover surveys

Shell age v size analysis

Sedimentation rate studies

Fish host checks

# Conclusions

- Baseline, regular, investigative monitoring and ongoing research are all needed

- The best combination of techniques help to guide us to :
  - Locations and measures to restore sustainable populations
  - Restoration targets e.g. Drain blocking to restore water table where there is low near-bed velocity
  - Sites for placement of captive bred juveniles

# Conclusions

- Sustainable *Margaritifera* populations relate only to very high end of high status so does not fit in well with WFD process of protection
- Does not relate to macroinvertebrate WFD / EQR monitoring as its habitat (needs very clean and very stable habitat) is not monitored
- Does not relate well to thresholds and averages – e.g. Quinlan et al. (2014) study - DO % saturation averages 81 - 103%, but minimum levels dropped as low as 0.26%
- Concentrate on research that will assist with understanding mechanisms and restoration management rather than "drop dead" thresholds that are not ecologically relevant (but loved by engineers!)



But well worth the effort!!!

# Thank you

FPM – Ian Killeen
NPWS – Áine O'Connor
Environment Agency
United Utilities
RPS –Francis Mackin
Kerry LIFE team - Richard O'Callaghan, Paul Phelan
FPM CEN group

