Southern Resident killer whale demographics and trends

Eric Ward, Mike Ford, Brad Hanson
eric.ward@noaa.gov
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1. Reconstructing historical population size

2. Demographic summary

3. Projections for decline

4. Data gaps
How big was SRKW population pre-1976?

• What is the historical population size?
  140?
  200?
  other?

• Where did 140 come from?
  \[ N(1971) + \text{total removals} + \text{shootings} \]

Source: SRKW Recovery Plan, p 54-56
Population dynamics in reverse

- Harvests 1962-1979 treated as known
- Assume max growth rate 4%
- Estimate $N(1962)$ given $N(1976, 1977, \ldots)$

**Sample R code for exploring effects of varying carrying capacity over 1962-1979**

```r
K = 115  # carrying capacity before removals (1962)
r = 0.04  # Rmax = 4%
# Create data frame, using year specific harvests,
df = data.frame(Yr = seq(1962, 1979), Harvest = c(2, 0, 1, 2, 1, 8, 7, 3, 13, 5, 1, 4, 0, 0, 0), N = NA)
df$N[1] = K  # project forward. make harvest occur before births/deaths
for(i in 2:dim(df)[1]) {
  # logistic growth model
  df$N[i] = (df$N[i-1] - df$Harvest[i-1]) + (df$N[i-1] - df$Harvest[i-1]) * r * (1 - (df$N[i-1] - df$Harvest[i-1]) / K)
}
```

**Figure 10:** Estimated population trajectory for Southern Resident killer whales incorporating harvests over the 1962-1979 time span.
SRKW have likely been small for some time

![Graph showing Southern Resident Population (1960-99)](image-url)

Reconstruction from Bain & Balcomb
Genetic data also suggest population size has been small (Ford et al. 2018)

- Effective Nb = 10-53 (mean = 22)
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What’s going on now?

• Lots of demography highlighted in 2011-2012 DFO NOAA workshops, Nov 2017 workshop at UBC

• SRKW have reduced fecundity and survival compared to NRKW and SEAK populations of killer whales

Ward et al. (2009), Ford et al. (2010), Ward et al. (2013), Ward et al. (2016)
Other fish-eating killer whales doing very well

- NRKW
  - 265 to 281 (2011 to 2017)
  - no strong signs of density dependence

- SRKW
  - 87 to 76 animals (2011 to 2017)
Recent declines appear similar to 1990s

SRKW Mortalities (pre-ESA listing, and since 2011)
Changing age structure

SRKW age and sex structure

- Juvenile
- Repro.F
- Old.F
- Young.M
- Old.M

Year

Count

Increasing trend toward male births

Northern

Southern

Sex at birth (0 = female)

1980 1990 2000 2010

0.00 0.25 0.50 0.75 1.00

1980 1990 2000 2010

0.00 0.25 0.50 0.75 1.00
But recovery may be limited by females

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Some females might not ever produce a calf again (grey)

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Looking forward: is this a crisis?

- Status quo projections suggested slight increase
- But high uncertainty (95% CIs for 2017 = 76 - 108)
- 2011-2012 workshops: 87 whales, 2017 = 76

Figure 16. Observed and projected SRKW population size, years 1974–2040.

Influence of new data on demography

Having survival or fecundity rates changed since the last status review (or bilateral workshops)?

We can examine survival rates estimated using data through 2010, versus estimates using data through 2016.

For both instances, we can fit GAMs that include the effect of age (separate splines by sex) and optionally a spline term over time.

These calls to `gam()` are just:

```r
# Model using data through 2010
survival_01 = gam(alive ~ s(age, by=sex) + s(time) + population, family = "binomial", data = X[which(X$time1 <= 2010), ])
# Model using full dataset
survival_02 = gam(alive ~ s(age, by=sex) + s(time) + population, family = "binomial", data = X)
```

No surviving calves produced in 2013, 2016, 2017
Population projected to decline, won’t meet recovery goals

- Rate depends on assumptions

Source: Dec 2016 status review
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Data gaps: SRKW versus other spp of concern

SRKW represent a declining population of a species / ecotype that is doing really well

More fish-eating killer whales in NE Pacific now than since < 1972

For many species, threat(s) are clear, can be prioritized. Less so for SRKW.
Data gaps: unanswerable questions?

- Are the fluctuations we’re seeing just chance?
- What are the reasons for individual deaths?
- Why are animals becoming pregnant but not producing live calves?
- If food limited, what prey is most limiting? Which stocks?
- Which season are the animals most nutritionally stressed?
- Which contaminants (if any) affect health, fecundity or survival?
- How does disease impact SRKW?
- Are any social behaviors, infanticide or other, affecting demographics?
- How is inbreeding impacting demographic rates?
- What (if anything) is causing the trend toward more male births?
Conclusions

• Historical population size of SRKW has likely been small, at least to the early 20th century
• SRKW projected to continue decline because
  • Fecundity appears to be slightly lower in the last 5-6 years
  • Small effective population size (~ 20-25), small number of successful breeding females
  • Trend toward more male births
• Relative importance of risks unclear