Juvenile coastal fish and their nursery habitats

– the role of New Zealand’s estuaries and coastal embayment’s
Background

- Estuaries and coastal embayments are important fish nurseries
- But are receiving environments for land based human activities, suffer from degradation
- Potential for a cascade of effects through ecosystems, including fisheries
How do we define a nursery habitat?

Beck *et al.* (2001): for a given habitat to be defined as a nursery habitat (NH), it needs to be demonstrated that the habitat’s contribution per area is greater than the average contribution per area for all habitats.

This definition was further refined by

Dahlgren *et al.* (2006): allowed for habitats where the average contribution per unit area was low, but given the large areas of that habitat, it still contributed the majority of the adult population’s recruitment (Effective Juvenile Habitat, EJH).
Recent and current estuarine fish research in New Zealand

1. What species are where, when, at what sizes/ages ✓

2. Specific habitat relationships ✓

3. Estuary, coast, latitudinal biogeography ✓

4. Linkages between habitat chains**

5. Effects of human induced degradation on system productivity, biodiversity, functioning**

6. Habitat change – land-based effects, marine-based effects, climate change – mitigation and restoration strategies ??
The species pools

**Fisheries**

- Snapper*
- Trevally*
- Kahawai*
- Gurnard*
- Grey Mullet
- Sand flounder*
- Yellowbelly flounder
- Tarahiki*
- Rig*
- School shark*

**Non-Fisheries**

- Spotties*
- Gobies
- Triplefins
- Speckled sole*
- Anchovies*
- Smelt*
- Yellow-eyed mullet*
- Parore*
- Garfish*
- Stargazers
- Hammerhead sharks*
- True sprats (2 species)*
  + 30 – 40 other species

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Upper North Island 2001+2003
31 estuaries

Upper South Island 2006
10 estuaries

Lower North Island 2007
9 estuaries

Lower South Island 2004
19 estuaries

Cooks Inlet, Stewart Island

Rangaunu Harbour, Northland
Habitat examples

Bare inter-tidal mud-flats

Biogenic habitats
- mangrove forests
- seagrass meadows
- horse mussel beds

Artificially adding habitat (ASUs)

Bio-geographic variation
Intertidal mud-flats (Pahurehure Inlet, Manukau Harbour)

- Important for sand and yellow-belly flounder juveniles

- Monitored from 2001–2007, small fish assemblages spatially stable, variation in recruitment strengths

(Morrison et al. 2002)
Mangrove forests

- Strong societal debate about their relative ecological values, including as juvenile fish nurseries

- 8 estuaries sampled, spanning gradient of estuarine environmental degradation, “pristine > strongly impacted”

- Measured both the small fish assemblages, and the environments from which they were sampled

- Sampled with fine mesh fyke nets, set over both the day and the night
• 19 species of fish sampled, but only 10 relatively common

• Using nursery habitat definitions, only three can be considered to be using mangroves as nursery habitats – grey mullet, short-finned eels, and parore
Sea-grass meadows

- One species only, *Zostera capricorni*, largely inter-tidal, can extend sub-tidally down to 7 m water depth
- Found throughout the country, but high abundances in relatively few regions
- Substantial historical losses, especially in proximity to human population centres
- Remaining large meadows tend to be in remoter areas of the country, with lower human population densities
Seagrass meadows - Whangapoua Estuary, Coromandel

- Sea-grass supported higher juvenile abundances of eight fish species (two commercial) relative to bare habitats

- Presence of small (< 2 m²) isolated sub-tidal sea-grass patches strongly elevates species abundances, relative to sites with only inter-tidal sea-grass

Snapper
n = 348
Fish examples:
- Snapper
- Specky Garfish
- Speckled triplefin
- Exquisite triplefin
- Jack mackerel
- Yellow-eyed mullet
- Estuarine triplefin
- Trevally
- Smooth pipefish

Fish per 100 m²

Seagrass meadows - Rangaunu Harbour, Northland
Adding seafloor structure - artificial seagrass units (ASUs)

- Assess fish responses to the addition of structure
- Set up array of different sized ASUs, and controls – Whangapoua Harbour
- Set out over fish recruitment season, retrieved after larval fish settlement
- Retrieved ASUs through fine-mesh drop-traps
**ASU findings**

- Elevated numbers of juveniles of spotties, snapper, parore, trevally, pipefish
- Also adult triplefins, seahorses, and clingfish
- Many of these species are feeding on passing zooplankton
- Suggests that structure rather than food may be the primary driving variable (supported by recent stable isotope work)
Bio-geographic scales

- Very high juvenile snapper abundances in Kaipara and Rangaunu seagrass meadows
- East Coast meadows support higher abundances of parore and spotties
- West Coast meadows in contrast support higher abundances of grey mullet (*Mugil cephalus*)
- Most sea-grass-associated species (9 or more, 3 commercial) are found north of Cook Strait
- In Southland, only a pipefish and a leatherjacket species display sea-grass associations
- The direct role of southern meadows as juvenile fish nurseries is modest compared to northern meadows
- These patterns also extend to other habitat types, e.g. mangrove forests
Habitat summary

- Biogenic habitats such as seagrass meadows, horse mussel beds, and mangrove forests are important for some juvenile fish species.

- However, other species prefer less-structured environments such as bare sand and mud flats.

- Loss of habitat and changes in relative habitat proportions are likely to have substantial effects on what juvenile fish are produced, and their relative abundances = changes in different fisheries.

- How to model and predict these potentially altering habitat landscapes??...

- How is juvenile fish abundance, survival and growth affected? – positive, neutral, negative??
Habitat chains and connectivity – Snapper

- Widespread and abundant in Northern New Zealand
- Important recreational and commercial fisheries
- Heavy direct research focus on fisheries in isolation
- Much lesser research focus on juvenile snapper, and habitat relationships
- Where are the nursery habitats/grounds – why do fish value them? – what are the threats to them? Can we mitigate or reverse negative effects?

Anderson et al. 1998
SNA 8 as an example...

Small snapper are rare on the open coast..
Coastal snapper densities – trawl surveys

- Circumstantial evidence for high importance of Kaipara Harbour

Figure X: Fish densities down the coast (20 km units), as measured from the northern end of Ninety Mile Beach.
Sampled inside west coast estuaries in 2003.
Relative estuarine contributions of 0+ fish may be a function of:
- size
- habitat mosaics (including seagrass)
## First approximations of juvenile snapper contributions from west coast estuaries

<table>
<thead>
<tr>
<th>Harbour</th>
<th>Areal extent (km²)</th>
<th>Tidal flat proportion</th>
<th>Beam trawl tows</th>
<th>Total distance towed (km)</th>
<th>0+ snapper density (no/km²)</th>
<th>Estimated population (low tide x density)</th>
<th>Population proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>High tide</td>
<td>Low tide</td>
<td></td>
<td></td>
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<tr>
<td>Herekino</td>
<td>5</td>
<td>0.8</td>
<td>0.84</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Whangape</td>
<td>10.1</td>
<td>3.3</td>
<td>0.67</td>
<td>6</td>
<td>1.3</td>
<td>16,209</td>
<td>54,073</td>
</tr>
<tr>
<td>Hokianga</td>
<td>106.5</td>
<td>28.6</td>
<td>0.73</td>
<td>14</td>
<td>3.5</td>
<td>6,515</td>
<td>186,335</td>
</tr>
<tr>
<td>Kaipara</td>
<td>743.1</td>
<td>431.6</td>
<td>0.42</td>
<td>24</td>
<td>7.6</td>
<td>3,854</td>
<td>2,400,000*</td>
</tr>
<tr>
<td>Manukau</td>
<td>365.6</td>
<td>139.7</td>
<td>0.62</td>
<td>73</td>
<td>22.7</td>
<td>2,683</td>
<td>374,740</td>
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<tr>
<td>Raglan</td>
<td>31.9</td>
<td>9.9</td>
<td>0.69</td>
<td>11</td>
<td>9.3</td>
<td>2,106</td>
<td>20,801</td>
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<tr>
<td>Aotea</td>
<td>31.9</td>
<td>8.3</td>
<td>0.74</td>
<td>11</td>
<td>11</td>
<td>510</td>
<td>4,222</td>
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<tr>
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<td>67.6</td>
<td>17.9</td>
<td>0.74</td>
<td>11</td>
<td>8.8</td>
<td>351</td>
<td>6,269</td>
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**Link to the SNA 8 fishery**

West coast (SNA8) snapper stock

- Estimated that 3 million recruits needed per annum to sustain stock
- Fishery now reliant on good recruitment each year
- Average catch age 5.6 years
- Held up by 1996, 1998, 1999 year classes

- Suspect that west coast estuaries contain sufficient juveniles to produce 3 million recruits → maintain the SNA8 fishery
Turned to otolith microchemistry..

- Used snapper collected in 2003 as 0+ juveniles
- Eight elements in sufficient concentrations for analysis
Sampled the coastal fishery in 2007

- Sampled the 2003 year class as 4+ year olds in 2007, when recruited to the fishery

- Fish collected from five spatial zones down the west coast that matched the 2000 tagging programme
  - Ninety Mile Beach
  - Kaipara
  - Manukau
  - north Taranaki Bight
  - south Taranaki Bight

- Collected 26–43 cm FL fish, aged, identified 4 years olds, 20–25 fish per zone (140 total)
- Used laser ablation to sample that part of the otolith laid down as 0+ fish

- Compared elemental composition against that of juveniles from known estuary sources
Four distinctly different estuary groups..

Table 4. Results of maximum likelihood analyses for (a) juvenile snapper and (b) unknown adults. Shown are the actual contribution (juveniles only), and the mean ± standard deviation based on 1000 simulations of the data.

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<th>Estimated contribution</th>
<th>SD</th>
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<td></td>
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<td>0.1164</td>
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<td>0.0540</td>
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<tr>
<td>Others</td>
<td>0.36</td>
<td>0.3570</td>
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98% of snapper were assigned to the Kaipara Harbour.
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Inside the Kaipara and other estuaries, juvenile snapper are strongly associated with biogenic (living) seafloor structure.
Sadly, such habitats are vulnerable to land-based impacts.

- Disappeared in late 1960’s, associated with heavy port dredging and cement fines dumping into harbour system [5 million m³ combined, 1920’s – 1960’s]
- No recovery since, permanent loss of 12+ km² of seagrass, including significant sub-tidal component. Significant losses from Waitemata, Manukau, Tauranga Harbour and others…
- Recent increases in seagrass cover in Kaipara Harbour; Snells Beach and St Heliers Bay
Effects of human induced degradation on ecosystem productivity, biodiversity, functioning (fish)

Gross general habitat changes
– Water turbidity
– Sedimentation…

Specific habitat element changes
– Seagrass
– Horse mussels
– Mangroves
– Green-lipped mussels
– Algal meadows
– Kelp forests
– Sands to muds..

Changes in
– fish assemblages
– productivity
– connectivity's
– trophic webs
– fish diversity

CHANGES IN FISHERIES PRODUCTION
Possible habitat change mitigation and restoration strategies..

- Mitigation and/or Restoration is not about directly enhancing fish numbers, but about underlying habitats (extent, quality, spatial mosaics) and habitat connectivities (fish movement) w.r.t. fishes life cycles.

- How is juvenile fish abundance, survival and growth affected? – positive, neutral, negative??

- Need to understand how fish use these chains of habitats throughout their life cycles, the threats to these chains, and what we need to do to protect/enhance restore the functioning of these habitats (embedded within ecosystems).
  
  – This will require across discipline approaches, including physical processes work, biogenic habitat physiology and dynamics, and numerical modelling.
  
  – Strong potential for adaptive management integrations.

Now have techniques for batch marking of large numbers of juvenile fish – e.g. VIE and CWT tags.
Where to from here?..

- What components of these research programmes might of most use to MFish, ARC, and others…?

- How can this information best be used?

- Where might this and related research most usefully go in the future?