GOPHER TORTOISE SURVEY OF HONEYMOON ISLAND STATE PARK

Final Report to Florida Fish and Wildlife Conservation Commission

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Florida Natural Areas Inventory

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FLORIDA Natural Areas INVENTORY

Cover Photographs:

top: Beach dune at Honeymoon Island SP (Rebecca Zeroth)

center: Eastern diamondback rattlesnake (*Crotalus adamanteus*) at Honeymoon Island SP (Robert Gundy)

bottom: Two sand-covered gopher tortoises (*Gopherus polyphemus*) at Caladesi Island SP (Rebecca Zeroth)

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ABSTRACT

FNAI scientists conducted a pilot survey for gopher tortoises at Honeymoon Island State Park, on 5 and 7 December, 2016. This report is a follow-up to the pilot survey and describes a full Line Transect Distance Sampling (LTDS) survey for gopher tortoises at Honeymoon Island State Park. A variety of unique coastal habitats were surveyed and over 300 burrows were scoped. The estimated viability, based on habitat quality and population size is Good, but not optimal. Because of its small land mass and other factors, this ranking cannot be increased, but it can be maintained with good land management practices.

INTRODUCTION

To address concerns regarding survey consistency, LTDS recently has been adopted as the preferred monitoring methodology through the Gopher Tortoise Candidate Conservation Agreement team. This method is widely used to estimate population size and density of wildlife species (Buckland et al. 2004) and provides a statistically valid, consistent method to evaluate tortoise populations. Standardized survey results will provide crucial baseline data, using a repeatable method, with which to compare future survey data and determine population trends or variation in response to habitat management activities.

The open source software Distance software 6.2 can be used to create LTDS survey designs and to analyze survey data. ArcGIS software is necessary for managing spatial data related to the survey [e.g., to define the survey area (sampling frame), and map transect and tortoise locations]. The sampling frame is the extent of suitable tortoise habitat on a particular property as determined by soils, vegetation (land cover), and land-use.

A pilot survey is generally conducted prior to the formal survey to determine the sampling intensity needed for the full survey. During the pilot survey, the length of transect surveyed per tortoise observation, called the tortoise encounter rate, is recorded. This value is used to calculate the distance of transect needed to achieve desirable results in the formal survey. There is flexibility in the amount of effort required for a pilot survey and in selecting locations for pilot survey transects, but it is important that the pilot survey captures variation in habitat type, quality, and tortoise distribution within the sampling frame.

The full LTDS survey is designed using Distance software 6.2 and incorporates the sampling frame and encounter rate from the pilot survey. The tortoise encounter rate (meters of transect sampled per tortoise observed) is used to extrapolate the total length of transect necessary to observe at least 60 objects (tortoises) and to derive abundance estimates with reasonable precision. As a general rule, to detect changes in population size over time, sampling should be intensive enough to produce a coefficient of variation (CV) of 15-20%, which is a practical expectation for most monitoring projects. If the CV exceeds 20%, the statistical power, confidence, and ability to detect trends in monitoring data are substantially reduced.

METHODS

LTDS Sampling

Based on the encounter rate of 424.9 obtained in the pilot survey, the transect distance for the full survey was 44,109.7m. This estimate was buffered to allow for some elimination should the habitat be deemed unsuitable for gopher tortoises during the full survey. ArcMap was used to generate east/west and north/south grid transects (Fishnet tool) across the sample frame. The original sampling frame was 85.32 ha with the transects spaced 40 m apart. FNAI scientists traversed these transects using a double observer approach (one observer navigating the transects with a Trimble Geo7 GPS unit and the second observer following closely behind focusing on looking for burrows the first observer missed). All usable burrows (non-collapsed) observed were searched with a burrow scoping camera to determine occupancy. Surveys were conducted on 13-16 February and 10-13 April, 2017.

At each scoped burrow a data dictionary was used to record additional burrow information. The visual status was recorded as either active (showed signs of recent activity such as tracks, slide, or digging), or inactive. The actual status was recorded as occupied, unoccupied, or undetermined (a burrow was recorded as undetermined if it was unable to be completely scoped; this may be because it curved too sharply, was waterlogged or the scope was not long enough to reach the end). The width of the burrow was measured to the nearest 0.5 cm with calipers inserted 50 cm inside the burrow.

All transect lengths were calculated in ArcMap. For each burrow data point the perpendicular distance from the burrow to the transect center line was calculated using the Near function. Each encounter is a single data point in the input file with two metrics: the length of the transect the burrow was found on and the perpendicular distance from the burrow to the transect center line. Lengths of transects where no tortoises were observed were also input, but without a perpendicular distance. These data were analyzed using Distance software 6.2.

Habitat Assessments

During the survey FNAI scientists used a rapid habitat assessment protocol to help determine habitat structure and quality. Habitat suitability points were taken at random locations on transects over 100 meters in length. Gopher tortoise suitability, basal area, canopy cover, overstory composition, percent midstory, midstory composition, ground cover composition, percent herb cover, percent bare sand, and woody encroachment were recorded along with a north facing photo. Gopher tortoise suitability was ranked as good, fair, poor, or unsuitable. Basal area was taken using a 10 factor prism, held horizontally at approximately 1.5 m. Trees for which the images overlapped were counted as 1, trees for which only the edges of the images overlapped were counted as 0.5 and trees for which the images did not overlap were not counted. The total counts were multiplied by 10. The total canopy cover was estimated and the dominant overstory composition was recorded as either pine, oak, mixed, other, or none. The midstory percent cover included all woody perennial vegetation ranging from 1-3 m tall within a radius of 5 m. The dominant vegetation was recorded as either pine, oak, shrub, palmetto, mixed, or other. The dominant ground cover type within a radius of 1 m was recorded as bare ground, litter, grass, woody, vine, or mixed. The percent herbaceous cover was estimated within a radius of 1 m and included all non-woody species. The percent cover for bare sand within a radius of 1 m was also noted separately from bare ground as a dominant ground cover type. Woody encroachment was estimated as the increase in density, cover, and biomass of woody species, and was recorded as low, medium, or high. At each location a georeferenced north-facing photo was taken using an Olympus Stylus TG-4 digital camera.

RESULTS and DISCUSSION

During the full survey some habitat was determined to be unsuitable for gopher tortoises because of issues with water table level or natural community classification and was eliminated from the sample frame. The edited sample frame was 62 ha. The total distance walked (excluding transects in unsuitable areas) was 32,116 m. A total of 361 burrows was scoped: 152 occupied, 207 unoccupied, 2 undetermined (Table 1; Figure 1). The occupancy rate was 42 percent. Several notable commensal species were observed in burrows, including: four eastern diamondback rattlesnakes (*Crotalus adamanteus*) (three of them in the same burrow), an eastern coachwhip (*Masticophis flagellum flagellum*), three southern toads (*Bufo terrestris*), an eastern narrow-mouthed toad (*Gastrophryne carolinensis*), a brown anole (*Anolis sagrei*), and an opossum (*Didelphis virginiana*).

Distance software 6.2 was used to run two model sets; one using conventional distance sampling (CDS) and one using multiple covariate distance sampling (MCDS) analysis with burrow width as a covariate (directions obtained from Smith and Howze 2016a). Each model was run twice, once with all burrows and once with occupied burrows only. Akaike's Information Criterion (AIC) (Akaike 1974) was used for model selection. If AIC values were within two units, the model with the lowest coefficient of variation (%CV) was selected.

The CDS Half-normal Cosine was selected as the best fitting model using AIC for all burrows (occupied, unoccupied, and undetermined). Within the sample frame there were an estimated

653 burrows, with a density of 10.48 burrows per ha. The CV (15.16) provides a 95% confidence interval for the estimate ranging from 487 to 878 burrows (Table 2; Appendix A).

The CDS Uniform Cosine was selected as the best fitting model using AIC for occupied burrows only. Within the sample frame there were an estimated 217 gopher tortoises, with an estimated density of 3.49 gopher tortoises per ha. The CV (15.89) provides a 95% confidence interval for the estimate ranging from 159 to 296 gopher tortoises (Table 3; Appendix B).

In assessing population viability for gopher tortoises it is important to take into account the condition of the available habitat (Tuberville et al. 2009), such as size, continuity, quality, management, environmental factors, and demographics. Honeymoon Island SP is a fairly small site, comprising only 62 ha of suitable habitat for gopher tortoises. As an island, it is vulnerable to catastrophic events, such as hurricanes, which can result in sea level changes and beach erosion. This was apparent during the pilot survey when several beach pilot transects, previously located on land, were under water. The water table is high throughout the island, and gopher tortoise burrows where noticeably shorter than at other sites.

Mapping for the natural communities of Honeymoon Island SP was obtained from the Cooperative Land Coverage (CLC) database. Burrows were discovered in beach dune, coastal strand, maritime hammock, mesic flatwoods and ruderal developed. Table 4 shows the occupancy rate by habitat.

Sixty-five habitat suitability points were taken (Table 5; Figure 2). Habitat points taken in the northern section of mesic flatwoods were all recorded as fair, poor, or unsuitable for gopher tortoises. This area could be made more suitable with management focused on frequent prescribed fire, 2-4 year intervals, and by cutting and removing understory hardwoods (FNAI 2010). This would reduce the woody midstory and help promote herbaceous ground cover for tortoises to forage. Brazilian pepper (*Schinus terebinthifolius*) was abundant throughout the island. This exotic plant may make habitat unsuitable for gopher tortoises by shading out native forbes and grasses. A study on Egmont key, where most of the interior of the island was shaded by a thick overstory of Brazilian pepper, found that removing this exotic species opened the forest floor to more direct sunlight (Dodd 1997). Gopher tortoises may benefit from pepper eradication from the island.

Island populations are generally isolated, offering no opportunity for new genetic variation. However, Caladesi Island SP, located just to the south of Honeymoon Island SP, also has a population of gopher tortoises. A pilot survey of Caladesi Island SP, conducted on 6 December, 2016, discovered 6 gopher tortoises and park rangers reported seeing gopher tortoises swimming between the two islands. It is therefore likely that some gene exchange does occasionally occur between the neighboring islands.

The relatively high density (3.5 tortoises per ha) of tortoises on this island makes them vulnerable to extirpation by infectious disease such as mycoplasmosis or upper respiratory tract disease (URTD). URTD has the potential to kill large numbers of tortoises in a relatively short time period (Seigel et al. 2003).

A stable gopher tortoise population will have an even sex ratio and mixed demographics (hatchling, juvenile, subadult, and adult) to indicate recruitment of younger tortoises into the population. Burrow width was measured at each burrow to help determine the demographic structure of the population. Burrow width is correlated with carapace length and can be used to approximate age classes in gopher tortoises (Alford 1980). Burrow width measurements were converted to approximate carapace length and classified as either hatchling (<5.5cm), juvenile (5.6-13.5cm), subadult (13.6-22.0cm), or adult (>22cm). Results, shown in Figure 3, show evidence of recruitment, with a good distribution of juveniles and subadults present in the population. Although no hatchlings were detected, this may be because of the difficultly in detecting very small burrows, and hatchlings sometimes shelter under vegetation rather than dig burrows (Smith et al. 2009). Figure 4, provided as supplemental information, shows the variation in burrow sizes.

Based on Element Occurrence A-D Rank Specifications (NatureServe 2011; Appendix C), the gopher tortoise population at Honeymoon Island SP is ranked as B, indicating it has Good viability and exhibits favorable characteristics, or 2 Medium quality-viable (Smith and Howze 2016b). At 217 the population does not meet the 250 mature gopher tortoises (Tuberville et al. 2009) recommended for a ranking of excellent. The available habitat also falls short of the 100 ha recommendation, and as it is an island there is no opportunity for expansion. However, the population is likely to persist for the foreseeable future and its unique island characteristics make it important to maintaining the conservation status of gopher tortoises.

This population can be best protected by reducing the negative impacts of anthropogenic induced climate change, conducting frequent prescribed fire to maintain or improve current habitat conditions, removing harmful invasive plants (such as Brazilian pepper), and preventing development.

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Table 1. Burrow scoping results during line transect distance sampling surveys (LTDS) at Honeymoon Island SP.

Sampling Frame (ha)	Burrows scoped (total)	Occupied burrows	Percent occupied	Undetermined burrows	Percent undetermined
62.31	361	152	42.34	2	0.55

Table 2. Distance software 6.2 results for all burrows (occupied, unoccupied, and undetermined) at Honeymoon Island SP. Model= model selected, # obs= total burrows observed, Effort (m)= total length of transect in meters, AIC= Akaike's Information Criterion, D= density of burrows, D LCL= lower confidence limit for density, D UCL= upper confidence limit for density, %CV= coefficient of variation, N= number of burrows, N LCL= lower confidence limit for number of burrows, N UCL= upper confidence limit for number of burrows, P= detection probability.

Model	# obs	Effort (m)	AIC	D	D LCL	D UCL	%CV	N	N LCL	N UCL	P
HN Cos 5% (CDS)	343	32116.33	1514.77	10.481	7.7892	14.102	15.16	653	487	878	0.47832

Table 3. Distance software 6.2 results for occupied burrows only at Honeymoon Island SP. Model= model selected, # obs= total gopher tortoises observed, Effort (m)= total length of transect in meters, AIC= Akaike's Information Criterion, D= density of gopher tortoises, D LCL= lower confidence limit for density, D UCL= upper confidence limit for density, %CV= coefficient of variation, N= number of gopher tortoises, N LCL= lower confidence limit for number of gopher tortoises, N UCL= upper confidence limit for number of gopher tortoises, P= detection probability.

Model	# obs	Effort (m)	AIC	D	D LCL	D UCL	%CV	N	N LCL	N UCL	P
UN Cos 5% (CDS)	167	32116.33	648.29	3.486	2.5534	4.7593	15.89	217	159	296	0.59849

Table 4. Percent of total burrows and burrow occupancy rate by Cooperative Land Cover (CLC) habitat type at Honeymoon Island SP.

Habitat type	Beach dune	Cabbage palm	Coastal strand	Maritime hammock	Mesic flatwoods	Ruderal developed
Percent of total burrows	**17**	**5**	**11**	**2**	**23**	**42**
Percent occupancy	**54**	**62**	**37**	**33**	**54**	**30**

Table 5. Habitat data for each habitat point (habitat suitability, basal area, canopy cover, overstory, midstory, ground cover, herb cover, bare sand, and woody encroachment) at Honeymoon Island SP.

Total habitat points	65
Gopher tortoise habitat suitability (% of all habitat points)	
good	32

fair	14
poor	46
unsuitable	8
Mean basal area (ft^2/ac)	15
Mean canopy cover (%)	16
Dominant overstory composition (% of all habitat points)	
pine	9
oak	0
mixed	14
other	37
none	40
Mean midstory cover (%)	28
Dominant midstory composition (% of all habitat points)	
oak	0
pine	0
shrubs	49
palmetto	0
mixed	20
other	18
none	12
Dominant ground cover composition (% of all habitat points)	
bare ground	23
litter	14
grass	43
woody	0
vines	0
mixed	20
Herb cover (%)	39
Bare sand (%)	28
Woody encroachment level (% of all habitat points)	
low	52
medium	23
high	25

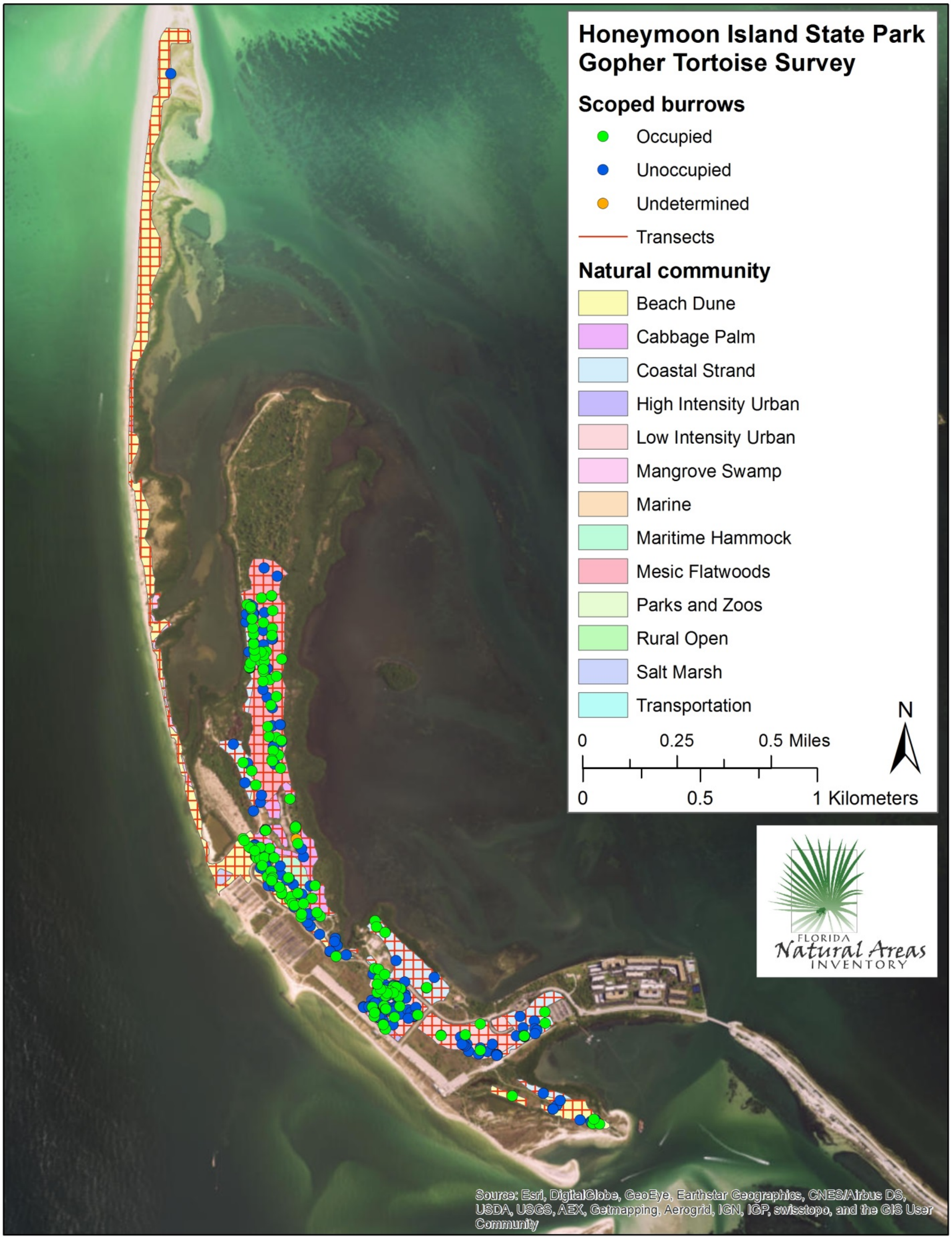

Figure 1: Location of scoped burrows, survey transects, and natural communities.

Figure 2: Natural communities within the sample frame and location of habitat suitability points with corresponding photo ID.

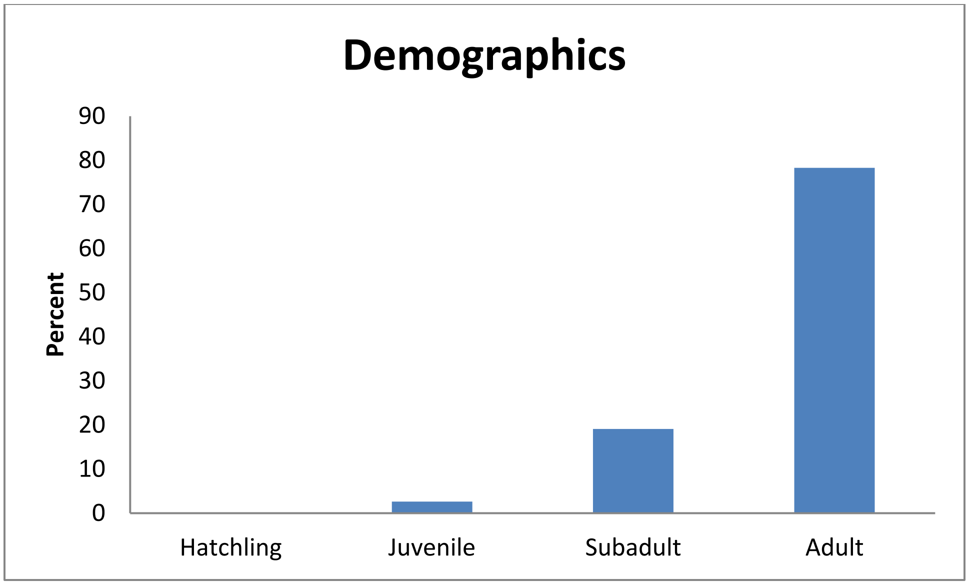

Figure 3: Percent of occupied burrows for four different age classes (Hatchling <5.5cm; Juvenile 5.6-13.5cm; Subadult 13.6-22.0cm; Adult >22cm) at Honeymoon Island SP.

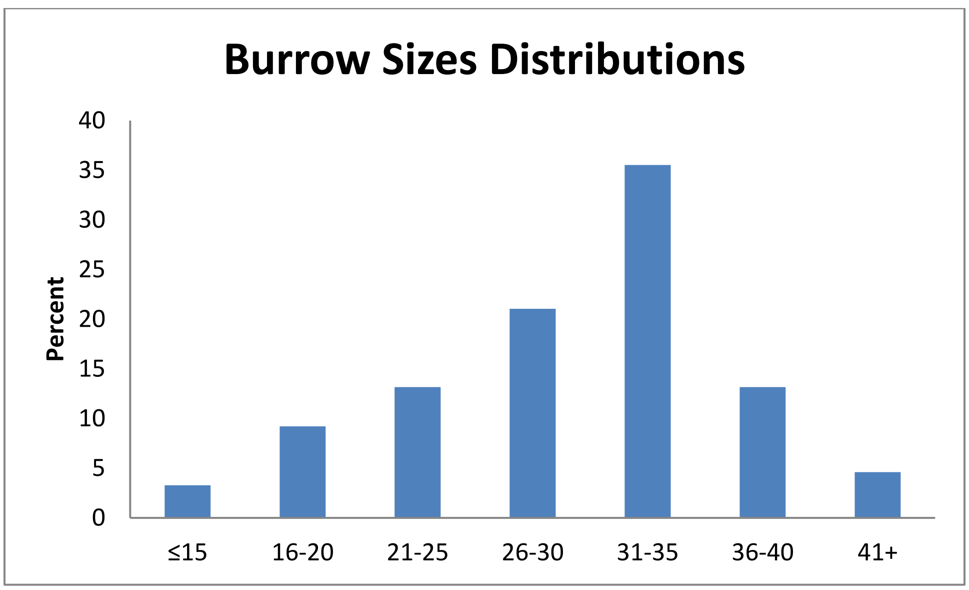

Figure 4: Percent of occupied burrows for seven different size classes at Honeymoon Island SP.

APPENDIX A: Honeymoon Island SP all burrows (occupied, unoccupied, and undetermined) Distance software 6.2 results

Selected model: Conventional distance sampling (CDS) Half-normal Cosine, 5% truncation

```
Parameter Estimation Specification
 ----------------------------------
 Encounter rate for all data combined
 Detection probability for all data combined
 Density for all data combined

 Distances:
 ----------
 Analysis based on exact distances
 Width: use measurement/interval endpoint which represents  95.0 percentile.

 Estimators:
 -----------
 Estimator  1
 Key: Half-normal
 Adjustments - Function                 : Cosines
            - Term selection mode      : Sequential
            - Term selection criterion : Akaike Information Criterion (AIC)
            - Distances scaled by      : W (right truncation distance)

 Estimator selection: Choose estimator with minimum  AIC
 Estimation functions: constrained to be nearly monotone non-increasing

 Variances:
 ----------
 Variance of n: Empirical estimate from sample
               (design-derived estimator R2/P2)
 Variance of f(0): MLE estimate

 Goodness of fit:
 ----------------
 Cut points chosen by program



 Glossary of terms
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 Data items:
 n    - number of observed objects (single or clusters of animals)
 L    - total length of transect line(s)
 k    - number of samples
 K    - point transect effort, typically K=k
 T    - length of time searched in cue counting
 ER   - encounter rate (n/L or n/K or n/T)
 W    - width of line transect or radius of point transect
 x(i) - distance to i-th observation
 s(i) - cluster size of i-th observation
 r-p  - probability for regression test
 chi-p- probability for chi-square goodness-of-fit test


 Parameters or functions of parameters:
 m    - number of parameters in the model
 A(I) - i-th parameter in the estimated probability density function(pdf)
 f(0) - 1/u = value of pdf at zero for line transects
 u    - W*p = ESW, effective detection area for line transects
 h(0) - 2*PI/v
 v    - PI*W*W*p, is the effective detection area for point transects
 p    - probability of observing an object in defined area
 ESW  - for line transects, effective strip width = W*p
 EDR  - for point transects, effective detection radius  = W*sqrt(p)
 rho  - for cue counts, the cue rate
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DS   - estimate of density of clusters
E(S) - estimate of expected value of cluster size
D    - estimate of density of animals
N    - estimate of number of animals in specified area


Effort        :    32116.33
# samples     :   167
Width         :    10.65183
# observations:   343



Model  1
   Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
      Results:
      Convergence was achieved with    8 function evaluations.
      Final Ln(likelihood) value =  -759.69199
      Akaike information criterion =   1521.3840
      Bayesian information criterion =   1525.2217
      AICc =   1521.3958
      Final parameter values:   5.0443841


Model  2
   Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
   Cosine adjustments of order(s) :  2
      Results:
      Convergence was achieved with   20 function evaluations.
      Final Ln(likelihood) value =  -755.38710
      Akaike information criterion =   1514.7742
      Bayesian information criterion =   1522.4497
      AICc =   1514.8094
      Final parameter values:   5.2263055     0.22979925

   Likelihood ratio test between models  1 and  2
      Likelihood ratio test value    =     8.6098
      Probability of a greater value =   0.003344
*** Model  2 selected over model  1 based on minimum AIC


Model  3
   Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
   Cosine adjustments of order(s) :  2, 3
      Results:
      Convergence was achieved with   13 function evaluations.
      Final Ln(likelihood) value =  -754.92483
      Akaike information criterion =   1515.8496
      Bayesian information criterion =   1527.3628
      AICc =   1515.9204
      Final parameter values:   5.2042258     0.21022250     0.75044440E-01

   Likelihood ratio test between models  2 and  3
      Likelihood ratio test value    =     0.9245
      Probability of a greater value =   0.336284
*** Model  2 selected over model  3 based on minimum AIC


Effort        :    32116.33
# samples     :   167
Width         :    10.65183
# observations:   343

Model
   Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
   Cosine adjustments of order(s) :  2


             Point        Standard    Percent Coef.        95 Percent
 Parameter   Estimate       Error      of Variation     Confidence Interval
 ---------  -----------  -----------  --------------  ----------------------
```
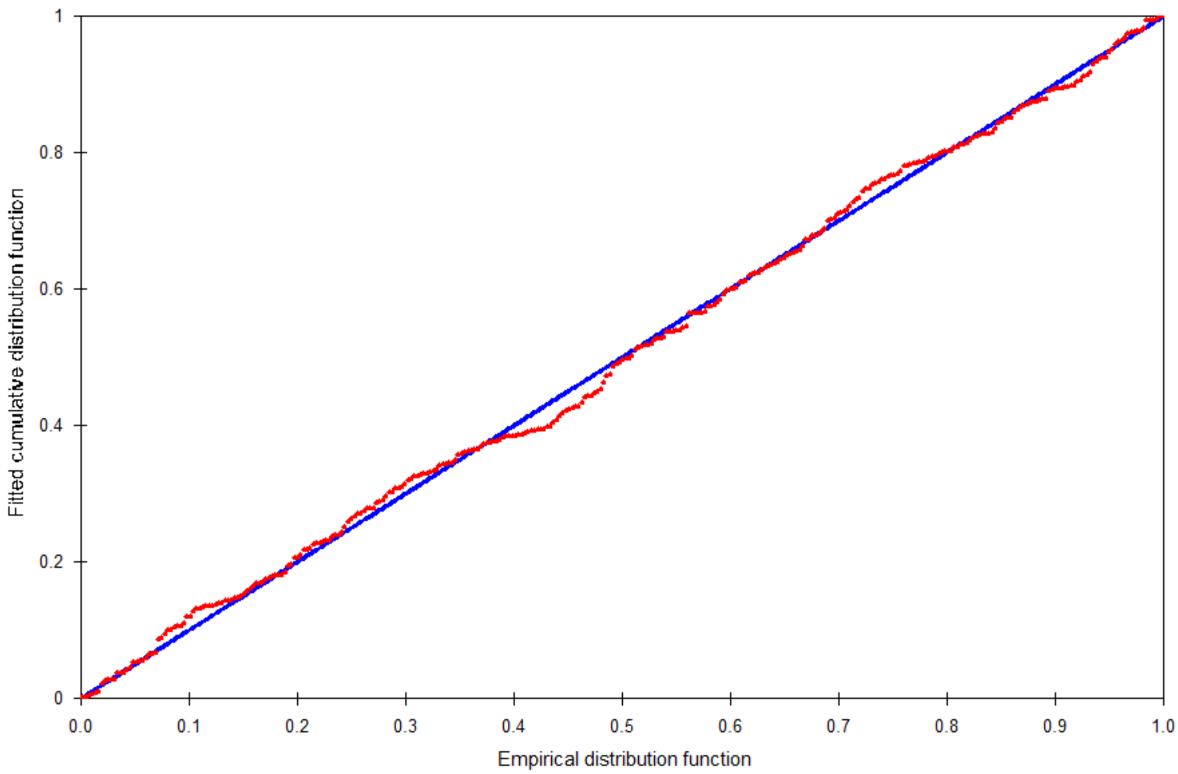

A(1)	5.226	0.2959			
A(2)	0.2298	0.7715E-01			
f(0)	0.19627	0.13394E-01	6.82	0.17164	0.22443
p	0.47832	0.32642E-01	6.82	0.41831	0.54695
ESW	5.0950	0.34770	6.82	4.4557	5.8260

Sampling Correlation of Estimated Parameters

	A(1)	A(2)
A(1)	1.000	0.220
A(2)	0.220	1.000



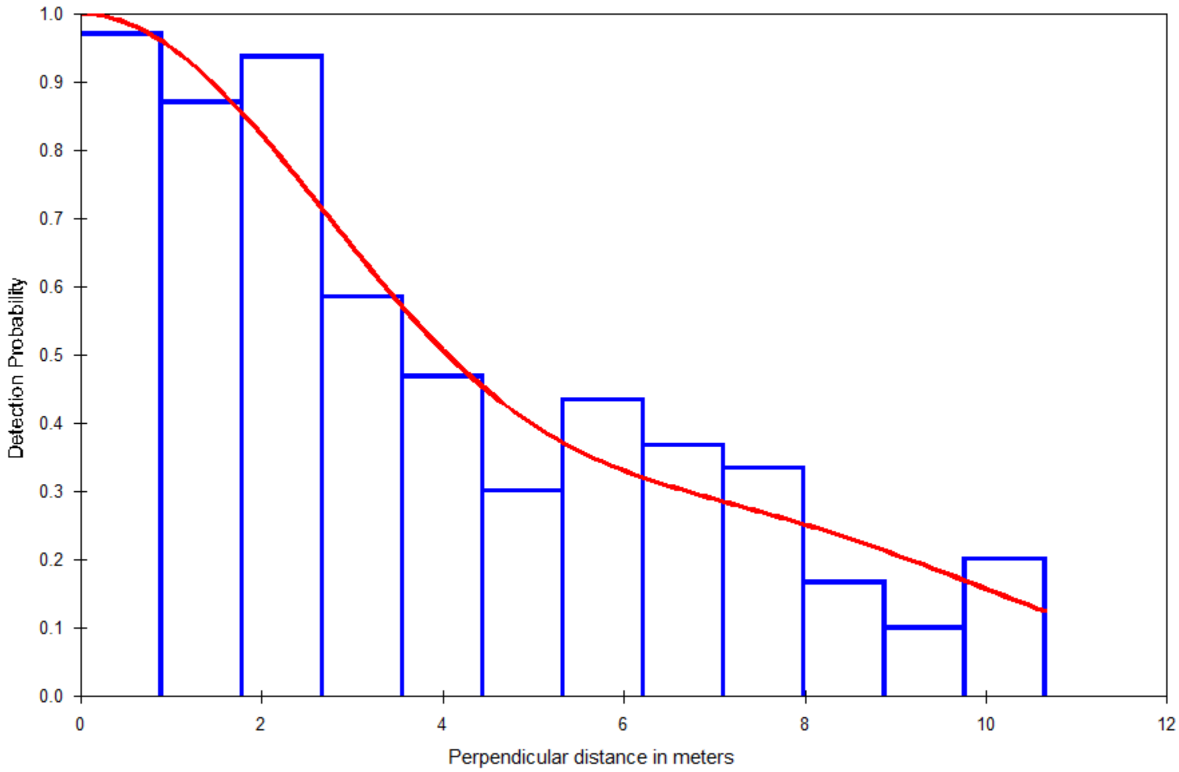
Kolmogorov-Smirnov test

D_n = 0.0367 p = 0.7456

Cramer-von Mises family tests

W-sq (uniform weighting) = 0.0515 0.800 < p <= 0.900
Relevant critical values:
W-sq crit(alpha=0.900) = 0.0460
W-sq crit(alpha=0.800) = 0.0622

C-sq (cosine weighting) = 0.0364 0.800 < p <= 0.900
Relevant critical values:
C-sq crit(alpha=0.900) = 0.0286
C-sq crit(alpha=0.800) = 0.0391

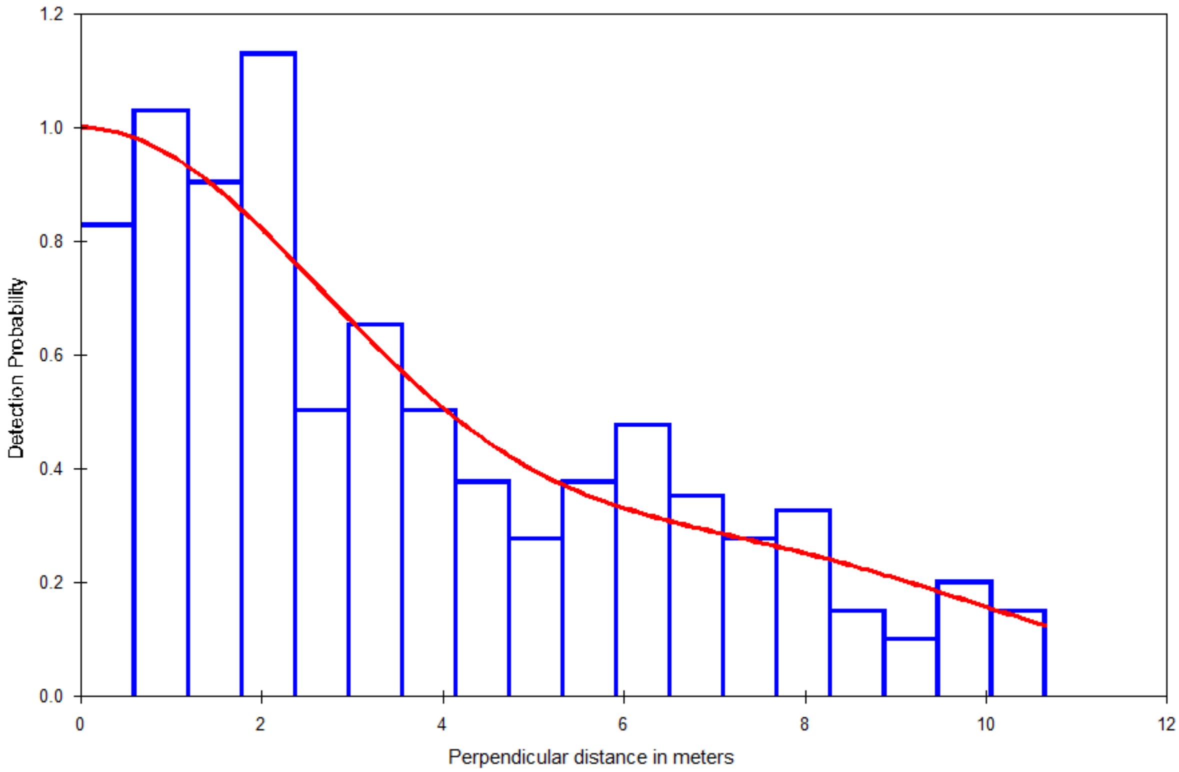


Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.888	58	58.97	0.016
2	0.888	1.78	52	54.55	0.119
3	1.78	2.66	56	47.00	1.724
4	2.66	3.55	35	38.34	0.290
5	3.55	4.44	28	30.47	0.201
6	4.44	5.33	18	24.53	1.737
7	5.33	6.21	26	20.61	1.408
8	6.21	7.10	22	18.10	0.840
9	7.10	7.99	20	16.11	0.938
10	7.99	8.88	10	13.99	1.138
11	8.88	9.76	6	11.51	2.636
12	9.76	10.7	12	8.82	1.147

Total Chi-square value = 12.1935 Degrees of Freedom = 9.00

Probability of a greater chi-square value, P = 0.20262

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

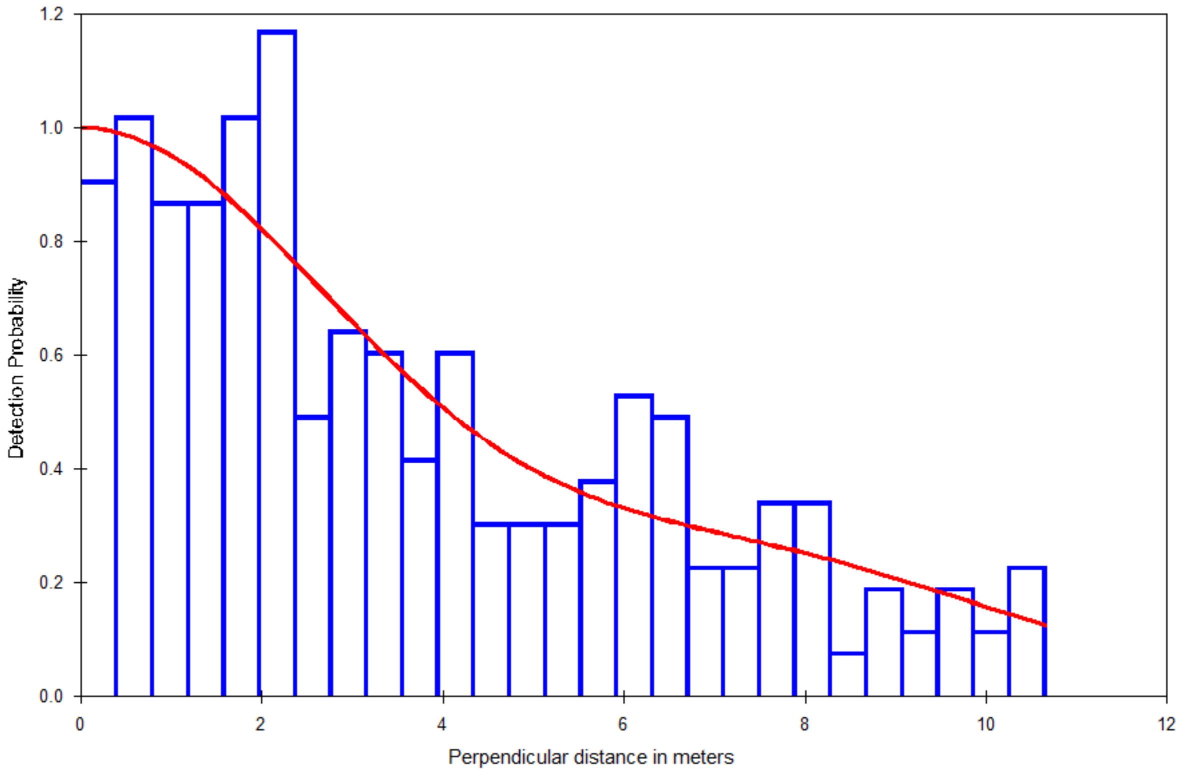


Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.592	33	39.60	1.101
2	0.592	1.18	41	38.23	0.200
3	1.18	1.78	36	35.68	0.003
4	1.78	2.37	45	32.28	5.009
5	2.37	2.96	20	28.45	2.510
6	2.96	3.55	26	24.60	0.080
7	3.55	4.14	20	21.08	0.056
8	4.14	4.73	15	18.12	0.537
9	4.73	5.33	11	15.80	1.457
10	5.33	5.92	15	14.07	0.061
11	5.92	6.51	19	12.81	2.991
12	6.51	7.10	14	11.83	0.398
13	7.10	7.69	11	10.96	0.000
14	7.69	8.28	13	10.07	0.855
15	8.28	8.88	6	9.07	1.041
16	8.88	9.47	4	7.97	1.975
17	9.47	10.1	8	6.78	0.219
18	10.1	10.7	6	5.58	0.032

Total Chi-square value = 18.5226 Degrees of Freedom = 15.00

Probability of a greater chi-square value, P = 0.23619

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.



Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.395	24	26.49	0.234
2	0.395	0.789	27	26.08	0.033
3	0.789	1.18	23	25.27	0.205
4	1.18	1.58	23	24.13	0.053
5	1.58	1.97	27	22.72	0.806
6	1.97	2.37	31	21.11	4.629
7	2.37	2.76	13	19.40	2.112
8	2.76	3.16	17	17.67	0.025
9	3.16	3.55	16	15.98	0.000
10	3.55	3.95	11	14.41	0.809
11	3.95	4.34	16	13.01	0.689
12	4.34	4.73	8	11.78	1.214
13	4.73	5.13	8	10.75	0.704
14	5.13	5.52	8	9.90	0.366
15	5.52	5.92	10	9.22	0.067
16	5.92	6.31	14	8.66	3.294
17	6.31	6.71	13	8.19	2.817
18	6.71	7.10	6	7.79	0.410
19	7.10	7.50	6	7.40	0.266
20	7.50	7.89	9	7.02	0.561
21	7.89	8.28	9	6.61	0.866
22	8.28	8.68	2	6.17	2.815
23	8.68	9.07	5	5.69	0.084
24	9.07	9.47	3	5.18	0.919
25	9.47	9.86	5	4.65	0.026
26	9.86	10.3	3	4.12	0.304
27	10.3	10.7	6	3.59	1.622

Total Chi-square value = 25.9290 Degrees of Freedom = 24.00

Probability of a greater chi-square value, P = 0.35678

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

```
Effort        :    32116.33
# samples     :   167
Width         :    10.65183
# observations:   343

Model  2
   Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
   Cosine adjustments of order(s) :  2
```

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	10.481	1.5885	15.16	7.7892	14.102
N	653.00	98.973	15.16	485.00	878.00

Measurement Units

Density: Numbers/hectares
ESW: meters

Component Percentages of Var(D)

Detection probability : 20.3
Encounter rate : 79.7

	Estimate	%CV	df	95% Confidence Interval	
n	343.00				
k	167.00				
L	32116.				
n/L	0.10680E-01	13.53	166.00	0.81856E-02	0.13934E-01
Left	0.0000				
Width	10.652				

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
m	2.0000				
LnL	-755.39				
AIC	1514.8				
AICc	1514.8				
BIC	1522.4				
Chi-p	0.35678				
f(0)	0.19627	6.82	341.00	0.17164	0.22443
p	0.47832	6.82	341.00	0.41831	0.54695
ESW	5.0950	6.82	341.00	4.4557	5.8260

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
D	10.481	15.16	253.18	7.7892	14.102
N	653.00	15.16	253.18	485.00	878.00

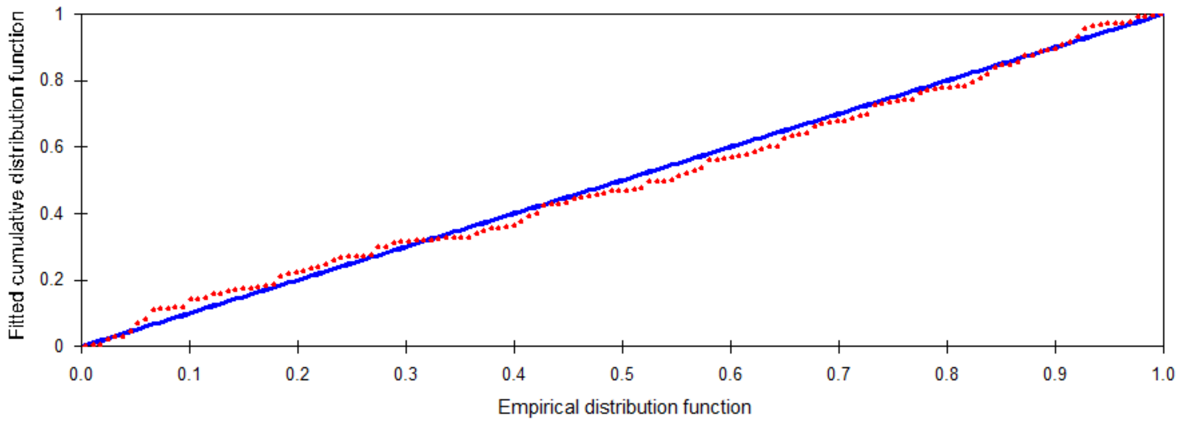
APPENDIX B: Honeymoon Island SP occupied burrows Distance software 6.2 results

Selected model: Conventional distance sampling (CDS) Uniform Cosine, 5% truncation

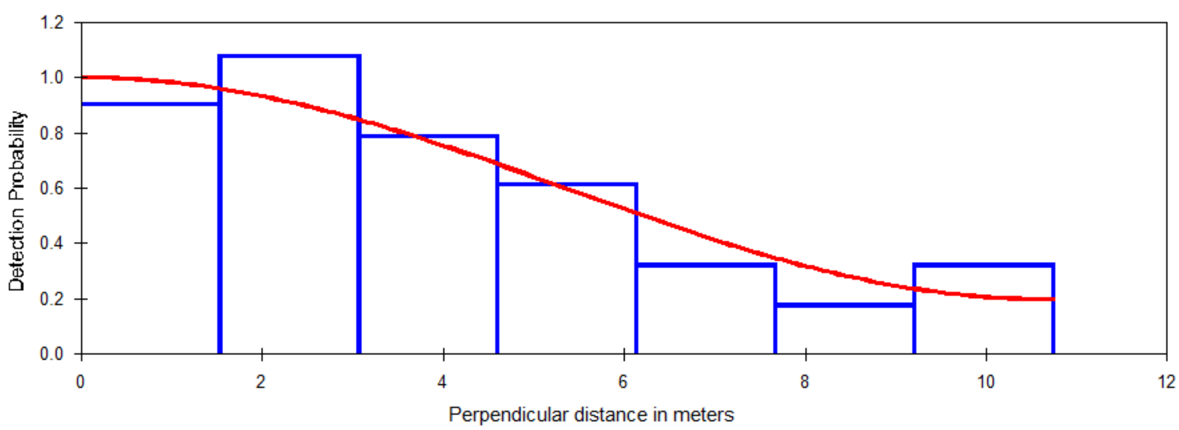
```
Parameter Estimation Specification
 ----------------------------------
 Encounter rate for all data combined
 Detection probability for all data combined
 Density for all data combined

 Distances:
 ----------
 Analysis based on exact distances
 Width: use measurement/interval endpoint which represents  95.0 percentile.

 Estimators:
 -----------
 Estimator  1
 Key: Uniform
 Adjustments - Function                 : Cosines
             - Term selection mode      : Sequential
             - Term selection criterion : Akaike Information Criterion (AIC)
             - Distances scaled by      : W (right truncation distance)

 Estimator selection: Choose estimator with minimum  AIC
 Estimation functions: constrained to be nearly monotone non-increasing

 Variances:
 ----------
 Variance of n: Empirical estimate from sample
                (design-derived estimator R2/P2)
 Variance of f(0): MLE estimate

 Goodness of fit:
 ----------------
 Cut points chosen by program



 Glossary of terms
 -----------------

 Data items:
 n    - number of observed objects (single or clusters of animals)
 L    - total length of transect line(s)
 k    - number of samples
 K    - point transect effort, typically K=k
 T    - length of time searched in cue counting
 ER   - encounter rate (n/L or n/K or n/T)
 W    - width of line transect or radius of point transect
 x(i) - distance to i-th observation
 s(i) - cluster size of i-th observation
 r-p  - probability for regression test
 chi-p- probability for chi-square goodness-of-fit test


 Parameters or functions of parameters:
 m    - number of parameters in the model
 A(I) - i-th parameter in the estimated probability density function(pdf)
 f(0) - 1/u = value of pdf at zero for line transects
 u    - W*p = ESW, effective detection area for line transects
 h(0) - 2*PI/v
 v    - PI*W*W*p, is the effective detection area for point transects
 p    - probability of observing an object in defined area
 ESW  - for line transects, effective strip width = W*p
 EDR  - for point transects, effective detection radius  = W*sqrt(p)
 rho  - for cue counts, the cue rate
 DS   - estimate of density of clusters
 E(S) - estimate of expected value of cluster size
```

```
D    - estimate of density of animals
N    - estimate of number of animals in specified area


Effort        :    32116.33
# samples     :   167
Width         :    10.74522
# observations:   144



Model  1
   Uniform key, k(y) = 1/W
      Results:
      Convergence was achieved with    1 function evaluations.
      Final Ln(likelihood) value =  -341.92237
      Akaike information criterion =   683.84473
      Bayesian information criterion =   683.84473
      AICc =   683.84473
      Final parameter values:


Model  2
   Uniform key, k(y) = 1/W
   Cosine adjustments of order(s) :  1
      Results:
      Convergence was achieved with   10 function evaluations.
      Final Ln(likelihood) value =  -323.14462
      Akaike information criterion =   648.28925
      Bayesian information criterion =   651.25903
      AICc =   648.31744
      Final parameter values:  0.67086705

   Likelihood ratio test between models  1 and  2
      Likelihood ratio test value    =    37.5555
      Probability of a greater value =   0.000000
*** Model  2 selected over model  1 based on minimum AIC


Model  3
   Uniform key, k(y) = 1/W
   Cosine adjustments of order(s) :  1, 2
      Results:
      Convergence was achieved with   16 function evaluations.
      Final Ln(likelihood) value =  -322.60144
      Akaike information criterion =   649.20288
      Bayesian information criterion =   655.14252
      AICc =   649.28796
      Final parameter values:  0.72576190     0.11220132

   Likelihood ratio test between models  2 and  3
      Likelihood ratio test value    =     1.0864
      Probability of a greater value =   0.297280
*** Model  2 selected over model  3 based on minimum AIC


Effort        :    32116.33
# samples     :   167
Width         :    10.74522
# observations:   144

Model
   Uniform key, k(y) = 1/W
   Cosine adjustments of order(s) :  1


             Point        Standard    Percent Coef.        95 Percent
 Parameter   Estimate       Error      of Variation     Confidence Interval
 ---------  -----------  -----------  --------------  ----------------------
   A( 1)     0.6709       0.8829E-01
   f(0)     0.15550      0.82170E-02       5.28      0.14009      0.17261
```

p	0.59849	0.31626E-01	5.28	0.53917	0.66434
ESW	6.4309	0.33983	5.28	5.7935	7.1385




```
Kolmogorov-Smirnov test
-----------------------

D_n                        = 0.0498                p  = 0.8679


Cramer-von Mises family tests
-----------------------------

W-sq (uniform weighting) = 0.0806          0.600 < p <= 0.700
  Relevant critical values:
    W-sq crit(alpha=0.700) = 0.0785
    W-sq crit(alpha=0.600) = 0.0968

C-sq (cosine weighting)  = 0.0567          0.600 < p <= 0.700
  Relevant critical values:
    C-sq crit(alpha=0.700) = 0.0499
    C-sq crit(alpha=0.600) = 0.0621
```



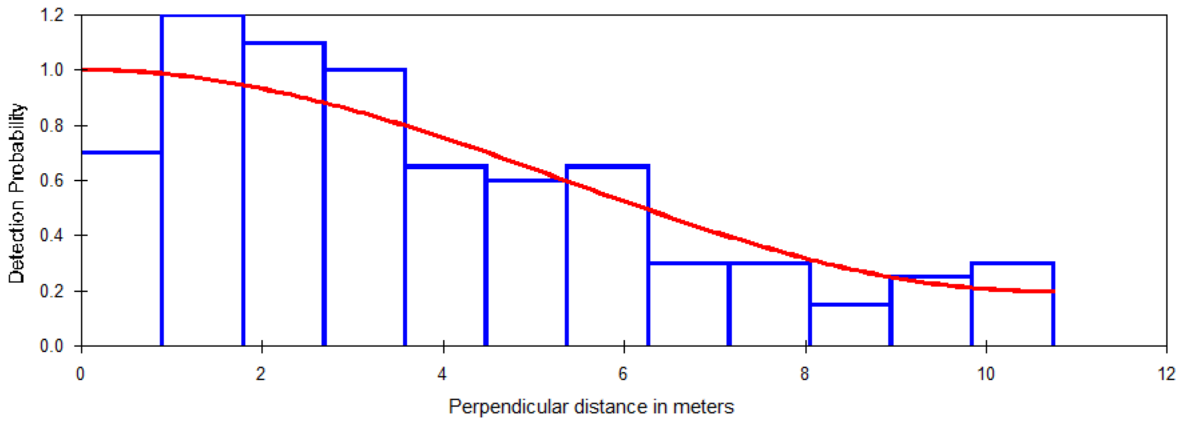
Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	1.54	31	33.91	0.250
2	1.54	3.07	37	31.27	1.050
3	3.07	4.61	27	26.51	0.009
4	4.61	6.14	21	20.57	0.009
5	6.14	7.68	11	14.63	0.902
6	7.68	9.21	6	9.87	1.518

7	9.21	10.7	11	7.23	1.967

Total Chi-square value = 5.7056 Degrees of Freedom = 5.00

Probability of a greater chi-square value, P = 0.33593

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

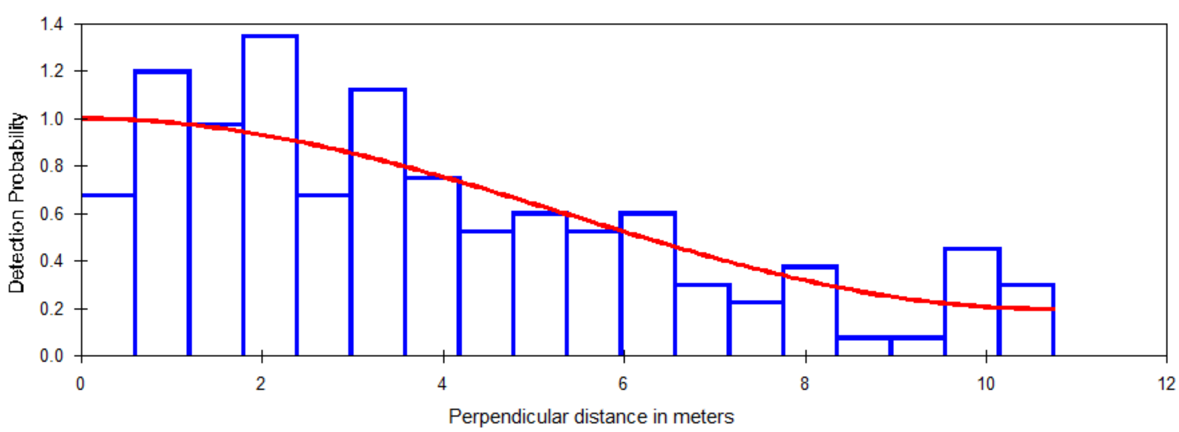


Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	0.895	14	19.96	1.779
2	0.895	1.79	24	19.42	1.082
3	1.79	2.69	22	18.37	0.718
4	2.69	3.58	20	16.89	0.574
5	3.58	4.48	13	15.07	0.285
6	4.48	5.37	12	13.05	0.084
7	5.37	6.27	13	10.95	0.383
8	6.27	7.16	6	8.93	0.960
9	7.16	8.06	6	7.11	0.174
10	8.06	8.95	3	5.63	1.230
11	8.95	9.85	5	4.58	0.038
12	9.85	10.7	6	4.04	0.949

Total Chi-square value = 8.2561 Degrees of Freedom = 10.00

Probability of a greater chi-square value, P = 0.60384

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.



Cell	Cut	Observed	Expected	Chi-square

i		Points	Values	Values	Values
1	0.000	0.597	9	13.34	1.412
2	0.597	1.19	16	13.18	0.605
3	1.19	1.79	13	12.86	0.002
4	1.79	2.39	18	12.39	2.539
5	2.39	2.98	9	11.79	0.660
6	2.98	3.58	15	11.07	1.391
7	3.58	4.18	10	10.27	0.007
8	4.18	4.78	7	9.39	0.607
9	4.78	5.37	8	8.47	0.026
10	5.37	5.97	7	7.53	0.038
11	5.97	6.57	8	6.61	0.291
12	6.57	7.16	4	5.73	0.525
13	7.16	7.76	3	4.93	0.753
14	7.76	8.36	5	4.21	0.148
15	8.36	8.95	1	3.61	1.886
16	8.95	9.55	1	3.14	1.460
17	9.55	10.1	6	2.82	3.577
18	10.1	10.7	4	2.66	0.675

Total Chi-square value = 16.6018 Degrees of Freedom = 16.00

Probability of a greater chi-square value, P = 0.41180

The program has limited capability for pooling. The user should judge the necessity for pooling and if necessary, do pooling by hand.

```
Effort        :    32116.33
# samples     :   167
Width         :    10.74522
# observations:   144

Model  2
   Uniform key, k(y) = 1/W
   Cosine adjustments of order(s) :  1
```

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
D	3.4860	0.55395	15.89	2.5534	4.7593
N	217.00	34.482	15.89	159.00	296.00

Measurement Units

```
Density: Numbers/hectares
    ESW: meters
```

Component Percentages of Var(D)

```
Detection probability   :  11.1
Encounter rate          :  88.9
```

	Estimate	%CV	df	95% Confidence Interval	
n	144.00				
k	167.00				
L	32116.				
n/L	0.44837E-02	14.99	166.00	0.33408E-02	0.60176E-02
Left	0.0000				
Width	10.745				

		Estimate	%CV	df	95% Confidence Interval
Uniform/Cosine					
	m	1.0000			
	LnL	-323.14			
	AIC	648.29			

	AICc	648.32				
	BIC	651.26				
	Chi-p	0.41180				
	f(0)	0.15550	5.28	143.00	0.14009	0.17261
	p	0.59849	5.28	143.00	0.53917	0.66434
	ESW	6.4309	5.28	143.00	5.7935	7.1385

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	D	3.4860	15.89	206.15	2.5534	4.7593
	N	217.00	15.89	206.15	159.00	296.00

APPENDIX C: Element Occurrence A-D Rank Specifications: Gopher Tortoise (*Gopherus polyphemus*), 28 May 2011

The following occurrence rank specifications apply to occurrences that are potentially rankable as A, B, C, D, or some combination of these ranks. Whenever appropriate, a combination rank such as AC or CD should be used to indicate the range of rank uncertainty; such combination ranks are much more useful than E. Assignment of ranks in the A-D range should be done by persons familiar with gopher tortoises.

Many occurrences are no longer extant or have insufficient information on the current tortoise population or habitat conditions and so cannot be ranked A-D; such occurrences should be ranked E, H, X, U, F, or NR. See the generic EO Rank Specifications in NatureServe Explorer for definitions of these other ranks.

A: Excellent viability. Occurrence exhibits optimal or at least highly favorable characteristics with respect to population size and/or quality and quantity of occupied habitat; and, if current conditions prevail, the occurrence is very likely to persist for the foreseeable future (i.e., at least 20-30 years) in its current condition or better. These occurrences have characteristics (e.g., size, condition, landscape context) that make them relatively invulnerable to extirpation or sustained population declines, assuming that habitat conditions are maintained or improved, even if they have declined somewhat relative to historical levels. Occurrences of this rank typically include at least 250 mature individuals (assuming that the population is not strongly male-biased). Occurrences of this size have a very high probability of long-term persistence (e.g., Tuberville et al. 2009). However, occurrences may be ranked A even if population size is not definitely known (e.g., the population is clearly very large but it is not known how large; the area of occupied habitat is exceptionally large [at least 100 hectares] and the tortoise population appears to exhibit at least average density). Occurrences with excellent estimated viability are ranked A even if one or more other occurrences have a much larger population size and/or much greater quantity of occupied habitat. In most cases, occurrences ranked A will occupy natural habitats. However, "natural" is an ambiguous concept, and occurrences that have been somewhat modified by human actions may still be assigned a rank of A if they otherwise meet the criteria. Occurrences that have significant populations of invasive plants or red imported fire ants (*Solenopsis invicta*) such that negative impacts on tortoises are expected should be ranked B if they otherwise meet the A criteria. Occurrences that meet the population size criteria for A but show little or no evidence of recruitment over the past 10-15 years (based on adequate information on population structure) may be ranked B, BC, or C, depending on the severity of the recruitment limitation (rationale: demographic models indicate that gopher tortoise population viability depends importantly on relatively high levels of hatchling survivorship; Tuberville et al. 2009). An occurrence rank may be down-ranked (e.g., from A to AB, or from A to B, etc.) as deemed appropriate if the tortoise population is known to be strongly male-biased; this ranking policy applies also to occurrences that otherwise meet the B or C criteria.

B: Good viability. Occurrence exhibits favorable but not optimal characteristics with respect to population size and/or quality and quantity of occupied habitat; and, if current conditions prevail, the occurrence is likely to persist for the foreseeable future (i.e., at least 20-30 years) in its current condition or better. B-ranked occurrences have good estimated viability and, if protected, contribute importantly to maintaining or improving the conservation status of the species. Occurrences of this rank typically should include at least 100 mature individuals (e.g., see Tuberville et al. 2009). However, occurrences can be ranked B even if population size is not known or is less than 100 mature individuals as long as the occurrence meets the qualitative conceptual guidelines for this rank. Occurrences that show little or no evidence of recruitment over the past 10-15 years but otherwise meet the B criteria should be ranked C.

C: Fair viability. Occurrence characteristics (size, condition, and landscape context) are non-optimal such that occurrence persistence is uncertain under current conditions, or the occurrence does not meet A or B criteria but may persist for the foreseeable future (i.e., at least 20-30 years) with appropriate protection or management, or the occurrence is likely to persist but not necessarily maintain current or historical levels of population size or genetic variability. This rank may be applied to relatively low-quality occurrences with respect to size, condition, and/or landscape context if they still appear to have reasonable prospects for persistence for the foreseeable future. Occurrences of this rank typically should include at least 20-25 mature individuals. Demographic models indicate that even small populations (20-50 individuals) of gopher tortoises have a high probability of persistence for at least several decades (Cox et al. 1987, Cox 1989, Miller et al. 2001, Tuberville et al. 2009).

D: Poor viability. If current conditions prevail, occurrence has a high risk of extirpation (because of small population size or area of occupancy, deteriorated habitat, poor conditions for reproduction, ongoing inappropriate management that is unlikely to change, unusually high adult mortality, or other factors). Questionably viable occurrences that could be restored to at least fair viability should not be ranked D if restoration is deemed feasible and plausible; in most such cases CD should be used. Very small occurrences that may be vulnerable to deleterious stochastic events may be ranked as follows: If the stochastic event is highly theoretical or of very low probability in the appropriate time frame (e.g., 20-30 years), then a C or CD rank may be appropriate. If a minority of other similar occurrences have disappeared as a result of, say, disease or inbreeding, then perhaps CD is best. If most of these small occurrences have been extirpated or are disappearing due to such events, then D is probably appropriate.