Suitable, Nursery or Effective Habitat?

- Habitat Suitability
  - Production of juveniles
- Nursery
  - Number recruits per unit area.
- Effective juvenile habitat
  - Total production of recruits
- Mediated by life-history and metapopulation connectivity
**Thesis Aims**

1. Illustrate the need to study near-shore juvenile habitats

2. Describe juvenile habitat suitability for important fisheries species from the inner Danish waters

3. Demonstrate the efficacy of otolith chemistry for differentiating between juvenile habitat areas of the inner Danish waters

**Conflicts in the Coastal Zone**

**Thesis Aim 1:**

Illustrate the value of studying near-shore juvenile habitats

1. Describe the extent of anthropogenic impacts in coastal marine habitats for commercially important fish of the NE Atlantic.

2. Illustrate current gaps in knowledge and describe pathways for future research.

Conflicts in the Coastal Zone - Results

<table>
<thead>
<tr>
<th>Common name</th>
<th>Binomial classification</th>
<th>Juvenile</th>
<th>Feeding</th>
<th>Spawning</th>
<th>Migration</th>
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<td>Whiting</td>
<td>Merlangus merlangus</td>
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</tbody>
</table>

Conflicts in the Coastal Zone - Conclusions

- Anthropogenic impacts on **92%** of species utilising the coastal zone.

- Highest rates of impacts at **juvenile** life-history stages (78%).

- **Cumulative impacts** in two ways
  - Multiple activities at each life-history stage (71%)
  - Impacts accumulating over multiple life-history stages (38%)

- Evidence of impacts on demographic rates / population level effects is scarce.
Thesis Aim 2:

Describe juvenile habitat suitability for important fisheries species from the inner Danish waters.

1. Undertake a survey of y0 flatfish in a variety of near-shore habitats.

2. Take concurrent measurements of the physical environment.

3. Use juvenile abundance and growth rates to model habitat suitability.

4. Build interpolative maps of juvenile habitat suitability.


**HAMs & HGMs from Targeted Survey - Survey**

**Habitat Association Models**

**Habitat Growth Models**
HAMs & HGMs from Targeted Survey
- Fish Analyses

Abundance \[ \text{NBI\textsc{nom}} \] Depth + Substrate + Temperature + Salinity + ln(Exposure) + Latitude + offset(ln(TrawlLength))

<table>
<thead>
<tr>
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<th>Depth</th>
<th>Substrate</th>
<th>Temp.</th>
<th>Salinity</th>
<th>Exposure</th>
<th>Latitude</th>
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</table>
HAMs & HGMs from Targeted Survey - HGM Models

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\[ \text{DLSGR } \mathcal{G}\text{ausian}(\log - \text{linked}) \sim Depth + Substrate + Temperature + Salinity \\
+ \ln(\text{Exposure}) + Age + CSDensity + Latitude + RE(\text{site}) \]

<table>
<thead>
<tr>
<th></th>
<th>Depth</th>
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<th>Temp.</th>
<th>Salinity</th>
<th>Exposure</th>
<th>Age</th>
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HAMs & HGMs from Targeted Survey - Interpolated Predictions

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- Modelled Environment
  - Bathymetry, Expo
  - Water temperature
- Limited to
  - Max depth 4m
  - Substrate types
  - August of 2013
HAMs & HGMs from Targeted Survey - Interpolated Predictions

Plaice HGM

- Successfully described habitat suitability in terms of the physical environment
- “Suitability” depends on the measure used to represent it
- Created interpolative maps of juvenile habitat suitability
- To improve these descriptions of habitat suitability:
  - Temporal resolution and scale
  - Mortality
  - Degree of connectivity between life-history stages
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**Juvenile fish habitat across the inner-Danish waters: Suitability modelling of coastal marine habitats for important fisheries species informed by historical surveys**

Elliot J. Brown*, Alexandros Kokkalis; Josianne G. Støttrup;

**Thesis Aim 2:**

Describe juvenile habitat suitability for important fisheries species from the inner Danish waters

1. Pair existing juvenile survey data with modelled environmental data to create habitat suitability models for 0-group fish

2. Create maps of habitat suitability for juveniles of these important fisheries species

---

**HAMs from Historic Surveys - Juvenile Surveys**

- “Yngeltogt” series of cruises from 1991 to 2007

- Johansen Juvenile Trawl

- Only July and August consistently sampled

- North of the Belt Seas

- Limited to shallower than 5m
HAMs from Historic Surveys
- Fish Data

- Fish data included species identification and individual lengths
- 0-group fish were identified by length frequency distributions and mixture models.

HAMs from Historic Surveys
- Environmental Data

- Modelled Environmental Data
  - Exposure Index, Substrate Type
  - Subset of possible hydrodynamic features
    - Monthly mean midday values at seafloor

- Limited to
  - Max depth 5m
  - Substrate types sampled
  - Sensible Environmental Parameters
HAMs from Historic Surveys - Models

\[ \text{Abundance}_0 \sim \text{NBinom} \]  
\[ \text{Depth} + \text{Substrate} + \text{Temperature} + \text{Salinity} + \text{Oxygen} \]
\[ + \text{Current Speed} + \text{POM} + \ln(\text{Exposure}) + \text{Latitude} + \text{RE(year)} \]
\[ + \text{offset} (\ln(\text{TrawlLength})) \]

### Plaice
- Substrate
- Depth
- Temp.
- Salinity
- Oxygen
- Current
- POM
- Exposure
- Latitude

### Flounder

### Sole

### Brill

---

### HAMs from Historic Surveys - Interpolated Maps

Plaice

---

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HAMs from Historic Surveys

Conclusions

- Produced validated empirical models of juvenile fish habitat suitability.
- Created maps of predicted density.
- Demonstrates the value of having regular monitoring surveys that cover juvenile habitats.
- These static empirical models of habitat suitability need to be combined with models of life-history connectivity.

Otolith Chemistry

Thesis Aim 3:

Demonstrate the efficacy of otolith chemistry for differentiating between juvenile habitat areas of the inner Danish waters

1. Differentiate between hybridising, co-habiting, conspecifics (European plaice and flounder) juveniles.
2. Differentiate between juveniles from contiguous coastal habitats across the inner Danish Waters using:
   1. European Plaice
   2. Common Sole

# Otolith Chemistry - Sampling

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- **Plaice vs Flounder**
  - 20 Sites
  - 37 co-habiting pairs

- **Plaice Distribution**
  - 150 0-group individuals
  - 56 sites
  - 4 areas

- **Sole Distribution**
  - 67 individuals
  - 3 / 4 areas

---

- **n = 115**
- **n = 37**
- **n = 36**
Otolith Chemistry
- Otolith Analysis

- Laser Ablation – Inductively Coupled Plasma Mass Spectrometry
  - LA-ICPMS
- Edge spots from ventroproximal region
- $^{7}$Li, $^{23}$Na, $^{24}$Mg, $^{39}$K, $^{43}$Ca, $^{55}$Mn, $^{57}$Fe, $^{65}$Cu, $^{66}$Zn, $^{88}$Sr, $^{115}$In, $^{138}$Ba and $^{208}$Pb

Otolith Chemistry
- Results

- 72% Individuals correctly identified
  - 73% of Flounder
  - 70% of Plaice
- More than 2/3 of plaice correctly re-allocated
- 80% of sole correctly re-allocated
**Otolith Chemistry - Results**

- Overall, high rates of correct classification
- Highest misclassification between
  - Skagerrak and North Kattegat
  - Southern Kattegat

**Otolith Chemistry - Conclusions**

- Significant differences in trace-element composition of co-habiting juvenile plaice and flounder otoliths
- Driven by either physiology or small scale habitat use

- Otolith chemistry could be an effective tool for tracing juvenile habitat contributions to adult fisheries of plaice and sole

- Otolith chemistry remains an effective tool for differentiating between juvenile habitats where they exist continuously along open coasts
Perspectives

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Fisheries Modelling
Otolith Chemistry
Juvenile Habitat Suitability Modelling
Spawning and Feeding Habitat Suitability Modelling
Particle Drift / IBM
Genetic Differentiation
Improve Estimates of Demographic Rates
Improve Temporal Scale and Resolution

Acknowledgements