One-way traffic: Black Bream passage through a storm surge barrier

Stephen Beatty*, James Tweedley, Joel Williams, James Keleher, Jeff Whitty, David Morgan, Mark Allen
Overview

- Background
- Aims
- Methods
- Results
  - Environmental variables
  - Acoustic detection summary
  - Bream movement and key habitats
  - Conditions of Bream passage
- Summary and implications
Background

- Small (12 km$^2$) shallow <3m
- Intermittently-open to the ocean
- Ramsar listed (37k birds from 90 species)
- Highly regulated ‘the most grossly enriched major wetland in WA’
- Very little information on the fishes
- Two surge barriers (only three in WA)
Extreme salinity variation
Vasse & Wonnerup estuaries
Diversity greatest in Wonnerup Inlet
Inlet surge barriers

- Built in 1908 and replaced in 1928 and 2004
- Prevent saltwater intrusion into the estuaries in summer and storm surges in winter
- Supposed to enable fish passage

![Diagram showing floodgate operation in different seasons](image)

- **Winter - Spring**
  - Floodgates OPEN
  - Fish gate OPEN + slot boards in

- **Summer - Autumn**
  - Sandbar OPEN
  - Floodgates CLOSED
## Fish Kills

- **Long history**
- **Recent near floodgates**
- **2013 major ~30000 fish**
  - Bream, Sea and Yelloweye Mullet

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Location</th>
<th>Estimated Number of Dead Fish</th>
<th>Suspected cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1905</td>
<td>Jan</td>
<td>Lower reaches of Vasse estuary</td>
<td>1000's</td>
<td>Dead and stagnant water</td>
</tr>
<tr>
<td>Pre 1960</td>
<td>Summers</td>
<td>Vasse and Wonnerup estuaries</td>
<td>1000s</td>
<td>Fish &quot;landlocked&quot; by floodgates</td>
</tr>
<tr>
<td>1966</td>
<td>April</td>
<td>Wonnerup Inlet</td>
<td>4000</td>
<td>Low dissolved oxygen</td>
</tr>
<tr>
<td>1984</td>
<td>Feb</td>
<td>Vasse estuary channel</td>
<td>1000's</td>
<td>Low dissolved oxygen, Heat wave</td>
</tr>
<tr>
<td>1988</td>
<td>Feb</td>
<td>Wonnerup Inlet</td>
<td>1000s</td>
<td>Low dissolved oxygen, High temperatures</td>
</tr>
<tr>
<td>1989</td>
<td>Feb</td>
<td>Vasse estuary channel</td>
<td>1000</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>1997</td>
<td>Feb</td>
<td>Vasse estuary channel</td>
<td>1000s</td>
<td>Low dissolved oxygen</td>
</tr>
<tr>
<td>1997</td>
<td>June</td>
<td>The deadwater</td>
<td>1000s</td>
<td>Sudden drop in salinity</td>
</tr>
<tr>
<td>2000</td>
<td>Dec</td>
<td>Vasse estuary and floodgates</td>
<td>1000</td>
<td>Low dissolved oxygen</td>
</tr>
<tr>
<td>2010</td>
<td>Feb</td>
<td>Vasse floodgates</td>
<td>2000</td>
<td>Low dissolved oxygen, Fish gates malfunction</td>
</tr>
<tr>
<td>2012</td>
<td>Feb</td>
<td>Vasse floodgates</td>
<td>1000s small fish</td>
<td>Low dissolved oxygen</td>
</tr>
<tr>
<td>2013</td>
<td>April</td>
<td>Vasse estuary floodgates and Vasse exit channel</td>
<td>10-38,000</td>
<td>Possible toxin/irritant impact, Low dissolved oxygen</td>
</tr>
</tbody>
</table>
**Black Bream**

- Annual recruitment (since 1998)
- Reduced broodstock due to fish kill? – unlikely only factor as continued presence of large fish
- 2015, 2016 successful recruitment
- Resilient but fish kills not ideal

---

**Seine netting juveniles**

- Sampling occasion (season and year)

---

**Gill net adults**

- $L_{50} = 163$ (2.6 yrs), 147 (2.1 yrs) mm TL

---

Tweedley et al. 2016, 2017
Aims

• Determine the movement patterns habitat use of Black Bream
  - Determine spatial/temporal mobility, habitat
  - Degree of passage through the Vasse barrier under range of operational / enviro scenarios
  - How do movement patterns relate to fish kill risk (presence in the kill zones above and below barrier)?
Methods

- V9 tag ~382 days
- Bream tagged = 41
- 11 receivers
- Continuous temperature / salinity loggers, sonar benthic habitat mapped for complexity, daily bar open/closure, binary and continuous gate variables
Receiver / water quality locations
Community involvement
Analyses

• Passage conditions through the Vasse Gate (fish penstock, surge barrier)
• GAM/Ms for spatial/temporal distribution (#fish/day) and daily distances moved
• Predictor variables:
  - Fixed: bar open/closed, surge barrier open/closed, proximity to artificial structure (bridges, gates)
  - Smoothed continuous: temperature, salinity, time (day of experiment), tide range, rainfall, distance from ocean, mean depths
Results
Surge barriers prevent tide and smooth salinity
...but key things to note:

- Bar opens and shuts a lot
- Flow period July - Sept = big surge gates open
- Slot boards in Sept – June = fish penstock operates (red line = gap height)
- Water level greater below gate Feb-onwards
Almost no (natural) complex structure
Acoustic detections summary

• Total of 2,307,576 detections (28 fish) 22nd May 2014 - 20th May 2015

• Survival rates:

  30 (73%) >July 2014
  17 (41%) >December 2014
  13 (32%) whole period

• 5 Bream (12%) possibly left to ocean
Bream movement and key habitats

- Most stayed within the array
- Overall mean daily movement fish at liberty = 2.73 km ± 0.06 km, Max 45 km
- No passage detected upstream of Wonnerup Gate
- No fish as far as Vasse River (Butter)
- 19 of the 21 Bream (90%) detected during the breeding period Deadwater
- The other two fish were above Vasse Gate at the time
• 5 / 17 Bream (29%) detected after December 2014 were above gate
Daily distance
Signif. effect of surge barrier open
Smoothed day and salinity

~coincides with spawning period
Number of fish / day below Vasse barrier

~coincides with spawning period
Passage through the surge barrier

<table>
<thead>
<tr>
<th>Fish ID</th>
<th>TL (mm)</th>
<th>Date first above Vasse</th>
<th>Date last above Vasse</th>
<th>Floodgate open?</th>
<th>Δ D/S to U/S (m) (potential passage day range)</th>
<th>Penstock gap (cm)</th>
<th>Date last detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>14688</td>
<td>290</td>
<td>6/7/14</td>
<td>8/7/14</td>
<td>Yes</td>
<td>-0.05</td>
<td>4.95</td>
<td>20/5/15</td>
</tr>
<tr>
<td>14726</td>
<td>370</td>
<td>7/7/14</td>
<td>29/12/14</td>
<td>Yes</td>
<td>-0.10</td>
<td>4.95</td>
<td>29/12/14</td>
</tr>
<tr>
<td>14690</td>
<td>287</td>
<td>12/11/14</td>
<td>20/5/15</td>
<td>No</td>
<td>0.00</td>
<td>0.00</td>
<td>20/5/15</td>
</tr>
<tr>
<td>14701</td>
<td>269</td>
<td>3/2/15</td>
<td>20/5/15</td>
<td>No</td>
<td>0.06 – 0.76</td>
<td>13.50</td>
<td>20/5/15</td>
</tr>
<tr>
<td>14709</td>
<td>305</td>
<td>28/3/15</td>
<td>27/4/15</td>
<td>No</td>
<td>0.00 – 0.51</td>
<td>13.50</td>
<td>27/4/15</td>
</tr>
<tr>
<td>14715</td>
<td>393</td>
<td>7/4/14</td>
<td>6/10/14</td>
<td>No</td>
<td>0.30 – 0.76</td>
<td>11.70</td>
<td>6/10/14</td>
</tr>
<tr>
<td>14729</td>
<td>360</td>
<td>28/1/15</td>
<td>30/4/15</td>
<td>No</td>
<td>-0.05 - 0.48</td>
<td>13.50</td>
<td>30/4/15</td>
</tr>
</tbody>
</table>

[Graph: Velocity (m/sec^-1) vs. Head difference (m)]
Floodgate probably open
(Est) D/S = 0.84 m
U/S = 0.89 m

Above Vasse
Webster Rd
Above Vasse Estuary Fork
Below Vasse Laymans
Deadwater Above Wonnerup
Below Wonnerup
Bar

Vasse Gates
Date
Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec  Jan  Feb  Mar  Apr  May

Depth of penstock opening (cm)

Water level (m)

Bar Closed
Bar Open
Bar manually opened
Major flow flood gates open

2015 2014
Bar Closed
Bar Open
Bar manually opened

Slot boards in
Slot boards out
Major flow flood gates open

6/7/14
Penstock 4.95cm
Floodgate probably open
(Est) D/S = 0.84 m
U/S = 0.89 m

Vasse Gates

Major flow period - flood gates open
Floodgate open

7/7/14 Penstock 4.95cm and floodgate open
D/S = 0.9 m
U/S = 1.0 m

14726 - 370 mm TI

Vasse Gates

Date
Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec  Jan  Feb  Mar  Apr  May

Depth of penstock opening (cm)

Water level (m)

Fish penstock opening (cm)

Slot boards in
Slot boards out
Major flow flood gates open

Bar Closed
Bar Open
Bar manually opened

2015 2014

Bar Closed
Bar Open
Bar manually opened

Vasse Gates

Slot boards out
Slot boards in
Major flow flood gates open

2015 2014

Bar Closed
Bar Open
Bar manually opened
Vasse Gates

Date
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May

Depth of penstock opening (cm)

Water level (m)

Bar Closed
Bar Open
Bar manually opened

Used Penstock

3/2/15
Penstock 13.5 cm
D/S = 0.12 m
U/S = -0.02 m

Major flow period - flood gates open

Vasse Gates

Slot boards out
Slot boards in
Major flow flood gates open

Water level below gate
Water level above gate

Bar Closed 
Bar Open 
Bar manually opened

Fish penstock opening (cm)

Water level (m)

0 5 10 15 20 25 30
-0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2

Apr 2014 May Jun Jul Aug Sep Oct Nov Dec Jan 2015 Feb Mar Apr May

Bar Closed
Bar Open
Bar manually opened

Above Vasse Webster Rd
Above Vasse Estuary Fork
Below Vasse
Laymans
Deadwater
Above Wonnerup
Below Wonnerup
Bar

Slot boards in
Slot boards out

Major flow flood gates open
7/4/14
Penstock 11.7 cm
D/S = 0.37 m
U/S = -0.10 m

Water level (m)
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2

Fish penstock opening (cm)
0
5
10
15
20
25
30

Depth of penstock opening (cm)

Bar Closed
Bar Open
Bar manually opened
Major flow flood gates open

Vasse Gates

Date
Apr 2014 May  Jun  Jul  Aug  Sep  Oct  Nov  Dec  Jan  Feb  Mar  Apr  May
Depth of penstock opening...gate
Slot boards in
Slot boards out
Major flow flood gates open
2015 2014
Bar Closed
Bar Open
Bar manually opened

Used Penstock
Summary

• Broad-scale movement greatest in winter/spring (spawning period)
• More fish detected below Vasse barrier winter/spring, but Deadwater likely spawning
• Non-tidal habitats upstream of Wonnerup and Vasse Gates are not utilised (much)……but
• 5 / 17 Bream (29%) detected after December 2014 were above barrier
• Fish passed 13.5cm and none passed <11.7 cm – 15 cm seems a reasonable criteria…but....
• Bream passaged with the ‘flow’ and seemed to be ‘stuck’ – suggests a trap
• Recommended that Bream be prevented from passaging (pre 1988 conditions)
• Oxygenation plant installed, sustainable solutions required
• PIT study underway
Special thanks to....

- **Dep. Fisheries**: Alicia Reagan for her exceptional coordination of community events
- **Busselton SHS**: Year 9 students and Renay Down
- **Georgiana Molloy SHS**: Hamish Gibson, Rebecca Teale
- **Community members**: Glen Stevens, Howard George, Jadon Wilder, Darcy Rochford, Peter Blake, Hazel Blake, Alan Hatfield, Ryan Blake, Skye Hatfield, Ralph Sohns, Jessica Hampton, Cassie Teasdale, Mark, Charmaine Brindley, Tom Brindley, Jessica Brindley, Alan Porter, Sophie Sparkes, Jacob Ness, Zane McTaggart, David Tromp, Tim Putt, Sandra Putt, Xavier Putt, Lachlan Putt, Ray Witterman, Fred (Dunsborough)
- Kath Lynch (GeoCatch/Dep. Water)
- Clive Piggott (Water Corporation)