State of the art tools for surveying horse populations and modeling fertility control

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Outline

1. Survey methods

2. Population models
Outline

1. Survey methods

2. Population models
Why survey?

• **Plan** fertility control treatments, such as:
  • How many animals to treat
  • Horse distribution / trapping sites

• **Evaluate efficacy** of population growth suppression actions:
  • Population growth rate
  • Population foaling rate

• Meet legal requirements!
Planning a survey

• **Primary goal**: estimate population size $\hat{N}$

• **Secondary goals?**
  • Foal ratio; horse distribution; range conditions; water; etc

• **Considerations**
  • Your budget & tolerance for uncertainty
  • Restrictions: area, horse population
  • Resources: volunteers, students, universities, other agencies, etc

• Then, choose a method
## Verified survey methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Requirements</th>
<th>Risk</th>
<th>Costs</th>
<th>Pop size restrictions</th>
<th>Area restrictions</th>
<th>Accuracy</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground count of known individuals</td>
<td>Volunteers; some horse color</td>
<td>Low</td>
<td>Low</td>
<td>Small</td>
<td>Small and accessible</td>
<td>Extremely high</td>
<td>Very labor intensive</td>
</tr>
<tr>
<td>Simultaneous double observer surveys</td>
<td>Aircraft</td>
<td>High</td>
<td>High</td>
<td>None</td>
<td>None</td>
<td>High</td>
<td>Best when few trees; can be biased by horse movement</td>
</tr>
<tr>
<td>Aerial photo mark-resight</td>
<td>Aircraft; lots of horse color</td>
<td>High</td>
<td>Very high</td>
<td>Small</td>
<td>Medium</td>
<td>High</td>
<td>Robust to trees &amp; horse movement</td>
</tr>
<tr>
<td>Mark-resight distance sampling</td>
<td>Aircraft</td>
<td>High</td>
<td>Medium / flexible</td>
<td>None</td>
<td>None</td>
<td>Low / flexible</td>
<td>Best for very large areas &gt;10 mil acres</td>
</tr>
<tr>
<td>DNA mark-recapture</td>
<td>Genetics lab</td>
<td>Low</td>
<td>Very high / flexible</td>
<td>Medium</td>
<td>Medium and accessible</td>
<td>High / flexible</td>
<td>Costs increase linearly with pop size and accuracy; takes long time to get results; no ground-truthing</td>
</tr>
</tbody>
</table>
Other survey methods

• Experimental:
  • Infrared aerial transects
  • Drones (unmanned aircraft)
  • Satellite imagery
  • Orthorectified aerial photography

• Not available, typically:
  • Aerial mark-resight with radio collars
  • Ground photo mark-resight (need tons of horse color)

• Unreliable:
  • Ground / road counts of unknown individuals
  • Game cameras
BLM: Double observer methods

- Pilot and 3 trained observers
- Each survey covers 100% of HMA, plus surrounding lands
- Record data on detection covariates for each group:
  - Then go home and do a bunch of math.
Double observer methods

\[ \hat{N} \text{ (bars = 95%CI)} \]

- MCP
  - Survey 1
  - Survey 2
  - Survey 3
- SW
  - Survey 1
  - Survey 2
- CM
- LO-SM
  - Removal between surveys

Truth
BLM Surveys

- BLM “shall maintain current inventory”
- Each HMA surveyed every 2-3 years
- Annually:
  - 20 million acres
  - 30k linear miles of transects
  - $1.2 million
Future directions

• Alternate methods: get people out of the air
  • Fecal DNA mark-recapture
  • Drones
  • Infrared flights
  • Satellite / orthorectified aerial imagery
Outline

1. Survey methods

2. Population models
Why use population models?

- **Plan** management actions
  - Who, how many, how often, what treatments

- **Evaluate** options
  - Outcomes and costs
Background

• Current population modeling tool: WinEquus
  • Solid population modeling, but...

• Weaknesses:
  • Difficult to compare scenarios
  • Only saves outputs, not inputs
  • Inflexible
  • No cost calculations
PopEquus

• Goals
  • Tool to evaluate management options: outcomes and costs
  • Find optimal scenarios

• Objectives
  • Accessible but powerful (easy to use and customizable)
  • Increase transparency
  • Tinkering
PopEquus

- Web application (user interface)
  - R code runs models
  - Geared to BLM, but customizable
  - Completion date: summer 2019 –ish

Why web app?
- Easy to update & add data
- Everyone uses most recent version
- Save inputs so others can verify results
- Interactive graphs & tables
- Easier to use than R!
PopEquus: management options

Single actions

- ✓ No action
- ✓ Removals
- ✓ PZP-22
- ✓ Spaying
  - ZonaStat
  - GonaCon
  - Gelding

Completed

Combinations

- ✓ Removal + spaying
  - PZP-22 + Removal
  - ZonaStat + Removal
  - GonaCon + Removal
  - Gelding + Removal
  - Spaying + PZP-22
  - Spaying + ZonaStat
  - Spaying + GonaCon
  - Spaying + Gelding
  - Spaying + PZP-22 + Removal
  - Spaying + ZonaStat + Removal
  ...

Not yet done
PopEquus: the bones

- Age structured population model
  - **Matrices** with survival and foaling rates
  - Stochastic projection
  - Tracks individual animals on range & in holding

- Calculates annual costs, per head
  - PGS treatments
  - Gathers
  - Adoptions
  - Holding costs

Projection matrix example:

<table>
<thead>
<tr>
<th></th>
<th>Foals</th>
<th>Yearlings</th>
<th>2</th>
<th>3</th>
<th>...</th>
<th>20+</th>
<th>...</th>
<th>...</th>
<th>...</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.52</td>
<td>0.67</td>
<td>...</td>
<td>0.75</td>
<td>0.919</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>0.919</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
<td>0</td>
<td>0</td>
<td>0.996</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>0</td>
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<td>...</td>
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<td>0</td>
<td>0</td>
<td>0.994</td>
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<td>...</td>
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<td>...</td>
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<td>...</td>
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<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
</tbody>
</table>

On range
- Foals
- Yearlings
- 2
- 3
- ...

Off range
- 20+
- ...
- ...
- ...
- 0.591
Output

BLM cumulative operating costs.

“All models are wrong; some are useful.”
- George Box
Tinker to optimize

• Example conditions
  • 600 animals starting population (includes foals)
  • AML 150-300
  • Helicopter gathers @ $800/head
  • Can gather 80% of population
  • Options: PZP-22, spaying, removals
PZP-22 for different ages

Model: PZP@$510 primer, $30 booster, increasing efficacy with boosters

<table>
<thead>
<tr>
<th>Scenario</th>
<th>OnRange $mil</th>
<th>OffRange $mil</th>
<th>TOTAL $mil</th>
<th>Animals Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time frame: years</td>
<td>10</td>
<td>25</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>No action</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>PZP only</td>
<td>2.70 (2.4-3.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>2.70 (2.4-3.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>PZP only, scenario 2</td>
<td>2.85 (2.5-3.2)</td>
<td>0.00 (0.0-0.0)</td>
<td>2.85 (2.5-3.2)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>PZP only, scenario 3</td>
<td>3.01 (2.7-3.4)</td>
<td>0.00 (0.0-0.0)</td>
<td>3.01 (2.7-3.4)</td>
<td>0 (0-0)</td>
</tr>
</tbody>
</table>

- Youngest PZP: 6 y.o.
- Youngest PZP: 4 y.o.
- Youngest PZP: yearlings

0% of trials went below pseudo extinction threshold of 30 animals.
PZP-22 at different intervals

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<td>Time frame: years</td>
<td>10</td>
<td>25</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>No action</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>PZP only</td>
<td>2.01 (1.8-2.2)</td>
<td>0.00 (0.0-0.0)</td>
<td>2.01 (1.8-2.2)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>PZP only, scenario 2</td>
<td>2.69 (2.4-2.9)</td>
<td>0.00 (0.0-0.0)</td>
<td>2.69 (2.4-2.9)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>PZP only, scenario 3</td>
<td>4.52 (4.0-5.1)</td>
<td>0.00 (0.0-0.0)</td>
<td>4.52 (4.0-5.1)</td>
<td>0 (0-0)</td>
</tr>
</tbody>
</table>

Model: Model: PZP@$510 primer, $30 booster, increasing efficacy with boosters, treat 100% of captured yearlings and older
Assumptions: no change in trappability or per head gather costs over time
Spaying different ages

<table>
<thead>
<tr>
<th>Scenario</th>
<th>OnRange $mil</th>
<th>OffRange $mil</th>
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<td>Time frame: years</td>
<td>10</td>
<td>25</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>No action</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only</td>
<td>1.32 (1.2-1.4)</td>
<td>0.00 (0.0-0.0)</td>
<td>1.32 (1.2-1.4)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only, scenario 2</td>
<td>1.43 (1.3-1.5)</td>
<td>0.00 (0.0-0.0)</td>
<td>1.43 (1.3-1.5)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only, scenario 3</td>
<td>1.57 (1.4-1.7)</td>
<td>0.00 (0.0-0.0)</td>
<td>1.57 (1.4-1.7)</td>
<td>0 (0-0)</td>
</tr>
</tbody>
</table>

Model: spay@$300/head

0% of trials went below pseudo extinction threshold of 30 animals.
### Spaying at different intervals

#### Model:
- Spay @ $300/head, spay 100% of captured yearlings and older

<table>
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<td>10</td>
<td>25</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>No action</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only</td>
<td>1.39 (1.3-1.5)</td>
<td>0.00 (0.0-0.0)</td>
<td>1.39 (1.3-1.5)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only, scenario 2</td>
<td>1.33 (1.3-1.4)</td>
<td>0.00 (0.0-0.0)</td>
<td>1.33 (1.3-1.4)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only, scenario 3</td>
<td>0.90 (0.9-0.9)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.90 (0.9-0.9)</td>
<td>0 (0-0)</td>
</tr>
</tbody>
</table>

- Spay every 4 years (1,5,9)
- Spay every 3 years (1,4,7)
- Spay in years 1 & 3 only

0% of trials went below pseudo extinction threshold of 30 animals.
Removals at different intervals

<table>
<thead>
<tr>
<th>Scenario</th>
<th>OnRange $mil</th>
<th>OffRange $mil</th>
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<td>25</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>No action</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Remove 300 every 3 years</td>
<td>6.5 (5.6-7.4)</td>
<td>5.9 (5.1-6.8)</td>
<td>6.51 (5.6-7.4)</td>
<td>694 (609-782)</td>
</tr>
<tr>
<td>Remove 200 every 4 years</td>
<td>6.0 (5.5-6.8)</td>
<td>5.08 (5.0-6.8)</td>
<td>6.6 (6.0-7.4)</td>
<td>662 (619-729)</td>
</tr>
<tr>
<td>Remove 150 every 5 years</td>
<td>4.51 (4.0-5.9)</td>
<td>4.89 (4.3-6.3)</td>
<td>526 (436-616)</td>
<td>526 (436-616)</td>
</tr>
</tbody>
</table>

- Remove to 300 every 3 years
- Remove to 200 every 4 years
- Remove to 150 every 5 years

0% of trials went below pseudo-extinction threshold of 30 animals.
Compare optimized scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>OnRange $mil</th>
<th>OffRange $mil</th>
<th>TOTAL $mil</th>
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<tr>
<td></td>
<td>10</td>
<td>25</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>No action</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Removals only</td>
<td>0.49 (0.5-0.5)</td>
<td>5.66 (5.4-6.1)</td>
<td>6.15 (5.8-6.6)</td>
<td>607 (597-646)</td>
</tr>
<tr>
<td>PZP only</td>
<td>2.70 (2.4-3.0)</td>
<td>0.00 (0.0-0.0)</td>
<td>2.70 (2.4-3.0)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Spay only</td>
<td>0.91 (0.9-0.9)</td>
<td>0.00 (0.0-0.0)</td>
<td>0.91 (0.9-0.9)</td>
<td>0 (0-0)</td>
</tr>
<tr>
<td>Removal and spay</td>
<td>0.59 (0.6-0.6)</td>
<td>4.23 (4.0-4.5)</td>
<td>4.82 (4.6-5.1)</td>
<td>436 (436-436)</td>
</tr>
</tbody>
</table>
Thanks to USGS and BLM, especially:

Paul Griffin    Kate Schoenecker    Mark Hannon    Jeff Laake    Brian Reichert
Alan Shepherd   Zack Bowen         Bruce Lubow     Lucy Burris    Kurt Jenkins
Holle Waddell   Bruce Rittenhouse  Dean Bolstad