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# Estimating Fatality to address FWS Wind Energy Guidelines Tier IV Analyses

Oct 30, 2013


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# Why is estimating fatality so hard?

- Estimate population abundance(dead…)
- Different circumstances than other studies?
  - Open population (carcasses enter and leave)
  - Super population estimate (all that ever entered)
  - Nonconstant density within plots below turbines
  - Nonhomogeneous population with greatly varying probabilities of detection
  - Different species enter and leave at different rates

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# Tier IV Protocol Design Considerations

- "…should be adequate to answer applicable Tier 4 questions at an appropriate level of precision" *Guidance Document, pg 35*

Examine Tier IV protocol design considerations

in context of Tier IV objectives

- Which questions are relevant to your site?
- What level of precision do you need?
- How do you achieve that level?

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# Tier IV Questions

- What are the bird and bat fatality rates for the project?
- What are the fatality rates of species of concern?
- How do the estimated fatality rates compare to the predicted fatality rates?
- Do bird and bat fatalities vary within the project site in relation to site characteristics?
- How do the fatality rates compare to the fatality rates from existing projects in similar landscapes with similar species composition and use?
- What is the composition of fatalities in relation to migrating and resident birds and bats at the site?
- Do fatality data suggest the need for measures to reduce impacts?

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# Found ≠ Dead

- # turbines searched
- Carcasses outside
- Inaccessible areas
- Carcasses removed
- Missed by searchers

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# Tier IV Protocol Design Considerations

- Duration and frequency of monitoring
- Number of turbines to monitor
- Delineation of carcass search plots, transects, and habitat mapping
- General search protocol
- Field bias and error assessment
- Estimators of fatality

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# Duration and frequency of monitoring

- **Duration**
  - Reflects period of interest, e.g., year, season
- **Frequency, i.e., search interval**
  - Tied to persistence time, not arrival
  - Rare to need daily searches
    - Daily only needed for research purposes
  - Trade-off with number of turbines to monitor

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# Number of turbines to monitor

- Sampling fraction
- Factor over which we have most control
  - => very important in project design
- If <10 turbines at site
  - Monitor 100%
- If >10 at site
  - Monitor as high a fraction as possible
- Trade-offs with search interval
  - e.g., ALL turbines @ 2d vs ½ turbines daily

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# Field bias and error assessment

## Searcher Efficiency & Carcass Persistence

- ID factors that *might* change SE or CP
  - e.g. habitat, size, season…
- Need <u>many</u> trial carcasses per factor combo
  - asy, Mod, Diff) = 9

**<u>Much</u> more if SE is small**

- Distribute carcasses throughout period
  - not all on one day or on small set of days, then gap
  - not many at one turbine

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# Field bias and error assessment
## Searcher Efficiency (proficiency)

- Time-limited searches? No
  - Slow down where searching is difficult
  - Narrower transects in difficult areas
- Critical:
  - SE trials conducted under *normal* protocol
  - Searchers cannot know they are being tested
    - Vary number of carcasses placed in a day and at a turbine
- Control SE
  - Clearing vegetation
  - Trained dogs

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# Field bias and error assessment
## Carcass Persistence

- Place trial carcasses based on relevant factors
- Check carcasses on day 1,2,3,4,6,8,10,14,21,28
  - Early monitoring is critical
- Is evidence of a carcass still detectable?
  - e.g. feather spots, body parts
- Censored data – i.e., don't observe removal

  only interval e.g., between day 10 and 14
- Model persistence time
- Estimate fraction persisting until next search

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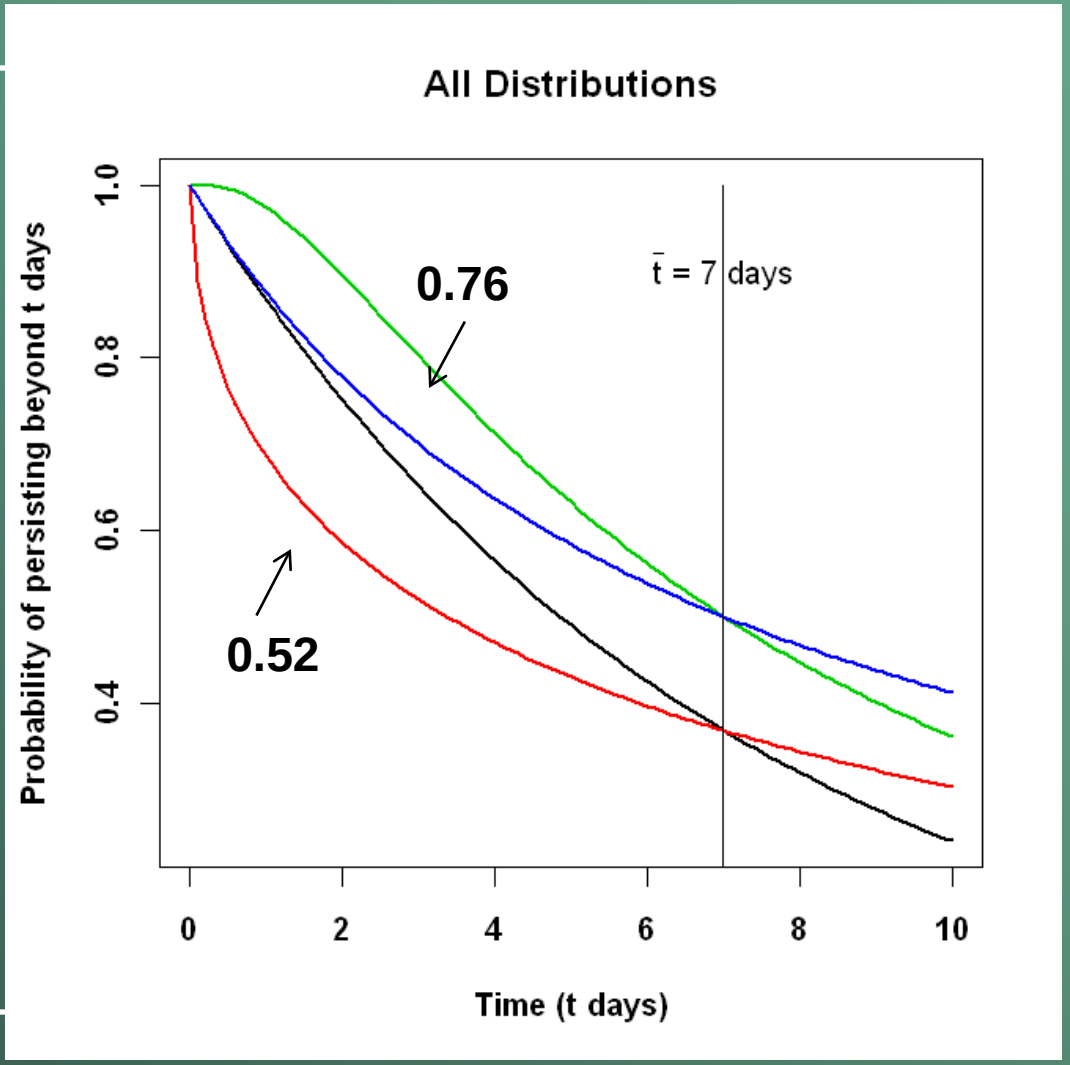
# Field bias and error assessment
## Carcass Persistence

Avg persistence time = 7days

≠

Pr(persisting through search interval)

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# Field bias and error assessment
## Carcass Persistence

- Use appropriate “survival analysis” tools
  - Bispo, Bio3
  - USGS Data Series 729

- Controlling average persistence time difficult
  - fencing or trapping out scavengers
- Control probability of persisting easy
  - length of search interval

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# Delineation of carcass search plots, transects, and habitat mapping

- Transect width
  - Wide in open terrain, narrow in brushy
- Recommend plot = 2X turbine height
  - Larger for raptors than bats

- How to account for unsearchable area?
- Do we have to search full area?

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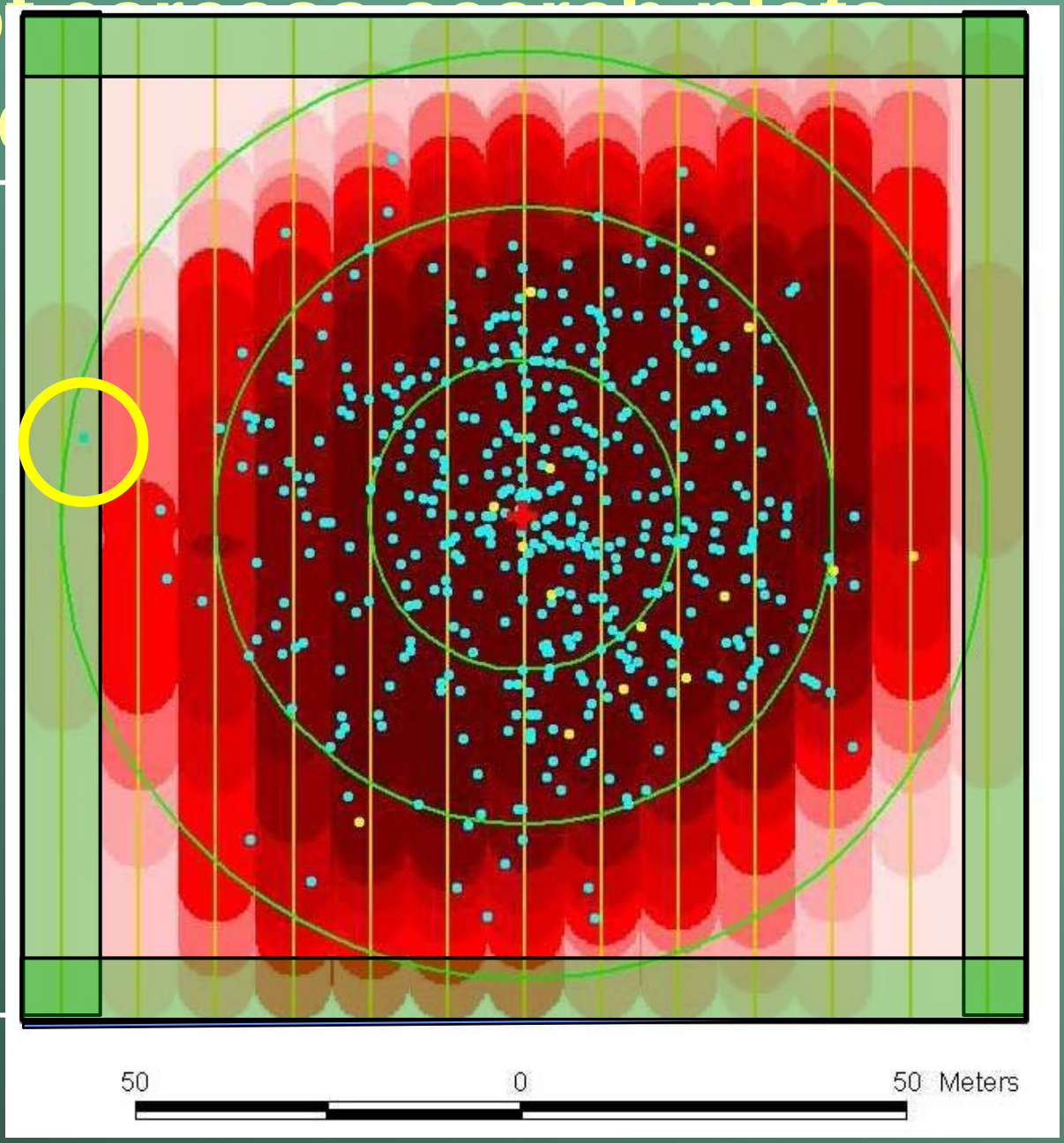
# Delineation of [illegible] transects, and [illegible]

- Carcass density not constant
- Reduce by 25%
- Perimeter:
  - Lose <1%

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From Arnett et al. 2005 BWEC Report

# Delineation of transects, and

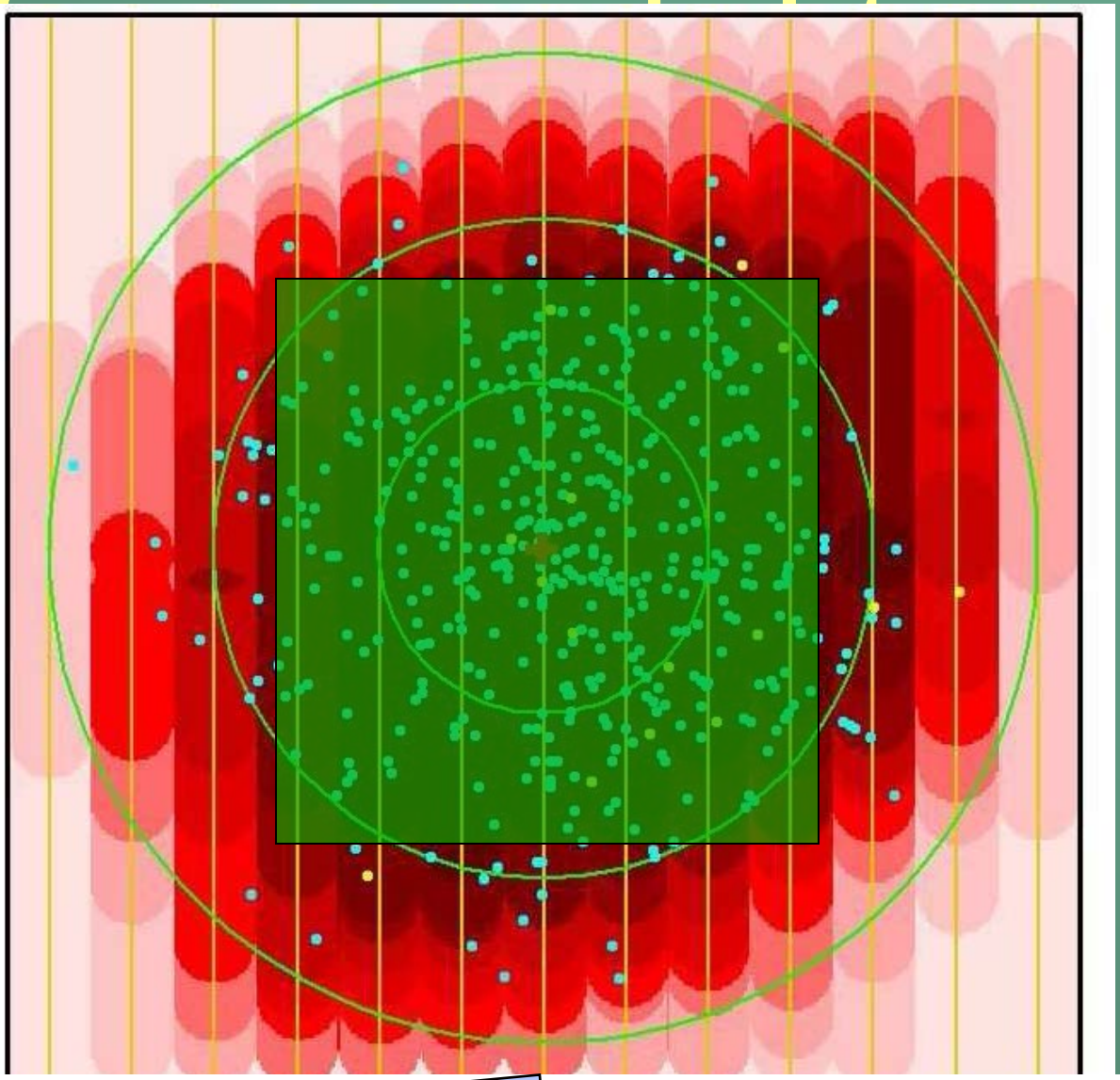
Reduce by 25%

Perimeter:

Lose <1%

Center:

Lose >85%



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"What ~~fraction of the plot is searchable?~~"

"What fraction of the carcasses were detectable?"

From Arnett et al. 2005 BWEC Report

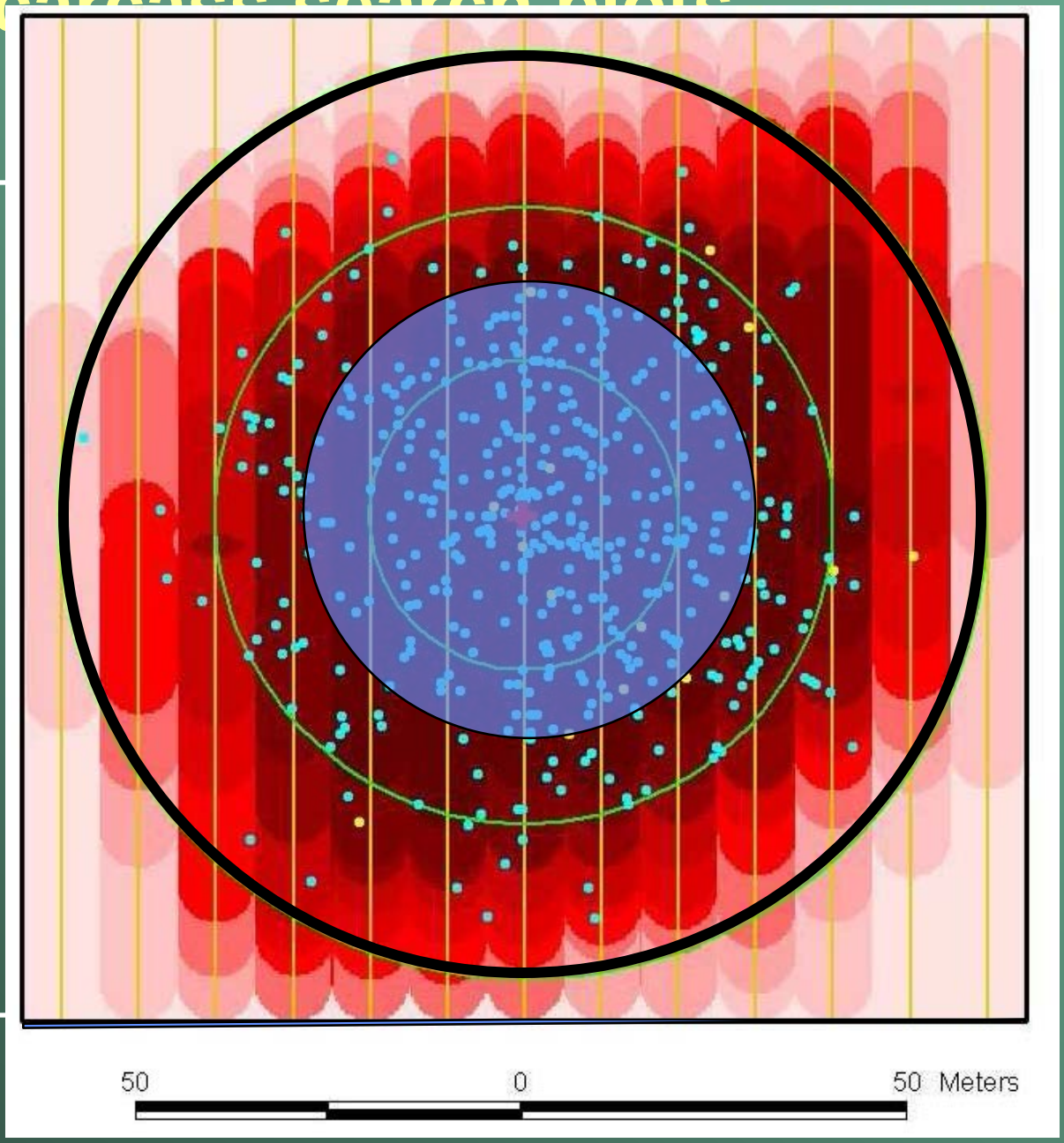
# Delineation of carcass search plots, transects, and

Carcass density not constant

↓ radius by ½

↓ searched area by ¾

↓ carcasses by ~¼

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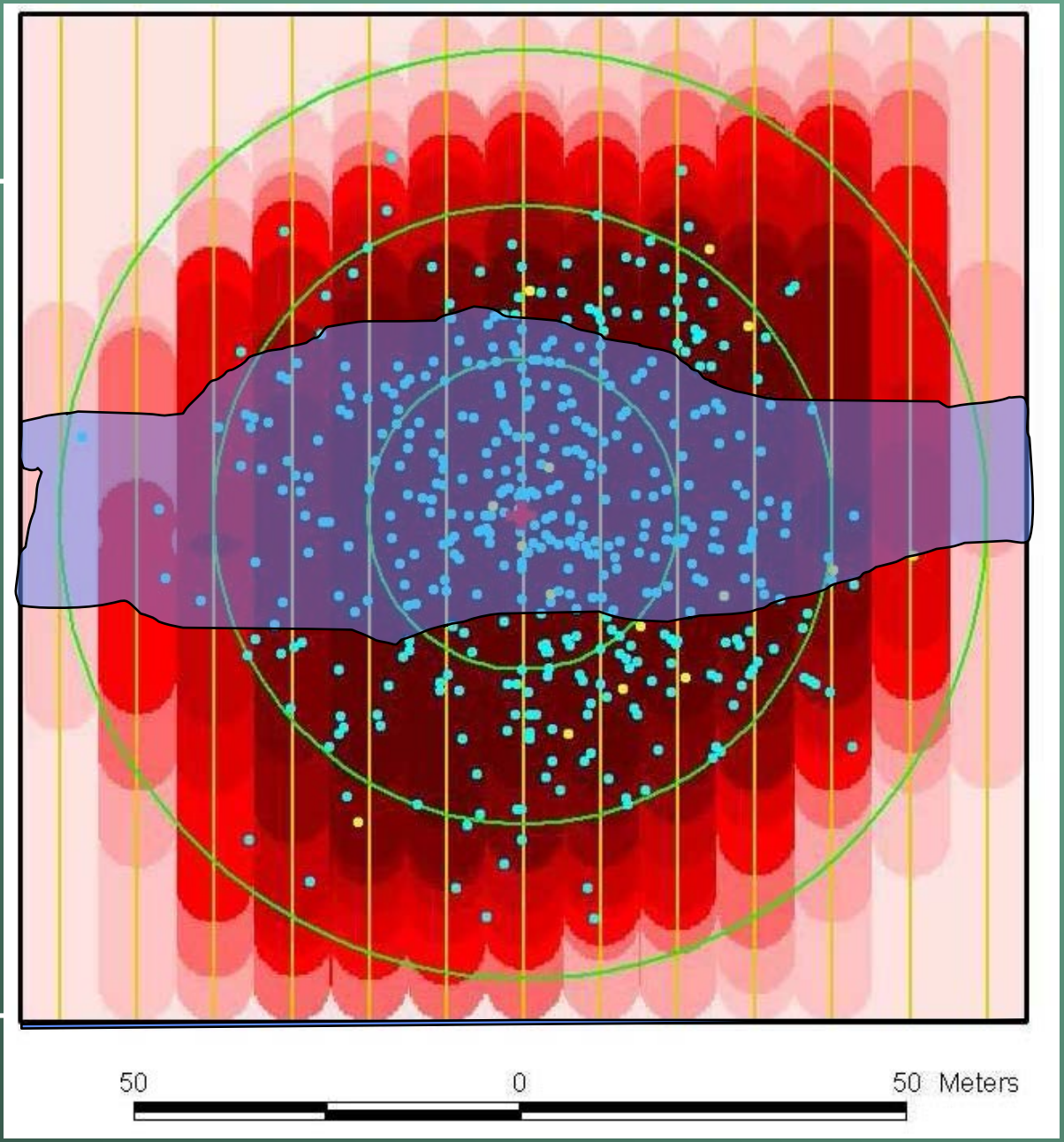
From Arnett et al. 2005 BWEC Report

# *Proportion in searched area*

- **Carcass density not constant**
- **Searched areas not regular**
- **Model**
- **density ~ dist**

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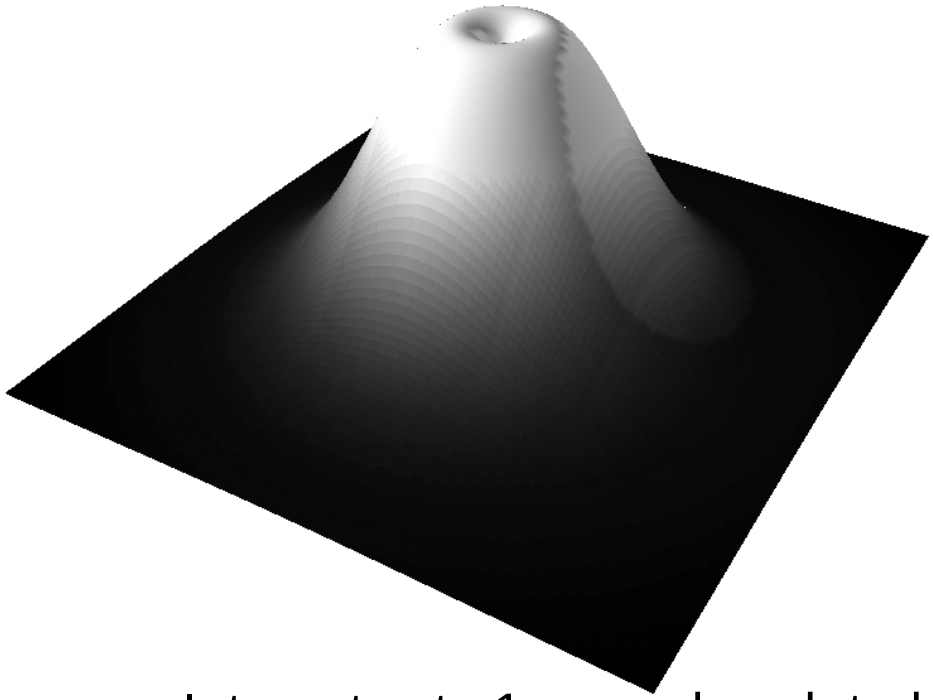
From Arnett et al. 2005 BWEC Report

# Proportion in searched area
## Relative density

**Carcass density not constant**

**Model:**

**relative density ~ distance**



Integrates to 1 around each turbine

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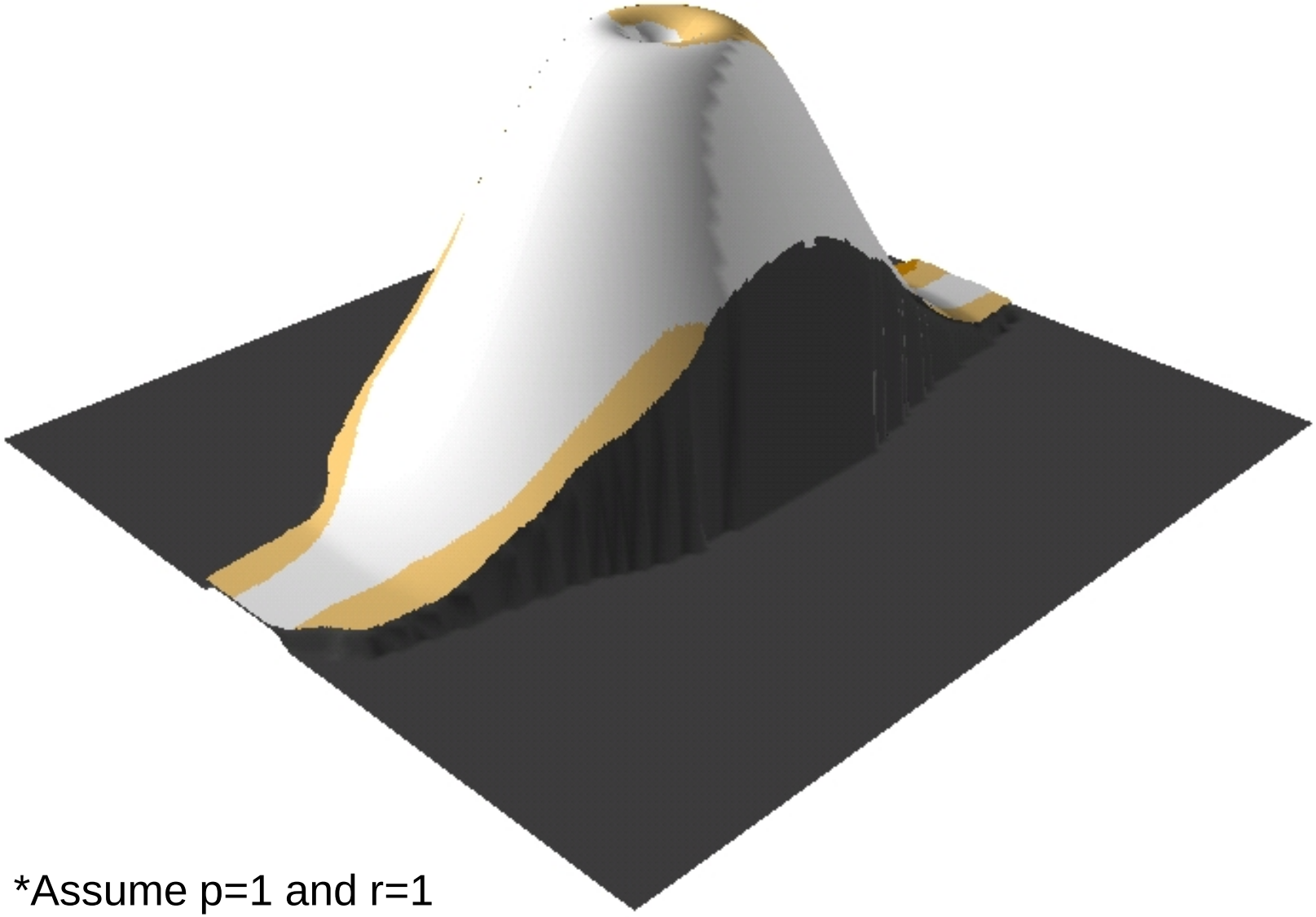
**25% searchable**
**vs 60% in searched area**

**Find 50* :**
**50/0.25 = 200**
**50/0.60 = 83**



*Assume p=1 and r=1

# Delineation of carcass search plots, transects, and habitat mapping

- Model density
  - Need a lot of location data
  - Need some data at far distances, e.g. up to 150m
    - (search roads and contiguous Easy areas)
- Habitat maps define searched area
- Control fraction of carcasses in searched area by focusing search on areas of highest densities

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# General search protocol

- Data records
- Location relative to turbine
  - → density models → proportion in searched area
- Date found and date of most recent search
  - → persistence probability
- Time since death
  - → informs estimators
- Covariates, e.g., size, habitat, season
  - → estimators

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# Estimators of Fatality

- k = # factor combos
- c = # carcasses found in factor combo
- Number of turbines to monitor = *n/N = f*
- Delineation of carcass search plots, transects, and habitat mapping = *s*
- Field bias and error assessment = *p, r*

$$\hat{F} = \sum_{i=1}^{k} \frac{c_i}{\hat{f}_i \hat{r}_i \hat{p}_i \hat{s}_i} = \sum_{i=1}^{k} \frac{c_i}{\hat{g}_i}$$

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# Estimators of Fatality

## Example: find 30 carcasses in one combo

- *f* = fraction of turbines searched (8/19) 42%
- s = fraction carcasses in srchd area 85%
- r = % persisting 75%
- p = % found by searchers 60%

72-98%

53-97%

35-85%

- Probability of detection =
  - 0.42 * 0.85 * 0.75 * 0.60 = 0.16

No uncertainty!

- Estimated fatality = 30 / 0.16 = ~~187.5~~

Wrong!

- Probability of detection = (0.07, 0.25)
  - => Total Fatality in combo: 118 – 361

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# Estimators of Fatality

## Example: find 30 carcasses in one combo

- f = fraction of turbines searched (19/19) 100%
- s = fraction inside plots srchd area 97%
- r = % persisting 90%
- p = % found by searchers 80%

95-99%
85-95%
74-86%

- Probability of detection =
  - 1.00 * 0.97 * 0.90 * 0.80 = 0.7
- Estimated fatality = 131 / 0.7 = 187.7
- Probability of detection = (0.63, 0.77)
  - => Total Fatality in combo: 170 - 206

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# Estimators of Fatality

- Several available
  - Huso et al.
  - Schoenfeld
  - Korner

  } USGS Data Series 729

  - Wolpert - Not yet publicly available
- Differ in assumptions

- Critical: Need VARIANCE estimate

# Variance

- Difficult
- Recent variations:
  - Bootstrap (Erickson et al.; Huso et al. DS 729)
  - Closed-form (Wolpert & Warren-Hicks 2012)
  - Other closed-form solutions → negative limits
- No estimate without measure of uncertainty
- Use common sense
  - Model says -15 ft might have been killed

send it back!

send it back!

# What are the fatality rates of species of concern?

- Current proposals:
  - Permit limited numbers of collision-caused deaths of certain species of concern, e.g. Ibat, G. eagle
- How to determine limits?
  - population models
  - collision risk models
- How will we know when limit exceeded?

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# What are the fatality rates of species of concern?

- Estimate Fatality
  - current post-con carcass search protocol
- Current protocol
  - adequate when carcass population is relatively high

    e.g. all birds, all bats, passerines…

  - inadequate when carcass population is small

    e.g. T&E species
  - inadequate to detect when set limit is exceeded

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# What are the fatality rates of species of concern?

- Current H-T-based estimators can only estimate 0 if no carcasses found
- Preliminary work: Use Bayesian estimators to detect whether limits might be exceeded

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# Can we answer Tier IV Questions?


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# Can we answer Tier IV Questions? Estimation questions

- What are the bird and bat fatality rates for the project?
  - per turbine? per MW nameplate?
  - per actual MWH produced? per 10,000 $m^2$ RSA?
  - Sampling unit = turbine… all others derived
- What are the fatality rates of species of concern?
- What is the composition of fatalities in relation to migrating and resident birds and bats at the site?
  - Estimate fatality for subgroups

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# Can we answer Tier IV Questions? Comparison Questions

- Do the estimated fatality rates compare to the predicted fatality rates?
- How do the fatality rates compare to the fatality rates from existing projects in similar landscapes with similar species composition and use?
- Do fatality data suggest the need for measures to reduce impacts?
  - Uncertainty matters - consider both CLs
  - Design to achieve needed precision

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# Can we answer Tier IV Questions? Relationship Questions

- Do bird and bat fatalities vary within the project site in relation to site characteristics?
  - Difficult without a lot of observed fatalities

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# Can we answer Tier IV Questions?

- Yes
- But all estimates need measure of uncertainty
- Be aware of uncertainty when interpreting

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# Acknowledgements

**Christy Johnson-Hughes**
**US Fish and Wildlife Service**
**US Geological Survey**
**David Dail and Dan Dalthorp**

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# THANK YOU!

Statistics means never being able to say you're certain

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