# Population Genetics & Trophic Ecology of Pike (*Esox lucius*) in Ireland.

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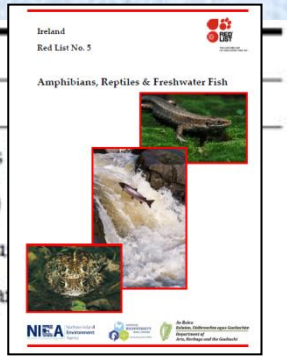
# Irish Freshwater fish species

- 24 freshwater species
- 11 native
- **13 non-native**
- *Esox lucius*
- 4 data deficient




| Common Name | | Scientific Name |
|---|---|---|
| *Species which spend their entire life or the major part thereof in freshwater* | | |
| River lamprey | | *Lampetra fluviatilis* (Linnaeus |
| Brook lamprey | | *Lampetra planeri* (Bloch 1784) |
| Sea lamprey | | *Petromyzon marinus* (Linnaeu |
| Killarney shad | | *Alosa fallax killarnensis* (Rega |
| Atlantic salmon | | *Salmo salar* Linnaeus 1758 |
| Brown trout/Sea trout | | *Salmo trutta* Linnaeus 1758 |
| Arctic char | | *Salvelinus alpinus* (Linnaeus 1758) |
| Pollan | | *Coregonus autumnalis pollan* (Pallas 1776) |
| European eel | | *Anguilla anguilla* (Linnaeus 1758) |
| Three-spined stickleback | | *Gasterosteus aculeatus* Linnaeus 1758 |
| Ten-spined stickleback | | *Pungitius pungitius* (Linnaeus 1758) |
| Pike | 1500s | *Esox lucius* Linnaeus 1758 |
| Common carp | 1600s | *Cyprinus carpio* Linnaeus 1758 |
| Tench | 1600s | *Tinca tinca* (Linnaeus 1758) |
| Common bream | Pre-1700s | *Abramis brama* (Linnaeus 1758) |
| Roach | 1889 | *Rutilus rutilus* (Linnaeus 1758) |
| Dace | 1889 | *Leuciscus leuciscus* (Linnaeus 1758) |
| Rainbow trout | 1899 - 'domesticated' | *Oncorhynchus mykiss* (Walbaum 1792) |
| Rudd | Pre - 1900 | *Scardinius erythrophthalmus* (Linnaeus 1758) |
| Chub | 2001 | *Leuciscus cephalus* (Linnaeus 1758) |
| Gudgeon | 1100s - no data | *Gobio gobio* (Linnaeus 1758) |
| Stoneloach | 1100s - no data | *Barbatula barbatula* (Linnaeus 1758) |
| Minnow | 1100s - no data | *Phoxinus phoxinus* (Linnaeus 1758) |
| Perch | 1100s - no data | *Perca fluviatilis* Linneaus 1758 |

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# Why Pike?

- Important species globally (tourism, angling, commercial fishing, etc.)
- Circumpolar – very adaptable
- Declines evident in many areas
- Invasive in others (Spain, Alaska)

In Ireland:

- Understudied
- Knowledge misconception
- Conflict

# Pike In Ireland

- Pike a stated preference for brown trout *Salmo trutta*
  - limited studies, >50cm
- Managed as an introduced species;
  - Controversial predator control operations
  - Human mediated transfers
- Removals drastically reduced in recent years


- **Relevant Research Questions:**
  - Are 'Irish' pike Irish?
  - What do pike eat and does it vary?

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# Genetics

# Why Pike?

- 3 main research questions:
  - Is there a structure to Irish pike populations?
  - Are 'Irish' pike Irish?
  - If not, where did they come from?

Victor Kutischev, Underwater-Ireland.com

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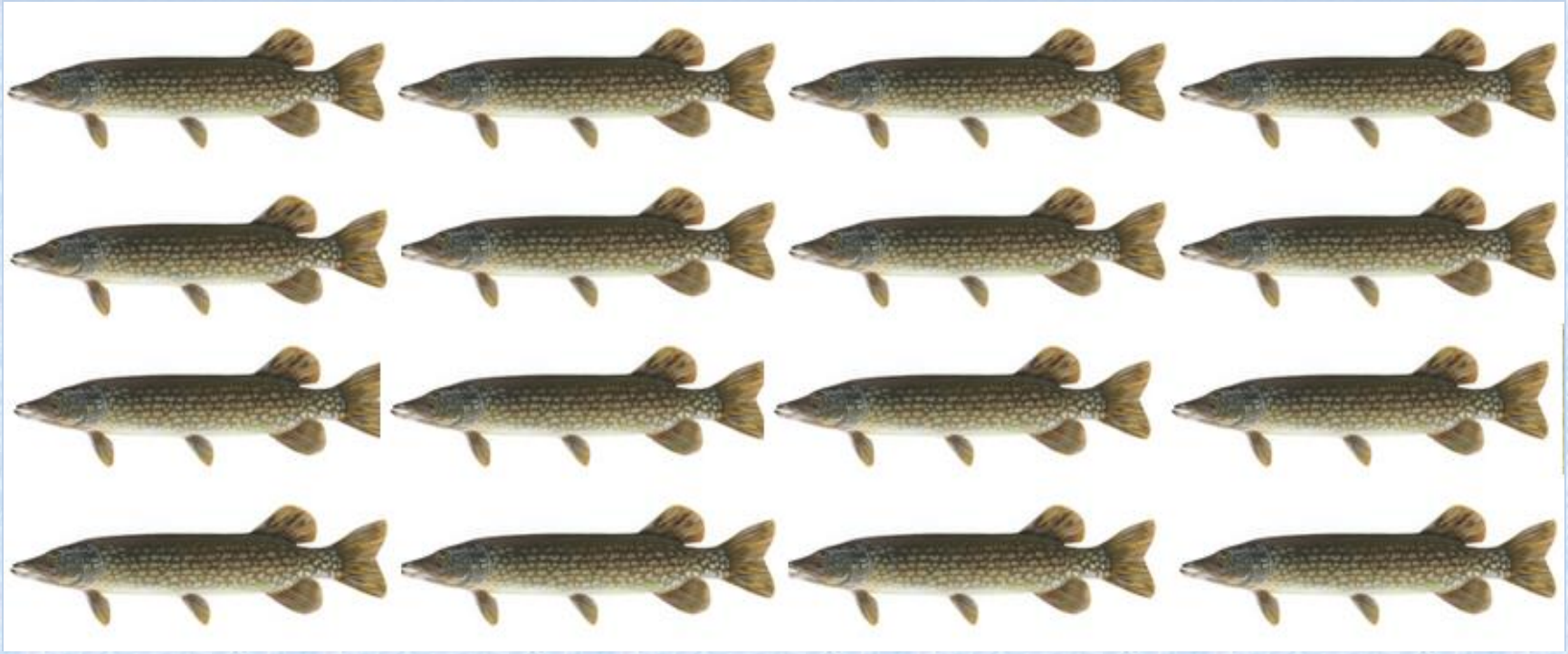
# GENETICS

- Pronounced invariability – Cretaceous radiation



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# GENETICS

- Microsatellite genetic investigation
- 752 pike from 15 locations around Ireland, plus European outgroups
- Only study to include Ireland found complete monomorphism with in the River Shannon (Jacobsen *et al*. 2005)

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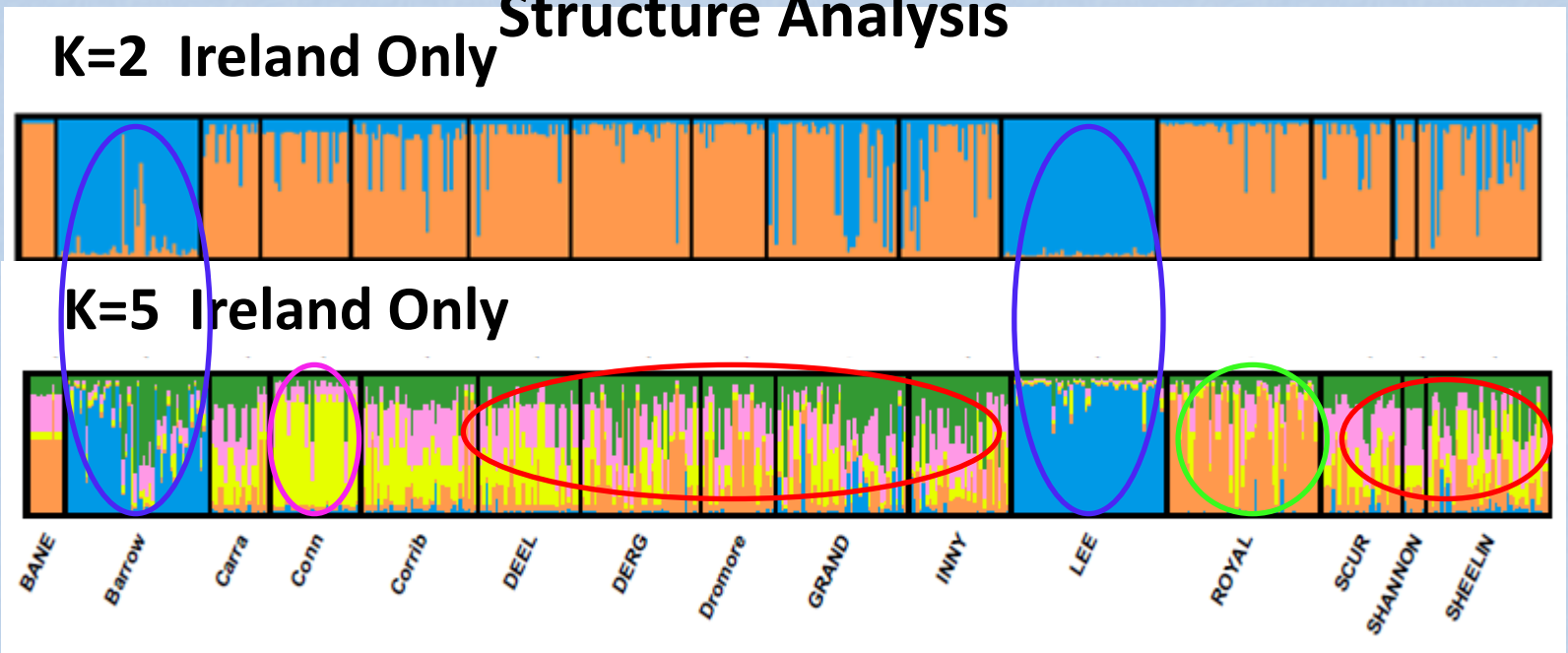
# GENETICS

- **Expected:** extreme lack of variation, historically bottlenecked population

  - founding effect

  -little or no population structure (transfers)

# GENETICS




- **Observed:** minimum of 2 Irish strains, some divergent populations

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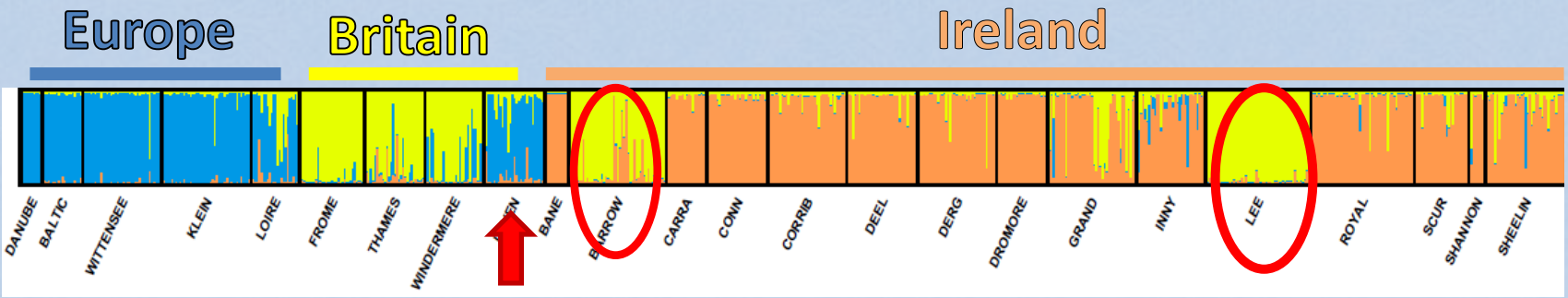
# STRUCTURE

## Structure Analysis

**K=3 All Groups**




- **Observed:** European Groups Separate
- English grouping complex
- 2 Irish strains hold
- At least one introduction from Britain

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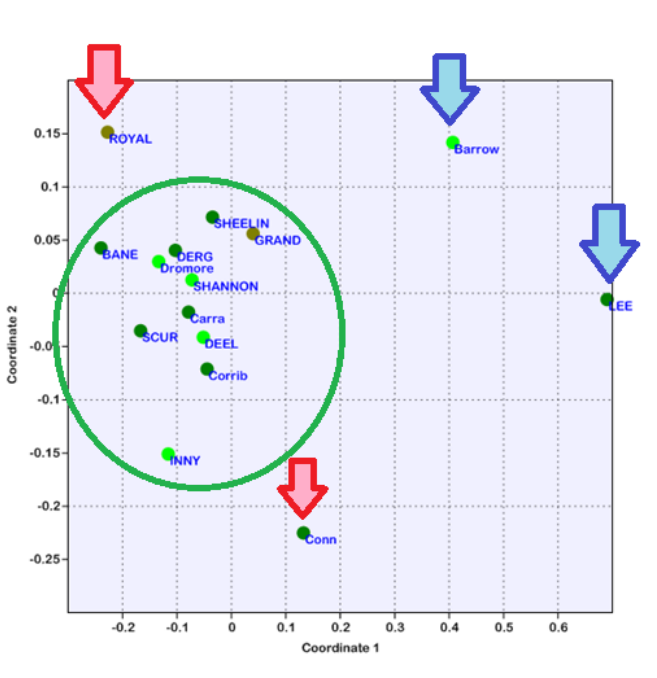
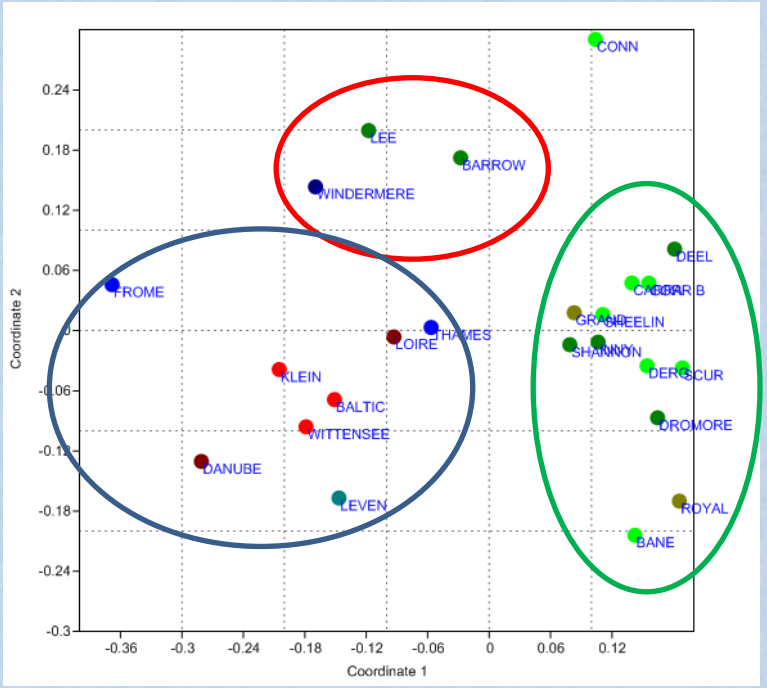
# DIFFERENTIATION

## Ireland Only




## All Groups




Plot of pairwise Fst values enabling visualisation of evolutionary relationships

$F_{ST}$ is a measure of the departure from random mating caused by population structure.

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# DIFFERENTIATION

| Class | Number of species | Number of subpopulations | Number of loci | $H_T$ | $H_S$ | $F_{ST}$ |
|---|---|---|---|---|---|---|
| Fish | 113 | 6.60 ± 0.46 | 28.08 ± 0.81 | 0.062 ± 0.004 | 0.053 ± 0.003 | 0.132 ± 0.016 |
| Marine | 57 | 6.40 ± 0.62 | 29.19 ± 1.22 | 0.064 ± 0.004 | 0.059 ± 0.004 | 0.062 ± 0.011 |
| Anadromous | 7 | 13.14 ± 3.12 | 27.43 ± 1.86 | 0.057 ± 0.007 | 0.052 ± 0.008 | 0.108 ± 0.044 |
| Freshwater | 49 | 5.90 ± 0.53 | 26.88 ± 1.18 | 0.062 ± 0.007 | 0.046 ± 0.005 | 0.222 ± 0.031 |
| Amphibia | 49 | 5.53 ± 0.57 | 22.59 ± 0.75 | 0.146 ± 0.012 | 0.097 ± 0.008 | 0.308 ± 0.033 |
| Birds | 28 | 4.75 ± 0.65 | 29.21 ± 1.34 | 0.059 ± 0.006 | 0.054 ± 0.006 | 0.078 ± 0.021 |
| Mammals | 83 | 4.82 ± 0.37 | 27.89 ± 0.85 | 0.077 ± 0.005 | 0.057 ± 0.004 | 0.207 ± 0.023 |
| Reptiles | 33 | 5.58 ± 0.73 | 23.73 ± 1.36 | 0.115 ± 0.014 | 0.086 ± 0.010 | 0.222 ± 0.036 |

Taken from: Hart & Reynolds, (2008). Handbook of fish biology and fisheries

## Ireland Only

**Mean Fst: 0.264 (95% C.I. 0.161 - 0.304)**

## All Groups

**Mean Fst: 0.328 (95% C.I. 0.252 - 0.448)**

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# AMOVA

**Table 3** Analyses of molecular variance (AMOVA) for pike populations. Four grouping scenarios are reported, the highest support is found for those displaying the largest $F_{CT}$ in relation to $F_{SC}$, i.e. the largest percentage of variation accounted for by the grouping design, which minimizes the variation within these groups.

| Grouping | Source of variation | d.f. | % variation | *F*-index | *P* |
|---|---|---|---|---|---|
| 1. Ireland<br>2. Britain<br>3. Europe | Among groups<br>Among populations within groups | 2<br>21 | 23.23<br>17.08 | 0.232 ($F_{CT}$)<br>0.223 ($F_{SC}$) | < 0.001<br>< 0.001 |
| 1. Main Ireland<br>2. Britain & Europe<br>3. Barrow, Lee, Windermere | Among groups<br>Among populations within groups | 2<br>21 | 25.15<br>14.06 | 0.252 ($F_{CT}$)<br>0.188 ($F_{SC}$) | < 0.001<br>< 0.001 |
| 1. Main Ireland<br>2. Europe & Leven<br>3. Britain, Barrow & Lee | Among groups<br>Among populations within groups | 2<br>21 | 24.69<br>14.27 | 0.247 ($F_{CT}$)<br>0.190 ($F_{SC}$) | < 0.001<br>< 0.001 |
| 1. Main Ireland<br>2. Europe, Leven & Thames<br>3. Barrow, Lee, Windermere<br>4. Frome<br>5. Conn | Among groups<br>Among populations with groups | 4<br>19 | 26.95<br>11.57 | 0.270 ($F_{CT}$)<br>0.158 ($F_{SC}$) | < 0.001<br>< 0.001 |

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# SUPPORT

- Three methods: Same story
- Nature of pike populations in Ireland is not as simple as first thought
- Distinct populations evident: at least one British introduction
- Unique 'Irish' alleles (4 = 10%)
  - 22% of alleles shared with Europe, not Britain
  - Incomplete sampling?
- Identifiable signals
  - Shannon movement (transfer) admixture
  - Royal & Barrowline signals
  - Conn founding event?

# SNPs

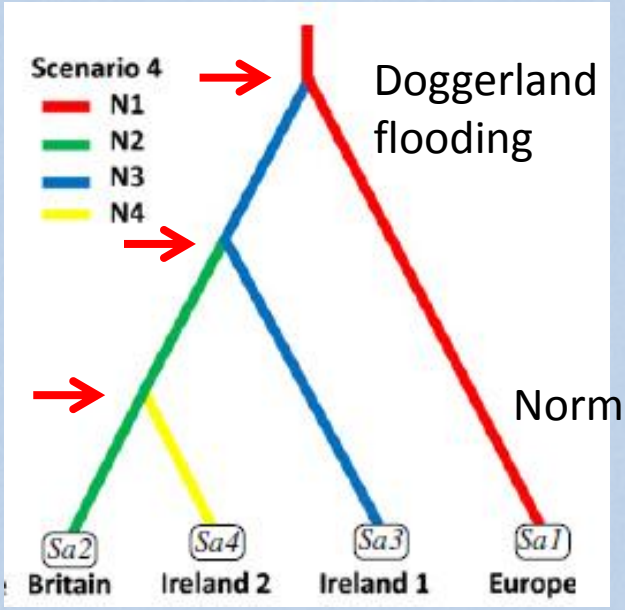
- Conclusion of original story – more info needed
- High monomorphism requires more fine scale method
- Single nucleotide polymorphims
- Instead of 6 microsatellites – 5-6000 SNPs
- Initial indications support conclusions of original study

# IMPLICATIONS?

- More questions:
  - Introduction date?
  - Multiple introductions ?
  - Possible Irish strain?
- Where to start?????

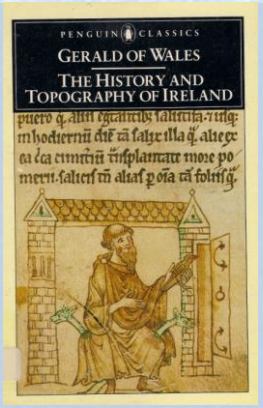
# DIYABC

- **DIYABC** – simulates data based on specified input values, then compares them to real input data
- 17 scenarios tested
- Inferences for introduction times / dates
- T1 – c. 8,000 ya
- T2 – c. 4,000 ya
- T3 – c. 1,000 ya



# Alternate Avenues

## Why 1600's?




- Seminal paper Went 1957
- Evidence given:
  - Giraldus Cambrensis (reliability?)
  - Gailliasc (foreign fish)
  - Documentation of lack of pike in local areas (17th & 19th Century)
  - Longfield's Anglo-Irish Trade in the Sixteenth Century (misquoted)

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# Alternate Avenues

## Archaeological Evidence

- Problems in Ireland:
  - Fish not a priority
  - Preservation issues – wet boggy land
  - Sites rarely sieved
- Consult the experts and online sources
- Double check: museum collections & experts
- **Confirmed:** Pike bones from Anglo-Norman Trim Castle – L13th- E14th century
- Fits well with other introduced species



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# Alternate Avenues

## Language & Folklore

- No evidence of pike in Irish folklore....
- Earliest written reference:
  - Edmund Spenser, Epithalamion 1595
- Language: *Gailliasc* – 'foreign fish': Normans were known as the *gaill*
- Philip O'Sullivan-Beare 1626 Zoilomastix, refute to Cambrensis – uses Liús
- Fitzmaurice misquotes Farran in saying 'gailliasc' is only Irish name
- Liús found to predate gailliasc

**LOCAL NAMES OF IRISH FISHES.**

By G. P. Farran. **1946**

Pike, *Esox lucius* L.

Mayo:—Liús **32**; giosán **O'R**.
Galway:—Gailliasc **2**, **72**; lús, pl. lúsaigh **13**.
Kerry:—Liús **7**; gailliasc **81**.
Waterford:—Gailliasc **8**.
Westmeath:—Giosán **O'R**.
Roscommon:—Giosán **O'R**.
Unlocalized:—Gailliasc **O'R**, **Din**, **17**; lús, liús **Din**; gedas **O'R**
geadas **O'R**, **Din**; giosán, giosóg **Din**; " galiesk or lusc " **3**
Gedd or gade near Moray Firth and Lowland Scotch **19**; gedda i
Danish and Norwegian.

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# CONTROVERSY

- Is it?
- '*leaves the debate on human introduction vs. natural colonisation, introduced vs. native status, and pike management wide open*'
  - Agree – but now it is better informed
- '*Changes in management that could result in further spread...would be ill advised*'
  - Agree - precautionary


- Glacial history of Ireland not clear – contested
  - Irish sea deglaciation '*one of the least certain elements*'
- Natural or man-mediated introduction 4ka? Does it matter?
  - What does that mean for status? Naturalised?

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# Conclusions

- Indications, not conclusive answers
- Population substructure is high and comparative to elsewhere in Europe
- Multiple approaches concur
- Cleithra – indicate pike present alive?

*'Absence of Evidence is **not** Evidence of Absence!'*

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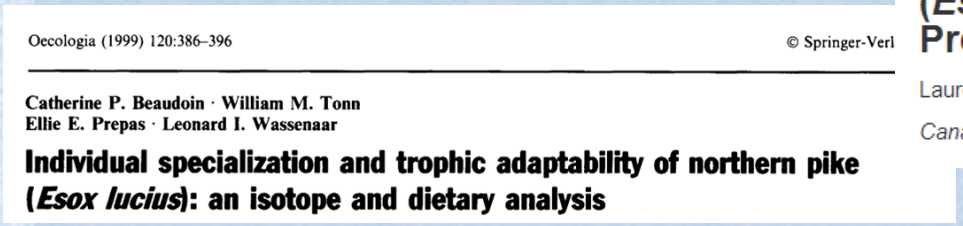
# Trophic Ecology

# Why Pike?

- Top down keystone predator
- Bad reputation
- Reported preference for brown trout *Salmo trutta* - limited studies, poor size range
- Narrow (often trout) focus, 1950-1980s
  - Changing ecosystems – invasive species, eutrophication, etc.
- General literature highlights flexibility
- Evidence of specialisation on invertebrates



Oecologia (1999) 120:386–396 © Springer-Verl

Catherine P. Beaudoin · William M. Tonn
Ellie E. Prepas · Leonard I. Wassenaar

**Individual specialization and trophic adaptability of northern pike (*Esox lucius*): an isotope and dietary analysis**

**Feeding Flexibility in Northern Pike (*Esox lucius*): Fish versus Invertebrate Prey**

Lauren J. Chapman, William C. Mackay, Craig W. Wilkinson

*Canadian Journal of Fisheries and Aquatic Sciences*, 1989, 46(4): 666-669, 10.1139/f89-085

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# RESEARCH QUESTIONS - IMPORTANT



- Comparisons across habitat type; rivers, lakes and canals
- Variations with size (ontogenetic switch)

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# METHODS

- Stable Isotope Analysis & Stomach Content Analysis
- SIA: longer time period, trophic level determination
- SCA: higher resolution, species identification

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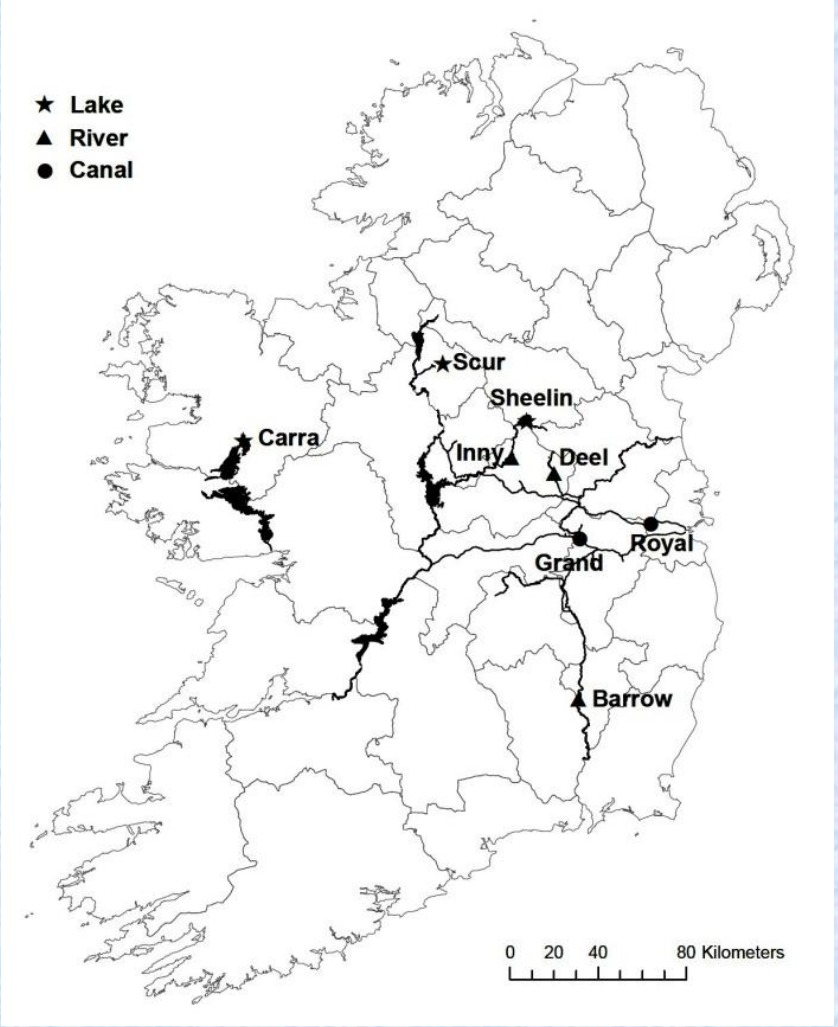
# SAMPLING

- 3 lakes
- 3 rivers
- 2 canals
- Covers range of habitat types & sizes
- 1 of each habitat type resampled

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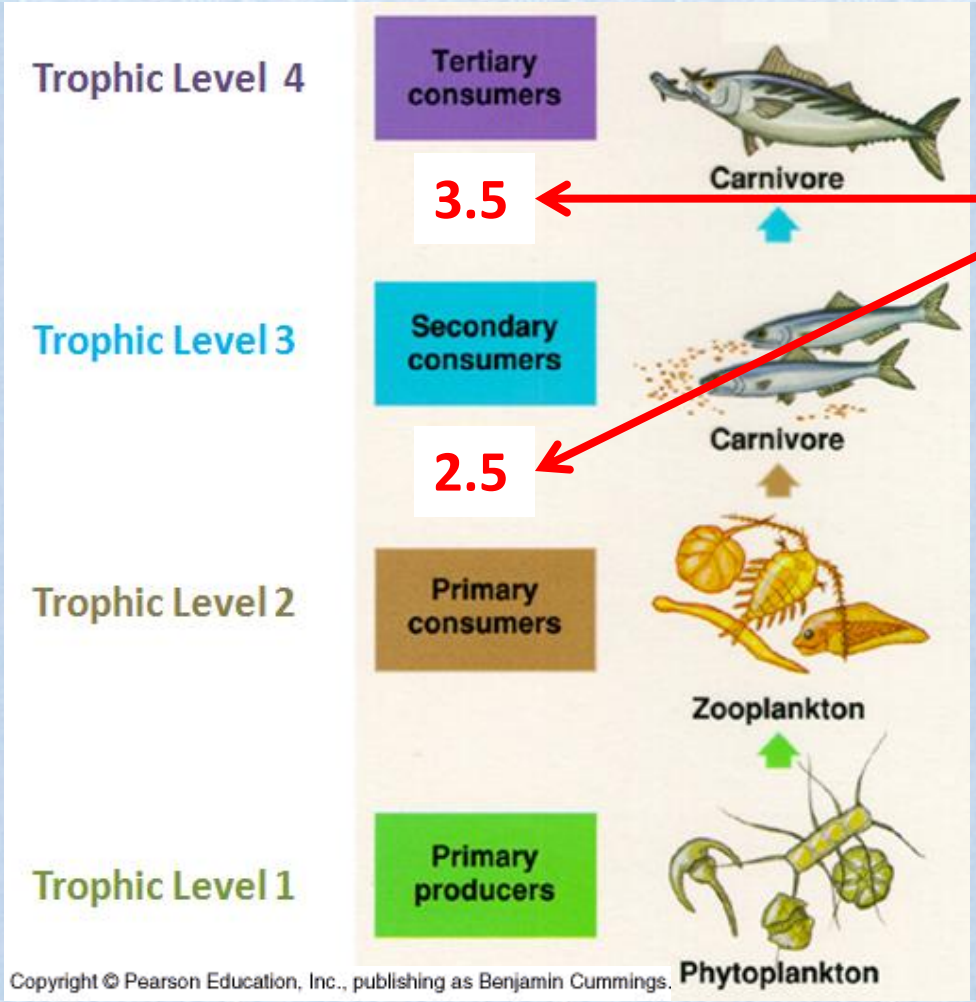
# Trophic Levels




| | | Avge TP |
|---|---|---|
| River | Deel | 3.8 |
| | Inny | 4 |
| | Barrow | 3.8 |
| Lake | Sheelin | 3.9 |
| | Carra | 3.7 |
| | Scur | 3.6 |
| Canal | Grand | 3.8 |
| | Royal | 3.2 |

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# % IRI

- Gravimetric, volumetric, numbers, points, etc….
  - Result will vary dependent on method used
- Index of Relative Importance-
  - % number
  - % weight
  - % occurrence
- Adjusted weight – account for size of fish
- Modified Points method that accounts for fish ‘fullness’

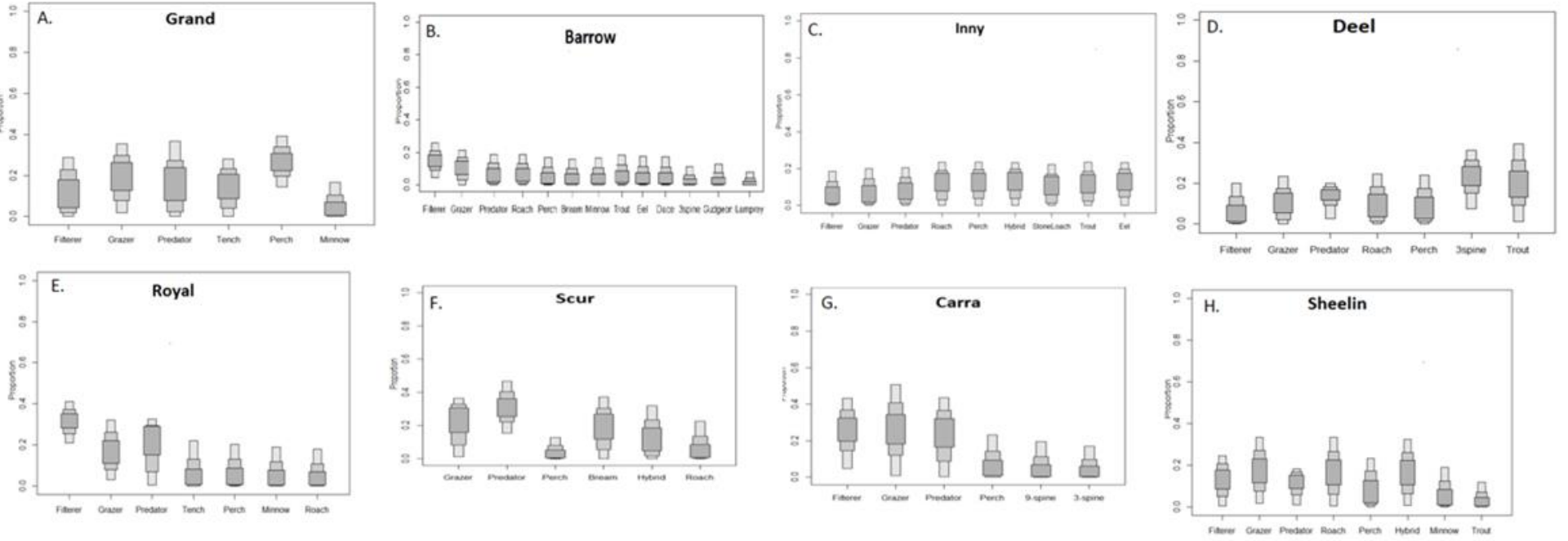
# % IRI

- Roach and *Asellus* most important
  - Pooled across all sites
    - See papers/thesis for finer detail

| | |
|---|---|
| Roach | 25% |
| Asellus | 25% |
| Perch | 10% |
| Gammarus | 9% |
| Frogs | 4% |
| 9 spine stickle | 3% |
| Trout | 3% |
| Minnow | 3% |
| Pike | 2% |
| Dace | 2% |
| Zygoptera | 2% |
| Ephemoptera | 2% |
| Molluscs | 2% |

# Diet Differences

- SIMPER: roach, *Asellus* and perch (in that order) primarily responsible for differences between sites
- Exceptions: Lough Carra &River Barrow frogs & dace
- SIAR: mixing model - uninformative

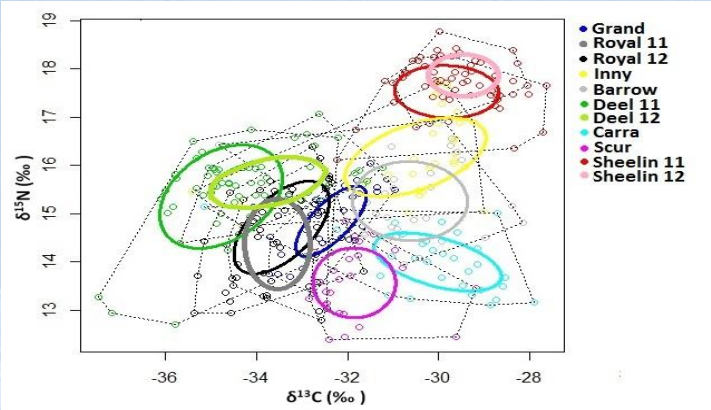


# SPECIALISATIONS

- SCA
  - Niche breath calculated using std Levins Index
    - 0 (consume a single item)
    - 1 (exploits available items in equal proportion)
  - Indspec software (proportional similarity index)
    - Individuals consume same as rest of population (i.e. generalisation) = 1
    - Strong individual specialisation = 0
- Results
  - Niche breadth: average 0.07 (0.01-0.13)
  - Average (IS) values = 0.25 (range 0.12-0.49)
  - Overlap average 0.18 (range 0.06 - 0.34)
- High individual specialisation - all eating different things…

# SPECIALISATIONS

- SIA
  - SIBER niche sizes (SIAR package)
- Conclusion – little overlap as individuals feed opportunistically
- No consistent patterns in diet between any of the sites examined – local variation

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# SPECIALISATIONS

- Wide range of N values – nearly full trophic level indicating a wide prey base and range of feeding strategies

- Diet relates to abundance

| Site | Spearman RS | P |
|---|---|---|
| Barrow | 0.679 | ***<0.01*** |
| Grand | 0.569 | ***<0.01*** |
| Royal | 0.416 | ***0.05*** |
| Scur | 0.386 | 0.07 |
| All | 0.522 | ***<0.001*** |

# Ontogenetic Switch

- Increase in fish with length: P≤0.05 7/11
- Decrease in invertebrates: P≤0.05 9/11
- Increase in empty stomachs: P≤0.05 2/11
- Increase in δ15N values: P≤0.05 10/11
- Increase in δ13C values: P≤0.05 9/11
- Ontogenetic slope?

- Delayed switch – Ireland >60cm vs literature <10cm
  - 5-6 year old fish, >6 years = rare, – limited impact?

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# Discussion

- Invertebrates much more important than expected throughout life (45.5% IRI)
- Trout appear not as important as previously reported in Ireland
- Generalist / opportunistic strategy highlighted
- Diet relates to abundance
- Historical information alone not sufficient

# Pike vs. Trout

- Can We Tell If Pike Preferentially Eat Trout?
  - This is not what the study was set up to test
- All indications point to generalist/opportunisitic nature
  - Findings largely in line with international literature
- However, few trout samples available for SIA
  - Unlikely to have clarified plots but may have helped with the mixing model if trout are a significant food source
- Are they a threat?
  - Possibly - combined with other threats
  - Yes they will eat them – they eat everything
    - Predation levels similar to cannibalism levels

# Pike vs. Trout

- Historical studies
  - Sampling size biases – must be taken into account
  - Context – empty stomach and numbers rather than proportions
  - IFT reports (1952-1970) – 'mainly trout' in stomachs – no numbers, or numbers only for trout, no other spp
  - No sizes or abundances either
  - First IFT report 1952 remarked on presence of smaller fish and inverts and habitat variations
  - Stocked trout – easy prey?
- Today – very different systems
  - Invasive competitors, habitat destruction, pollution, eutrophication, lice, etc…..

# Further Diet Studies
## Recommendations

- Seasonal
- Full size range (netting lakes – size selective)
- Full species sampling and survey (SIA, abundances)
- Set sampling times
- Combined complimentary methods = more power
- Multiple analyses methods - IRI vs. numbers – more complete view
  - Gravimetric methods – single heavy fish
  - Numeric methods - invertebrates
- Possibly stomach flushing issues – incomplete clearance, high occurrence of empty stomachs, teeth, net regurgitation – issues for invertebrate prey
- Historical data access

# OPINIONS

- Scientist – independent – impartial
  - Managers & stakeholders – 'politics'
  - Precautionary approach – differs based on trout or pike view…..
    - Best available evidence
  - A political not a biological question
    - Angling interests, not environment or ecology
- Native – indications based on best available information – <u>not</u> definitive proof.
  - First and only study carried out to date

# DEBATE

- Success of operations ??
  - Ever fully remove – extremely doubtful
    - Increase of smaller size pike with similar biomass? Competition?
    - Selective removals of smaller individuals?
  - Evidence of trout recovery? Limited?
  - 1970s trout aspirations Lough Sheelin
    - 16,000 pike being culled per year
    - 200,000 stocked trout per year
  - Re-think translocation operations…..particularly between strains and habitats (morphology)
  - Transfer study (nets removed)

# DEBATE

- Effect on coarse fish
  - High predation on roach and perch - much higher than trout
    - –Helpful?
  - Also cannibalise
  - Appear to predate on species in relation to occurrence
  - Contradictory study? Site specificities? Size range examined? Details needed
    - –E.g. Carra 84% inverts, 13% frogs - IRI
  - Modelling?
    - –Encourage ecosystem modelling


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