Comparative survival of razorback sucker in Reach 3

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Background

- **LCR MSCP Reach 3**
  - Between Davis and Parker dams
  - Suite of non-native sport fish
  - Lake Havasu

- **Razorback sucker**
  - No known natural population
  - Over 75,000 stocked since 2006
  - Population numbers in thousands
  - Post-stocking survival unknown
  - Spawning aggregates observed
    - From Laughlin downstream to Needles
Study Area

- Divided into four ‘zones’
  - **3-1** - Riverine clear waters downstream of Davis Dam
  - **3-2** - Topock Marsh, Lake Havasu delta
  - **3-3** - Wide basin of Lake Havasu
  - **3-4** - Lower Lake Havasu, Bill Williams River NWR
Zone 3-1 (Laughlin)

- Laughlin Lagoon
- Razorback Island
Zone 3-1 (Needles)

- Palms
- Cliffs
- Cabana
- Tower
- White Wall
- Power Lines
- US 95 bridge
- Needles Dredge Yard
Zone 3-2

- Park Moabi
- Golden Shores
- Pulpit
- Sand Dune
- Trampas Cove
- Blankenship Bend
- Two Lobe Cove
- Rearing Cove
- Castle Rock
- Clear Bay
PIT Scanning - Equipment

- **Submersible PIT scanners**
  - 80 x 80 cm antenna
  - Fully submersible to 10 meters
  - Retrieved via boat hook
  - 24-96 hour battery life

- **Large submersible PIT scanners**
  - 120 x 80 cm antennae
  - Submersible up to 10 meters
  - 96 hour battery life

- **Shore based unit PIT scanner**
  - 190 x 80 cm antenna
  - 50 meter cable connects logger to antenna
  - 96 hour battery life
Data Sources

- 7-8 sampling trips per year
  - During peak spawning
    - Typically January-April
  - 3 overnight deployments
  - Up to 8 submersibles
  - One shore based

- Annual monitoring activities
  - Trammel netting (roundup)
  - Electrofishing

- Assimilated all Reach 3 data
  - M&A scanning in 3-1, 3-2 and 3-4 for bonytail
  - Reclamation in 3-1 and 3-2
Population Estimates

- Single census estimate
  - Modified Peterson formula
    \[ N^* = \frac{(M+1)(C+1)}{R+1} \]
- 134.2 kHz PIT tagged fish
- PIT scanned or captured
Post-Stocking Survival

- A multi-state mark recapture model was developed
  - Program MARK
  - Multi-state model - observable (A) and unobservable (B) states
  - Release and scanning data merged into sample years
    - Sample year approximately November through April
  - Two age classes – first year post-release (1) and adult (2)
  - 3 individual covariates - first year apparent survival ($\Phi_1$)
    - TL at release
    - Season of Release (dummy coded 0 – autumn, 1 – spring)
    - Time at large prior to first available sample year
First Available Sample Year

Autumn Release
September 2011

Nov 2011
14 Months
PIT Scanning

Spring Release
April 2011

Nov 2011
7 Months
PIT Scanning
Observable State and Transition

$p_A = \text{encounter probability}$

$\Phi_A = \Phi_B$

$p_B = 0$
No Transition

$\psi = 0$

$p = \text{encounter probability}$

$\Phi = \text{apparent survival}$
Results – PIT scanning 2012-2016

- 9,895 unique individuals with a verified marking record contacted.
  - 1,417 bonytail
  - 8,457 razorback sucker
  - 21 flannelmouth sucker

- 5,441 at large for more than a year (post-tagging)
  - 7 bonytail
  - 5,419 razorback sucker
  - 15 flannelmouth
## Results – Population Estimates

\[ N^* = \frac{(M + 1)(C + 1)}{R + 1} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Number Marked</th>
<th>Number Captured</th>
<th>Number recaptured</th>
<th>Population estimate (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>228</td>
<td>642</td>
<td>59</td>
<td>2454 (1910-3150)</td>
</tr>
<tr>
<td>2012</td>
<td>934</td>
<td>1373</td>
<td>284</td>
<td>4508 (4015-5061)</td>
</tr>
<tr>
<td>2013</td>
<td>1335</td>
<td>1730</td>
<td>518</td>
<td>4456 (4089-4856)</td>
</tr>
<tr>
<td>2014</td>
<td>1931</td>
<td>2385</td>
<td>933</td>
<td>4935 (4629-5262)</td>
</tr>
<tr>
<td>2015</td>
<td>2674</td>
<td>2211</td>
<td>1201</td>
<td>4923 (4652-5209)</td>
</tr>
</tbody>
</table>
### MARK Model Output

<table>
<thead>
<tr>
<th>Model</th>
<th>AICc</th>
<th>ΔAICc</th>
<th>AICc Weights</th>
<th>Model Likelihood</th>
<th>Number of Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>season+t*prescan}, \phi_{2_t}, p_t, \psi.)</td>
<td>40131.62</td>
<td>0.000</td>
<td>0.563</td>
<td>1.000</td>
<td>29</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>season+t*prescan}, \phi_{2_t}, p_t, \psi=0)</td>
<td>40132.32</td>
<td>0.704</td>
<td>0.396</td>
<td>0.703</td>
<td>27</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>season+t*prescan}, \phi_{2., p_t}, \psi.)</td>
<td>40137.24</td>
<td>5.620</td>
<td>0.034</td>
<td>0.060</td>
<td>26</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>season+t*prescan}, \phi_{2., p_t, \psi=0})</td>
<td>40140.34</td>
<td>8.717</td>
<td>0.007</td>
<td>0.013</td>
<td>25</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>prescan}, \phi_{2_t}, p_t, \psi.)</td>
<td>40164.77</td>
<td>33.154</td>
<td>0.000</td>
<td>0.000</td>
<td>25</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>prescan}, \phi_{2_t}, p_t, \psi=0)</td>
<td>40169.44</td>
<td>37.818</td>
<td>0.000</td>
<td>0.000</td>
<td>25</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+season+prescan+t<em>TL+t</em>prescan}, \phi_{2. p_t, \psi.})</td>
<td>40172.44</td>
<td>40.824</td>
<td>0.000</td>
<td>0.000</td>
<td>23</td>
</tr>
<tr>
<td>(\phi_{1_t+TL+prescan+t<em>TL+t</em>prescan}, \phi_{2_t}, p_t, \psi.)</td>
<td>40174.47</td>
<td>42.847</td>
<td>0.000</td>
<td>0.000</td>
<td>25</td>
</tr>
</tbody>
</table>
Post-Stocking Survival – Six Months

Total length at release (mm)

First year survival

2011  2012  2013  2014  2015
Release Cohort Encounters

465 fish released in February 2015

$y = 2 \times 10^{-5} e^{0.021x}$

$R^2 = 0.3819$
## Adult survival

<table>
<thead>
<tr>
<th>Survival period</th>
<th>Estimate</th>
<th>Lower limit</th>
<th>Upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model averaged</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012-2013</td>
<td>0.901</td>
<td>0.580</td>
<td>0.984</td>
</tr>
<tr>
<td>2013-2014</td>
<td>0.793</td>
<td>0.680</td>
<td>0.873</td>
</tr>
<tr>
<td>2014-2015</td>
<td>0.743</td>
<td>0.642</td>
<td>0.823</td>
</tr>
<tr>
<td>2015-2016</td>
<td>0.505</td>
<td>0.365</td>
<td>0.644</td>
</tr>
<tr>
<td><strong>With transition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012-2013</td>
<td>0.944</td>
<td>0.527</td>
<td>0.996</td>
</tr>
<tr>
<td>2013-2014</td>
<td>0.825</td>
<td>0.752</td>
<td>0.881</td>
</tr>
<tr>
<td>2014-2015</td>
<td>0.773</td>
<td>0.720</td>
<td>0.820</td>
</tr>
<tr>
<td>2015-2016</td>
<td>0.523</td>
<td>0.474</td>
<td>0.573</td>
</tr>
<tr>
<td><strong>Without transition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012-2013</td>
<td>0.851</td>
<td>0.669</td>
<td>0.942</td>
</tr>
<tr>
<td>2013-2014</td>
<td>0.746</td>
<td>0.687</td>
<td>0.797</td>
</tr>
<tr>
<td>2014-2015</td>
<td>0.694</td>
<td>0.654</td>
<td>0.731</td>
</tr>
<tr>
<td>2015-2016</td>
<td>0.448</td>
<td>0.427</td>
<td>0.469</td>
</tr>
</tbody>
</table>
Discussion

- A stable razorback sucker population of over 4,000 individuals persists in lower Colorado River Reach 3
  - Dependent on stocking
- Size at release appears to be the most important factor impacting post-release survival
- Season does not appear to influence post-release survival
  - Year to year variation may mask effect
- Population dynamics appear to differ from similar studies in Lake Mohave
  - Size at release and survival relationship different
  - Adult survival?
Thanks to our partners for their support

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