Appendix VII

EXAMPLE INPUT AND OUTPUT FROM DISTANCE

This appendix includes an example analysis for the June 1993 survey of the Centennial Pronghorn Herd in southeastern Wyoming. It demonstrates some of the different models implemented in DISTANCE and some aspects of model selection. To save paper, four pages of the analysis have been reduced to fit each page in the appendix. The input specifies an analysis of grouped data for a clustered population. By default, DISTANCE tested for cluster size bias. Distance band cut-points were adjusted for the actual mean survey height of 343 feet AGL. This analysis requested estimates using five models (key + adjustment terms):

1. Uniform + Cosine/Sequential: DISTANCE attempts to fit consecutively higher models (e.g., one with 1 cosine term, then one with 2 cosine terms, then one with 3 cosine terms, etc.) until there is no further improvement in the estimate. DISTANCE selected a model with 1cosine term. Note that the detection curve does not fit the A band very well. It underestimates the population size.
2. Uniform + 3 Cosine Terms: This estimate forced DISTANCE to use 3 cosine terms. Note that the detection curve is more flexible and fits the histogram of observed distances better. However, the Goodness-of-Fit test cannot be performed because there aren't enough degrees of freedom. The standard errors for this model are much larger than those for Model 1. This illustrates the "penalty" of fitting more terms to the model.
3. Half-normal + Cosine/Sequential: DISTANCE selected a model with 1 cosine term. The model fits the histogram better than Model 1 although it does not reach the top of the A band. Model 3 is simpler than Model 2 but the estimate is not substantially different. It is better than the previous 2 models.
4. Negative Exponential: This simple model fits the histogram pretty well. However, it does not have a shoulder near the line so it is not robust. In this analysis, it fits better than the previous models. It had the lowest (i.e., "best") AIC.
5. Hazard + Cosine/Sequential: DISTANCE fit a 2 parameter model. The hazard model forces a shoulder near the line on the detection probability function. This model fits the histogram pretty well, particularly the A band. The estimate is about as good as Model 4. It has the second lowest AIC of the 5 models and would also be acceptable. However, Model 5 is the least precise of the models.

Cluster size bias was not significant in this analysis.

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```
ASSIGN OUTPUT='A527_93.OUT';
ASSIGN LOG='A527_93.LOG'/REPLACE;
OPTIONS;
TITLE='Centennial Prongborn Herd - June 20-21, 1993';
DIST=PERP/MEASURE='METERS';
LENGTH/MEASURE='MILES';
AREA/UNITS='SQ. MILES';
OBJECT=CLUSTER/EXACT;
END;
DATA;
STRATUM/AREA=1153.6/LABEL='Centennial Prongborn Herd - Occupied Habitat';
SAMPLE=28.6/LABEL='Line 1 (N41 81.00-E)';
15.2 1
13.4 1
13.3 5
14.2 1
16.4 2
171.8 1
13.1 1
14.8 1
198.8 1
88.5 1
184.3 1
51.8 1
186.8 1
17.3 1
52.8 4
194.8 1
200.8 1;
SAMPLE=32.3/LABEL='Line 2 (N41 84.88-W)';
146.5 5
89.3 1
12.4 1
88.8 1
87.5 1
171.8 1
61.5 2
15.5 1
15.1 1;
SAMPLE=29.9/LABEL='Lines 3 (N41 87.88-W), 4 (N41 18.88-E), and 5 (N41 13.88-W)';
79.3 2
81.4 1
166.5 1
95.5 2
78.8 1
164.5 1
15.8 2
15.9 1
55.3 1
17.8 1;
SAMPLE=36.1/LABEL='Lines 6 (N185 29.88-S), 7 (N185 32.88-W), and 8 (N185 35.88-S)
';
144.8 1
71.3 2
94.5 1
```

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```
56.1 2
150.8 2
164.5 1
133.5 2
88.9 5
162.5 2
175.5 2
45.6 1
91.3 1
137.5 1
78.8 1
78.8 1
88.8 1
82.8 1
15.8 1
89.5 1
83.8 1;
SAMPLE=28.7/LABEL='Line 9 (N185 38.88-W)';
211.8 1
94.5 1
14.8 2
82.3 1
91.3 3
152.8 2
15.3 1;
SAMPLE=23.5/LABEL='Line 10 (N185 41.88-S)';
13.5 1
81.3 1
15.8 4
49.4 2
87.8 1
156.5 1
98.8 5
12.8 1
73.3 1
94.1 1
87.5 2
87.8 4
141.5 3
79.8 5
93.8 1;
SAMPLE=24.9/LABEL='Line 11 (N185 44.88-N)';
14.4 1
164.5 1
169.5 1
13.5 1
12.3 1
87.5 1
71.4 2
143.5 1
38.8 1
27.9 1
13.2 1
88.8 1
148.8 1
```

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```
73.3 1
11.7 1
81.4 2
84.3 1
12.5 4
28.4 1
79.8 1
15.4 1
195.5 1
155.5 1
164.5 1
47.8 1;
SAMPLE=9.8/LABEL='Line 12 (N41 31,W184.83-N4)';
76.3 1
153.8 1
153.8 2
12.7 1
13.8 1
135.8 1
172.5 1
143.5 1
138.5 1
138.5 2
37.8 2
37.8 2
89.1 1
154.5 2
179.5 1
88.8 1
42.3 1
181.8 1
174.5 1
138.8 1;
SAMPLE=18.6/LABEL='Lines 13 (N185 88.88-S) and 14 (N185 82.88-S)';
82.5 1
12.8 1
47.4 2
14.5 1
43.8 1
14.4 2
89.5 2
13.8 1
41.5 1
144.8 1
155.8 1
185.8 1
14.8 1
14.8 1
88.5 1
15.4 1
18.7 18
14.5 1
94.3 1
198.5 1
32.8 1
```

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```
161.5 1
169.5 1;
SAMPLE=13.6/LABEL='Line 15 (N185 59.88-S)';
148.5 1
141.5 2
77.3 4
79.8 1
12.8 1
164.4 1
173.5 1
77.4 1
94.3 2
153.8 1
14.3 1
15.4 1
282.8 1
89.4 1
47.1 1;
SAMPLE=27.8/LABEL='Line 16 (N185 56.88-N)';
171.5 1
16.8 2
17.1 2
28.3 1
42.3 1
12.1 1
44.8 1
15.8 1
15.6 3
15.5 1
85.5 1
87.8 1
15.4 1
16.4 1
87.3 1
156.5 1
184.5 1
49.4 2
75.3 1
39.3 1
44.4 2
47.8 1
15.8 1
44.6 1
15.8 1;
SAMPLE=29.1/LABEL='Line 17 (N185 53.88-S)';
41.5 1
89.5 3
15.8 1
45.1 1
188.5 2
186.5 1
45.1 1
29.5 1
158.8 3
142.5 1
```

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```
146.0 1
159.5 1
41.5 1
87.3 1
15.9 1
95.3 1
198.5 2
103.5 1
207.0 2
209.0 3
218.5 2
49.2 3
98.5 3
197.0 1
10.5 1
189.0 1
218.0 1
209.5 1
87.3 1
179.0 1
41.3 1
165.0 1
168.0 2
65.5 1
18.3 1
39.4 1
13.4 1
215.0 1
78.5 1
15.4 1
58.1 1
178.0 2
146.5 1
148.0 1
263.5 1
233.0 1
70.0 1;
SAMPLE=27.6/LABEL='Line 18 (H185 58.00-H)';
62.1 1
186.0 1
13.4 2
45.0 1
187.5 1
44.3 1
141.0 4
12.5 1
79.5 1
88.0 1
86.0 1
45.0 2
154.5 1
42.4 1
162.5 3
86.5 1
13.0 1
```

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```
83.0 1
19.1 1
165.0 1
167.5 3
88.0 1
89.4 1
176.0 1
183.0 1
18.4 1
155.5 1
76.0 1
152.0 3
15.5 1;
SAMPLE=25.1/LABEL='Line 19 (H185 47.00-S)';
78.0 1
186.0 1
42.5 1
162.5 1
12.4 4
13.4 1
88.3 2
83.0 1
167.5 2
99.5 1
14.0 3
42.4 3
42.0 2
85.5 2
171.0 1
103.5 1
46.0 3
187.0 1
176.0 2
99.0 1
199.5 2
193.0 2
15.1 1
18.0 1;
END;
PRINT OPTIONS;
PRINT DATA;
ESTIMATE;
PRINT OPTIONS;
DISTANCE/INTERVALS=0.0,28.6,57.2,114.6,229.0;
ESTIMATOR/KEY=UNIFORM/ADJUST=COSINE/SELECT=SEQUENTIAL;
ESTIMATOR/KEY=UNIFORM/ADJUST=COSINE/SELECT=SPECIFY/MAP=3;
ESTIMATOR/KEY=HNORMAL/ADJUST=COSINE/SELECT=SEQUENTIAL;
ESTIMATOR/KEY=NEXPON/ADJUST=COSINE/SELECT=SEQUENTIAL;
ESTIMATOR/KEY=HAZARD/ADJUST=COSINE/SELECT=SEQUENTIAL;
PICK=NONE;
END;
END;
```

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
Centennial Pronghorn Herd - June 28-21, 1993 Page 1

```
                    ************************************
                    *       Program Options            *
                    *          Listing                 *
                    ************************************

TITLE = Centennial Pronghorn Herd - June 28-21, 1993
TYPE = LINE
OBJECT=CLUSTERS
DISTANCE=PERP
        /MEASURE= METERS
        /UNITS= METERS
        /CONVERT=       1.0000
        /EXACT
LENGTH  /UNITS= MILES
        /MEASURE= MILES
        /CONVERT=       1.0000
AREA    /UNITS= SQ. MILES
        /CONVERT=       1189.3

SF =   1.00          EPS =  .10000E-04       PVALUE =    .150
ITERATIONS =    30   MAXFIT =   5            BOOTSTRAPS =   1000
LOOKAHEAD =  1       SEED =              0.
SQUEEZE = OFF        PRINT =  SELECTION      SELECT = EXPONENTIAL
CURRENT PROGRAM LIMITS:
# of strata =  100                  # of samples =  700
# of ungrouped observations =  1000  # of distance intervals =   30
# of estimators =  5                 # of adjustment terms =  5
# of goodness of fit tests =  3
```

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
Centennial Pronghorn Herd - June 28-21, 1993 Page 2

```
                    ************************************
                    *          Data Listing            *
                    ************************************

Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area:          1153.0000

Sample: Line 1 (N41 01.00-E)
Effort:  21.6000      # of observations:    17.
Observation #     Distance        Cluster size
-------------   ------------    --------------
           1        35.200              1.
           2        33.400              1.
           3        13.300              5.
           4        14.200              1.
           5        16.600              2.
           6       171.00               1.
           7        19.100              1.
           8        14.800              1.
           9       180.00               1.
          10        88.500              1.
          11       184.30               1.
          12        53.900              1.
          13       181.00               1.
          14        17.300              3.
          15        52.000              4.
          16       184.00               1.
          17       280.00               1.

Sample: Line 2 (N41 04.00-N)
Effort:  32.3000      # of observations:     9.
Observation #     Distance        Cluster size
-------------   ------------    --------------
           1       146.50               5.
           2        88.300              1.
           3        12.400              1.
           4        88.800              1.
           5        87.500              1.
           6       171.00               1.
           7        61.500              2.
           8        15.500              1.
           9        15.100              1.

Sample: Lines 3 (N41 07.00-N), 4 (N41 10.00-E), and 5 (N41
Effort:  25.3000      # of observations:    10.
Observation #     Distance        Cluster size
-------------   ------------    --------------
           1        79.300              2.
           2        41.400              1.
           3       166.50               1.
           4        95.500              2.
           5        78.000              1.
```

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```
           6       144.50               1.
           7        15.900              2.
```

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
Centennial Pronghorn Herd - June 28-21, 1993 Page 3

```
Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area:          1153.0000

Sample: Lines 3 (N41 07.00-N), 4 (N41 10.00-E), and 5 (N41
Effort:  25.3000      # of observations:    10.
Observation #     Distance        Cluster size
-------------   ------------    --------------
           8        15.300              1.
           9        95.300              1.
          10        17.800              1.

Sample: Lines 6 (N185 25.00-E), 7 (N185 32.00-N), and 8 (N
Effort:  26.1000      # of observations:    28.
Observation #     Distance        Cluster size
-------------   ------------    --------------
           1       146.00               1.
           2        76.300              2.
           3        94.500              1.
           4        56.100              2.
           5       159.00               3.
           6       144.50               1.
           7       133.50               2.
           8        44.900              5.
           9       162.50               2.
          10       175.50               2.
          11        45.600              1.
          12        91.300              1.
          13       137.50               1.
          14        78.800              1.
          15        79.800              1.
          16        84.800              1.
          17        60.300              1.
          18        15.800              1.
          19        89.500              1.
          20        83.800              1.

Sample: Line 9 (N185 38.00-N)
Effort:  28.7000      # of observations:     9.
Observation #     Distance        Cluster size
-------------   ------------    --------------
           1       211.00               1.
           2        94.500              1.
           3        14.800              2.
           4        92.300              1.
           5        41.300              3.
           6       152.00               2.
           7        15.300              1.
```

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/28/97 14:55
Centennial Pronghorn Herd - June 28-21, 1993 Page 4

Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Line 10 (W105 41.00-S)
Effort: 23.3000 # of observations: 15.

Observation #	Distance	Cluster size
1	13.500	1.
2	81.300	1.
3	15.000	4.
4	43.600	2.
5	87.000	1.
6	134.50	1.
7	58.000	5.
8	12.000	1.
9	73.300	1.
10	44.100	1.
11	47.500	2.
12	37.000	4.
13	141.50	1.
14	79.000	5.
15	51.000	1.

Sample: Line 11 (W105 44.00-N)
Effort: 26.3000 # of observations: 25.

Observation #	Distance	Cluster size
1	34.400	1.
2	144.50	1.
3	149.50	1.
4	13.500	1.
5	12.300	1.
6	37.500	1.
7	71.000	2.
8	143.50	1.
9	30.000	1.
10	37.500	1.
11	13.200	1.
12	80.000	1.
13	140.00	1.
14	73.300	1.
15	11.700	1.
16	41.600	2.
17	84.300	1.
18	12.500	4.
19	30.000	1.
20	79.100	1.
21	15.400	1.
22	195.50	1.
23	195.50	1.

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/28/97 14:55
Centennial Pronghorn Herd - June 28-21, 1993 Page 5

Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Line 11 (W105 44.00-N)
Effort: 26.3000 # of observations: 25.

Observation #	Distance	Cluster size
24	184.50	1.
25	67.000	1.

Sample: Line 12 (W41.31,W106 03-NW)
Effort: 7.80000 # of observations: 28.

Observation #	Distance	Cluster size
1	76.300	1.
2	153.00	1.
3	153.00	2.
4	12.700	1.
5	13.900	1.
6	135.00	1.
7	172.50	1.
8	141.50	1.
9	130.50	1.
10	130.50	2.
11	37.000	2.
12	37.000	2.
13	35.100	1.
14	154.50	2.
15	179.50	1.
16	80.000	1.
17	42.300	1.
18	101.00	1.
19	174.50	1.
20	138.00	1.

Sample: Lines 13 (W105 88.00-S) and 14 (W105 82.00-S)
Effort: 18.0000 # of observations: 22.

Observation #	Distance	Cluster size
1	82.500	1.
2	12.000	1.
3	47.600	2.
4	14.500	1.
5	43.600	1.
6	14.600	2.
7	58.500	2.
8	13.000	1.
9	41.500	1.
10	166.00	1.
11	185.00	1.

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/28/97 14:55
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Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Lines 13 (W105 88.00-S) and 14 (W105 82.00-S)
Effort: 18.0000 # of observations: 22.

Observation #	Distance	Cluster size
12	185.00	1.
13	14.000	1.
14	14.000	1.
15	88.500	1.
16	15.600	1.
17	18.700	10.
18	16.500	1.
19	90.300	1.
20	188.50	1.
21	72.000	1.
22	141.50	1.
23	149.50	1.

Sample: Line 15 (W105 59.00-S)
Effort: 13.0000 # of observations: 15.

Observation #	Distance	Cluster size
1	148.50	1.
2	141.50	2.
3	77.300	4.
4	79.600	1.
5	12.000	1.
6	146.00	1.
7	173.50	1.
8	77.000	1.
9	74.300	2.
10	153.00	1.
11	14.300	1.
12	15.600	1.
13	262.00	1.
14	88.000	1.
15	47.100	1.

Sample: Line 16 (W105 56.00-N)
Effort: 27.0000 # of observations: 25.

Observation #	Distance	Cluster size
1	171.50	1.
2	16.000	2.
3	17.100	2.
4	28.300	1.
5	62.300	1.
6	12.100	1.

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/28/97 14:55
Centennial Pronghorn Herd - June 28-21, 1993 Page 7

Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Line 16 (W105 56.00-N)
Effort: 27.0000 # of observations: 25.

Observation #	Distance	Cluster size
7	44.000	1.
8	15.000	1.
9	15.600	3.
10	15.500	1.
11	45.500	1.
12	87.000	1.
13	15.400	1.
14	14.000	1.
15	87.300	1.
16	154.50	1.
17	144.50	1.
18	45.600	2.
19	75.300	1.
20	31.300	1.
21	44.000	2.
22	47.000	1.
23	15.000	1.
24	44.600	1.
25	15.000	1.

Sample: Line 17 (W105 53.00-S)
Effort: 25.3000 # of observations: 47.

Observation #	Distance	Cluster size
1	41.500	1.
2	89.500	3.
3	15.000	1.
4	45.100	1.
5	188.50	2.
6	146.50	1.
7	45.100	1.
8	39.500	1.
9	158.00	3.
10	141.50	1.
11	144.00	1.
12	159.50	1.
13	41.500	1.
14	87.300	1.
15	15.500	1.
16	93.300	1.
17	198.50	2.
18	183.50	1.
19	287.00	2.

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Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Line 17 (W185 53.00-S)
Effort: 29.3000 # of observations: 47.

Observation #	Distance	Cluster size
20	289.00	3.
21	216.50	2.
22	49.300	3.
23	90.500	3.
24	157.00	1.
25	18.500	1.
26	189.00	1.
27	210.00	1.
28	285.50	1.
29	87.300	1.
30	179.00	1.
31	41.300	1.
32	165.00	1.
33	168.00	2.
34	45.500	1.
35	12.300	1.
36	37.500	1.
37	13.400	1.
38	215.00	1.
39	94.500	1.
40	15.400	1.
41	58.100	1.
42	178.00	2.
43	146.50	1.
44	148.00	1.
45	243.50	1.
46	233.00	1.
47	76.000	1.

Sample: Line 18 (W185 50.00-N)
Effort: 27.4000 # of observations: 38

Observation #	Distance	Cluster size
1	42.100	1.
2	186.00	1.
3	13.400	2.
4	45.000	1.
5	107.50	1.
6	98.300	1.
7	161.00	4.
8	12.500	1.
9	75.500	1.
10	98.000	1.

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Line 18 (W185 50.00-N)
Effort: 27.4000 # of observations: 38

Observation #	Distance	Cluster size
11	86.000	3.
12	45.000	2.
13	154.50	1.
14	42.400	1.
15	162.50	3.
16	86.500	1.
17	13.000	1.
18	83.000	1.
19	34.100	1.
20	169.00	1.
21	167.50	3.
22	88.000	1.
23	89.000	1.
24	171.00	1.
25	181.00	1.
26	14.000	1.
27	155.50	1.
28	76.000	1.
29	152.00	3.
30	15.500	1.

Sample: Line 19 (W185 47.00-S)
Effort: 25.1000 # of observations: 26.

Observation #	Distance	Cluster size
19	176.00	2.
20	99.000	1.
21	199.50	2.
22	193.00	2.
23	15.100	1.
24	19.000	1.

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Stratum: Centennial Pronghorn Herd - Occupied Habitat
Area: 1153.0000

Sample: Line 19 (W185 47.00-S)
Effort: 25.1000 # of observations: 26.

Observation #	Distance	Cluster size
19	176.00	2.
20	99.000	1.
21	199.50	2.
22	193.00	2.
23	15.100	1.
24	19.000	1.

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```
=======================================
=      Estimation Options             =
=          Listing                    =
=======================================
```

Parameter Estimation Specification

Encounter rate for all data combined
Detection probability for all data combined
Expected cluster size for all data combined
Density for all data combined

Distances:

Analysis based on distance intervals
Width specified as: 220.0000

Clusters:

Analysis based on exact sizes
Expected value of cluster size computed by : regression of ln(s(i)) on z(i)

Estimators:

Estimator 1
Key: Uniform, k(y) = 1/w
Adjustments - Function : Cosines
- Term selection mode : Sequential
- Term selection criterion: Likelihood ratio test

Estimator 2
Key: Uniform, k(y) = 1/w
Adjustments - Function : Cosines - number of terms: 3
- Term selection mode : User specified

Estimator 3
Key: Half-normal, k(y) = Exp(-y**2/(2*A(1)**2))
Adjustments - Function : Cosines
- Term selection mode : Sequential
- Term selection criterion: Likelihood ratio test

Estimator 4
Key: Negative Exponential, k(y) = Exp(-y/A(1))
Adjustments - Function : Cosines
- Term selection mode : Sequential
- Term selection criterion: Likelihood ratio test

Estimator 5
Key: Hazard Rate, k(y) = 1 - Exp(-(y/A(1))**A(2))
Adjustments - Function : Cosines
- Term selection mode : Sequential
- Term selection criterion: Likelihood ratio test

Estimator selection: None, display all estimates
Estimation functions: constrained to be nearly monotone non-increasing

Variances:

Variance of n: Empirical estimate from sample
Variance of f(0): MLE estimate

Goodness of fit:

Based on grouped distance data intervals

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 vue 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
p-p = probability for regression test
chi-p= probability for chi-square goodness-of-fit test

Parameters as functions of parameters:
m = number of parameters in the model
A(j) = j-th parameter in the estimated probability density function(adf)
f(0) = 1/u = value of pdf at zero for line transects
u = 1/f(0) = ESW, effective detection area for line transects
n(0) = 2*PI/u
a = PI*W**2, 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)
ES = 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

*** Model 2 selected over model 3 based on likelihood ratio test

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Probability Function Estimation
Model Selection/Fitting

Effort : 334.0000
samples : 14
width : 228.0000
observations: 285

Note: The number of adjustment parameters allowed has been reduced to 3 because of limited number of intervals.

Model 1
Uniform key, k(y) = 1/W
Results:
Convergence was achieved with 1 function evaluations.
Final Ln(likelihood) value = -414.58281
Akaike information criterion = 829.00400
Final parameter values:

Model 2
Uniform key, k(y) = 1/W
Cosine adjustments of order(s) : 1
Results:
Convergence was achieved with 4 function evaluations.
Final Ln(likelihood) value = -390.28174
Akaike information criterion = 782.56350
Final parameter values: .689249

Likelihood ratio test between models 1 and 2
Likelihood ratio test value = 48.4685
Probability of a greater value = .000000
*** Model 2 selected over model 1 based on likelihood ratio test

Model 3
Uniform key, k(y) = 1/W
Cosine adjustments of order(s) : 1, 2
Results:
Convergence was achieved with 6 function evaluations.
Final Ln(likelihood) value = -389.28897
Akaike information criterion = 782.57750
Final parameter values: .550455 .153488
Note: Parameters are being constrained to obtain monotonicity.

Likelihood ratio test between models 2 and 3
Likelihood ratio test value = 1.9855
Probability of a greater value = .158887

Program DISTANCE - Analysis of Distance Sampling Data 92.2 01/30/97 14:55
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Probability Function Estimation
Parameter Estimates

Effort : 334.0000
samples : 14
width : 228.0000
observations: 285

Model
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	
A(1)	.6892	.84555E-01	13.99		
f(0)	.783378E-02	.369768E-03	5.25	.434519E-02	.775962E-02

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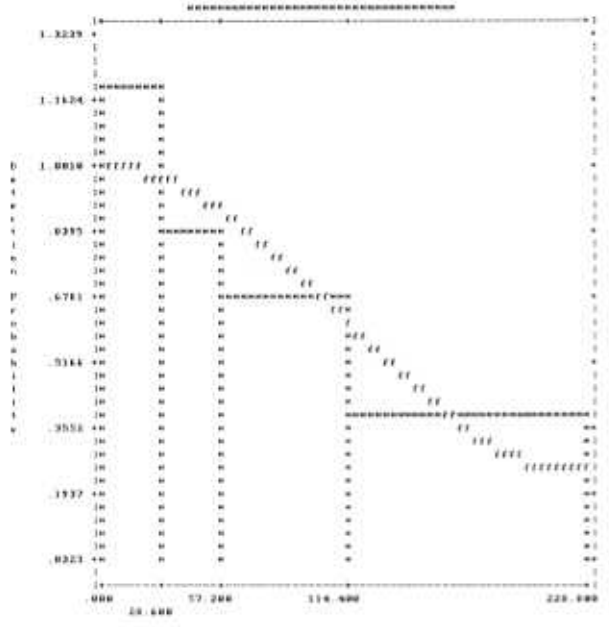
Probability Function Estimation
Detection Probability Plot



Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Probability Function Estimation
Chi-Square Goodness of Fit Test

Cell #	Cut Points	Observed Values	Expected Values	Chi-square Values
1	.000	28.6	49.0	16.670
2	28.6	57.2	46.0	2.631
3	57.2	114.	75.0	.577
4	114.	229.	89.0	.815
				.636

Total Chi-square value = 4.8538 Degrees of Freedom = 2

Probability of a greater Chi-square value = .13148

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

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Probability Function Estimation
Model Selection/Fitting

Effort : 334.8000
samples : 14
Width : 228.8000
observations: 285

Model
Uniform key, h(y) = 1/w
Cosine adjustments of order(s) : 1, 2, 3
Results:
Convergence was achieved with 14 function evaluations.
Final ln(like)(fhood) value = -388.74325
Akaike information criterion = 793.52650
Final parameter values: .467985 -.413388 .227888
Note: Parameters are being constrained to obtain monotonicity.

Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Probability Function Estimation
Parameter Estimates

Effort : 334.8000
samples : 14
Width : 228.8000
observations: 285

Model
Uniform key, h(y) = 1/w
Cosine adjustments of order(s) : 1, 2, 3

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval
A(1)	.4680	.2153	32.42	
A(2)	-.1331E-01	.6114	4566.41	
A(3)	.2279	.5964	261.79	
f(0)	.9227E-02	.1145E-02	12.42	.627136E-02 .13575E-01

Sampling Correlation of Estimated Parameters

	A(1)	A(2)	A(3)
A(1)	1.000	-.983	.920
A(2)	-.983	1.000	-.970
A(3)	.920	-.970	1.000

```
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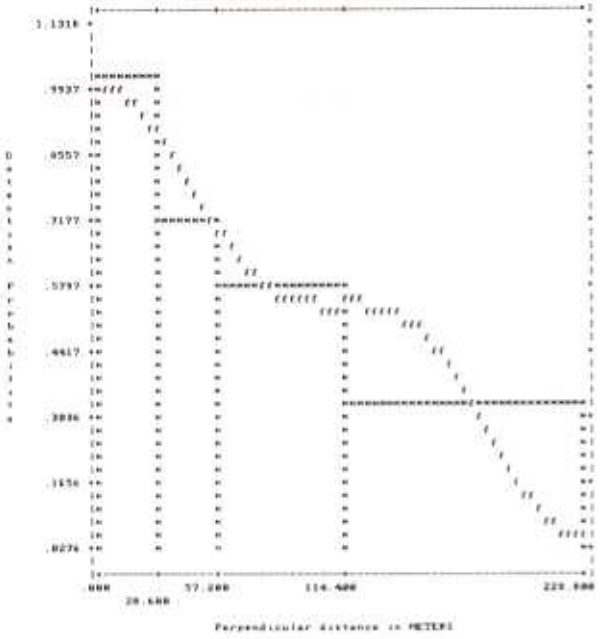
                    ========================================
                    *  Probability Function Estimation     *
                    *    Detection Probability Plot        *
                    ========================================
```

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Program DISTANCE - Analysis of Distance Sampling Data V2.2     01/30/97 14:55
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                    ========================================
                    *  Probability Function Estimation     *
                    *  Chi-Square Goodness of Fit Test     *
                    ========================================

 Cell          Cut          Observed     Expected   Chi-square
  #           Points         Values       Values      Values
 ---------------------------------------------------------------
   1          .000           28.6         65.0        64.75          .270
   2         28.6            57.2         48.0        52.41          .580
   3         57.2            114.         79.0        77.84          .017
   4         114.            229.         88.0        88.75          .000
 ---------------------------------------------------------------

No Degrees of Freedom for the test.  No test possible.
```



```
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                    ========================================
                    *  Probability Function Estimation     *
                    *     Model Selection/Fitting          *
                    ========================================


Effort          :    334.0000
# samples       :    14
Width           :    229.8000
# observations:    293

Note: The number of adjustment parameters allowed has
 been reduced to   2 because of limited number of intervals.


Model  1
   Half-normal key, h(y) = Exp{-y**2/(2*A(1)**2)}
      Results:
      Convergence was achieved with    4 function evaluations.
      Final Ln(likelihood) value =     -378.43466
      Akaike information criterion =     782.86930
      Final parameter values:    128.428061


Model  2
   Half-normal key, h(y) = Exp{-y**2/(2*A(1)**2)}
   Cosine adjustments of order(s) :  2
      Results:
      Convergence was achieved with   14 function evaluations.
      Final Ln(likelihood) value =     -369.87531
      Akaike information criterion =     782.13026
      Final parameter values:    129.888987      .194243

   Likelihood ratio test between models  1 and  2
      Likelihood ratio test value    =      2.7181
      Probability of a greater value =      .099154
*** Model  2 selected over model  1 based on likelihood ratio test


Model  3
   Half-normal key, h(y) = Exp{-y**2/(2*A(1)**2)}
   Cosine adjustments of order(s) :  2, 3
      Results:
      Convergence was achieved with   22 function evaluations.
      Could not achieve requested precision of estimates.
      Final Ln(likelihood) value =     -388.54121
      Akaike information criterion =     783.16248
      Final parameter values:    134.450883     -.039721      .283883
      Note: Parameters are being constrained to obtain monotonicity.

   Likelihood ratio test between models  2 and  3
      Likelihood ratio test value    =      .3678
```



```
      Probability of a greater value =      .328283
*** Model  2 selected over model  3 based on likelihood ratio test
```

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Probability Function Estimation
Parameter Estimates

Effort	334.0000
# samples	14
Width	228.0000
# observations:	285

Model
Half-normal key, h(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
A(1)	125.9	12.38	9.53	
A(2)	.1562	.1217	62.88	
f(0)	.888055E-02	.749188E-03	9.36	.666578E-02 .941438E-02

Sampling Correlation of Estimated Parameters

	A(1)	A(2)
A(1)	1.000	.464
A(2)	.464	1.000

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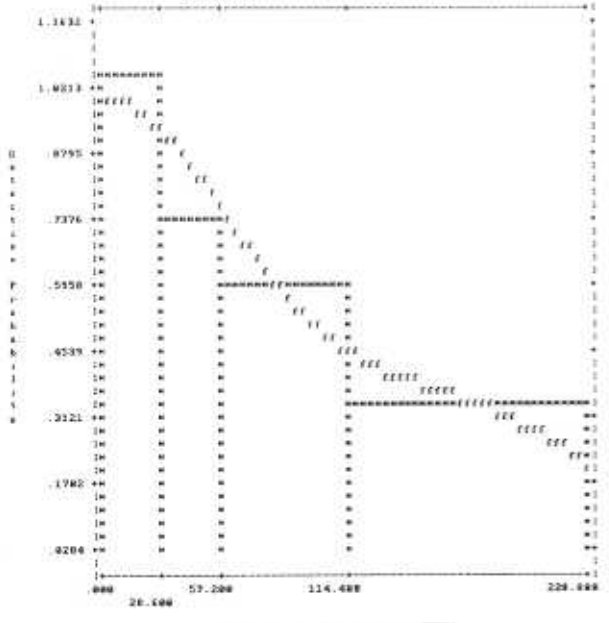
Probability Function Estimation
Detection Probability Plot



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Probability Function Estimation
Chi-Square Goodness of Fit Test

Cell	Cut Points		Observed Values	Expected Values	Chi-square Values
1	.000	28.6	69.0	63.68	.443
2	28.6	57.2	48.0	55.38	.183
3	57.2	114.	75.0	76.83	.861
4	114.	228.	93.0	89.13	.000

Total Chi-square value = 1.4871 Degrees of Freedom = 1

Probability of a greater chi-square value = .22236

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

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Probability Function Estimation
Model Selection/Fitting

Effort	334.0000
# samples	14
Width	228.0000
# observations:	285

Note: The number of adjustment parameters allowed has been reduced to 2 because of limited number of intervals.

Model 1
Negative Exponential key, h(y) = Exp(-y/A(1))
Results:
Convergence was achieved with 15 function evaluations.
Could not achieve requested precision of estimates.
Final Ln(likelihood) value = -388.69613
Akaike information criterion = 779.39238
Final parameter values: 142.165999

Model 2
Negative Exponential key, h(y) = Exp(-y/A(1))
Cosine adjustments of order(s) : 1
Results:
Convergence was achieved with 4 function evaluations.
Final Ln(likelihood) value = -388.69378
Akaike information criterion = 781.38748
Final parameter values: 142.163618 -.006552

Likelihood ratio test between models 1 and 2
Likelihood ratio test value = .0045
Probability of a greater value = .944167
*** Model 1 selected over model 2 based on likelihood ratio test

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Probability Function Estimation
Parameter Estimates

Effort	334.0000
N samples	14
Width	228.0000
N observations	285

Model
Negative Exponential key, h(y) = Exp(-y/A(1))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval
A(1)	142.2	20.67	14.48	
f(0)	.87929E-02	75652E-03	8.68	.74387E-02 .10465E-01

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Probability Function Estimation
Chi-Square Goodness of Fit Test

Cell	Cut Points	Observed Values	Expected Values	Chi-square Value
1	.000	28.6	45.8	44.92 .254
2	28.6	57.2	48.6	53.89 .488
3	57.2	114.	71.8	78.92 .900
4	114.	228.	89.8	88.87 .910

Total Chi-square value = .7542 Degrees of Freedom = 2

Probability of a greater chi-square value = .68588

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

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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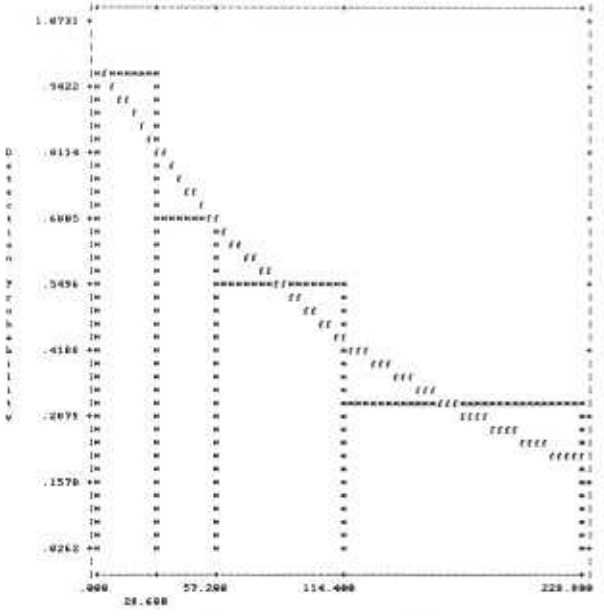
Probability Function Estimation
Detection Probability Plot



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Probability Function Estimation
Model Selection/Fitting

Effort	334.0000
N samples	14
Width	228.0000
N observations	285

Note: The number of adjustment parameters allowed has been reduced to 1 because of limited number of intervals.

Model 1
Hazard Rate key, h(y) = 1 - Exp(-(y/A(1))**-A(2))
Results:
Convergence was achieved with 13 function evaluations.
Final Ln(likelihood) value = -398.42977
Akaike information criterion = 781.64158
Final parameter values: 66.135134 1.000000
Note: Key parameter 2 is at a lower or upper bound

Model 2
Hazard Rate key, h(y) = 1 - Exp(-(y/A(1))**-A(2))
Cosine adjustments of order(s) : 2
Results:
Convergence was achieved with 7 function evaluations.
Could not achieve requested precision of estimates.
Final Ln(likelihood) value = -398.42965
Akaike information criterion = 783.64138
Final parameter values: 66.135149 1.000000 -.000844
Note: Key parameter 2 is at a lower or upper bound
Note: Parameters are being constrained to obtain monotonicity.

Likelihood ratio test between models 1 and 2
Likelihood ratio test value = .00002
Probability of a greater value = .987538
*** Model 1 selected over model 2 based on likelihood ratio test

Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Probability Function Estimation
Parameter Estimates

Effort	334.0000
N samples	14
Width	228.0000
N observations	265

Model
Hazard Rate key, h(y) = 1 - Exp(-(y/A(1))**-A(2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval
A(1)	66.14	24.17	36.55	
A(2)	1.000	.2786	27.86	
f(0)	.839216-02	.120788-02	14.39	.633968-02 .111095-01

Sampling Correlation of Estimated Parameters

	A(1)	A(2)
A(1)	1.000	.817
A(2)	.817	1.000

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Probability Function Estimation
Chi-Square Goodness of Fit Test

Cell	Cut Points		Observed Values	Expected Values	Chi-square Values
1	.000	28.6	43.0	44.69	.000
2	28.6	57.2	48.0	53.94	.654
3	57.2	114.	79.0	74.64	.255
4	114.	229.	85.0	89.74	.906

Total Chi-square value = .1951 Degrees of Freedom = 1

Probability of a greater chi-square value = .31851

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

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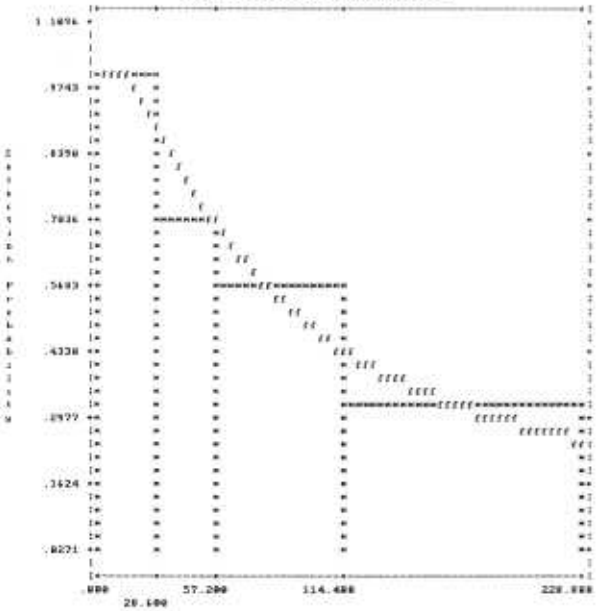
Probability Function Estimation
Detection Probability Plot



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Expected Cluster Size Estimation

Effort	334.0000
N samples	14
Width	228.0000
N observations	265

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

Expected cluster size estimated based on regression of: log(s(i)) on g(x(i))

Regression Estimates

Slope	=	.354434E-01	Std error	=	.182503
Intercept	=	.211668	Std error	=	.791157E-01
Correlation	=	.8297	Student-t	=	.347709
Df	=	263	Pr(T < t)	=	.635841

Expected cluster size = 1.4145 Standard error = .391048E-01

Mean cluster size = 1.4421 Standard error = .554748E-01

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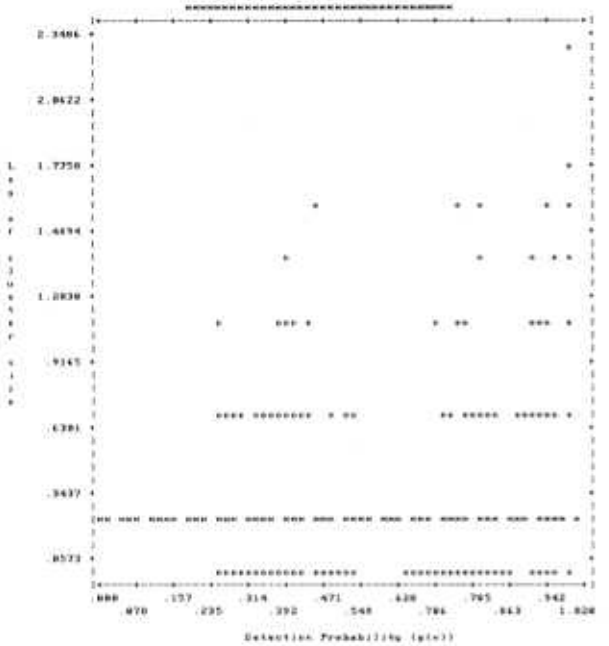
Cluster Size Regression Plot



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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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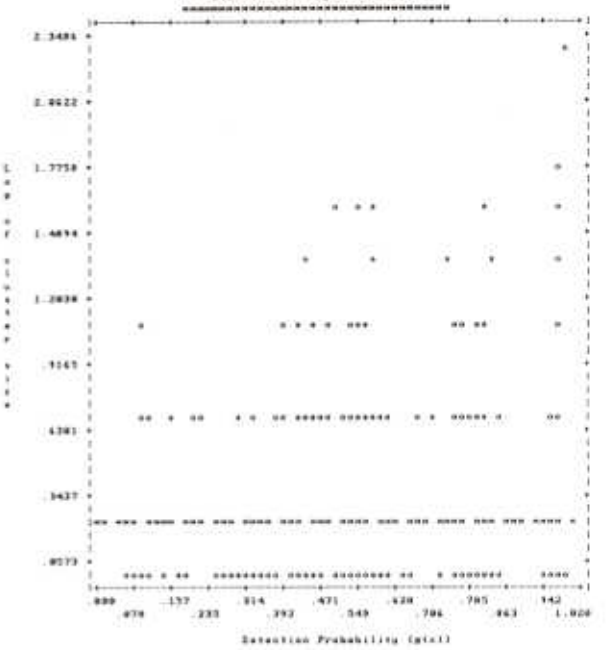
Cluster Size Regression Plot



File: c:\dist2.2\A527_93.OUT Page 36

Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Expected Cluster Size Estimation

Effort : 334.0000
samples : 14
Width : 228.6000
observations: 285

Model
Uniform key, h(y) = 1/w
Cosine adjustments of order(s) : 1, 2, 3

Expected cluster size estimated based on regression of: log(s(i)) on g(=i(i))

Regression Estimates

Slope	=	.5143378E-01	Std error	=	.186285
Intercept	=	.2846618	Std error	=	.7388728E-01
Correlation	=	.0288	Students-t	=	.466247
Df	=	283	Prob(> t)	=	.685714

Expected cluster size = 1.4273 Standard error = .3948E-01

Mean cluster size = 1.4421 Standard error = .5947E-01

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Program DISTANCE - Analysis of Distance Sampling Data V2.2 01/30/97 14:55
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Expected Cluster Size Estimation

Effort : 334.0000
samples : 14
Width : 228.6000
observations: 285

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

Expected cluster size estimated based on regression of: log(s(i)) on g(=i(i))

Regression Estimates

Slope	=	.5147538E-01	Std error	=	.184182
Intercept	=	.2848864	Std error	=	.7285336E-01
Correlation	=	.0294	Students-t	=	.494489
Df	=	283	Prob(> t)	=	.649187

Expected cluster size = 1.4265 Standard error = .3956E-01

Mean cluster size = 1.4421 Standard error = .5947E-01

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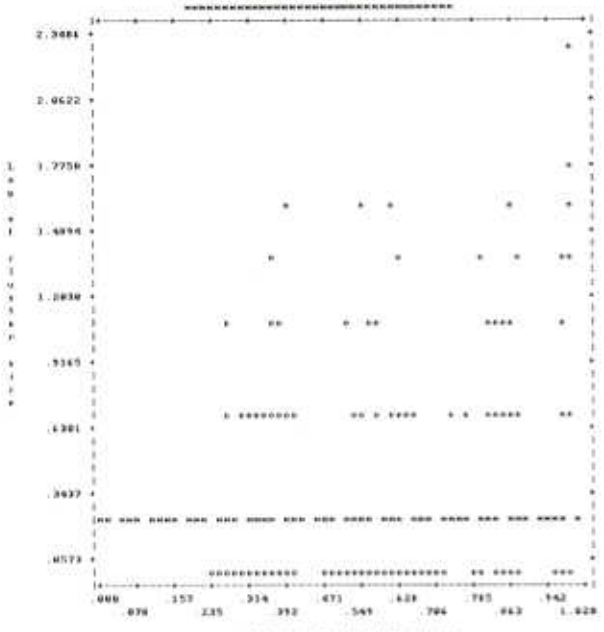
Cluster Size Regression Plot



File: c:\dist2.2\A527_93.OUT Page 42

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Expected Cluster Size Estimation

Effort : 334.0000
samples : 14
Width : 220.0000
observations: 285

Model
Negative Exponential key, k(y) = Exp(-y/A(1))

Expected cluster size estimated based on regression of: log(s(i)) on g(x(i))

Regression Estimates

Slope	=	.432966E-01	Std error	=	.113589
Intercept	=	.112886	Std error	=	.7218846E-01
Correlation:		.0227	Students-t	=	.381168
DF	=	283	Pr(T < t)	=	.648318

Expected cluster size = 1.4268 Standard error = .356718E-01

Mean cluster size = 1.4421 Standard error = .5547AE-01

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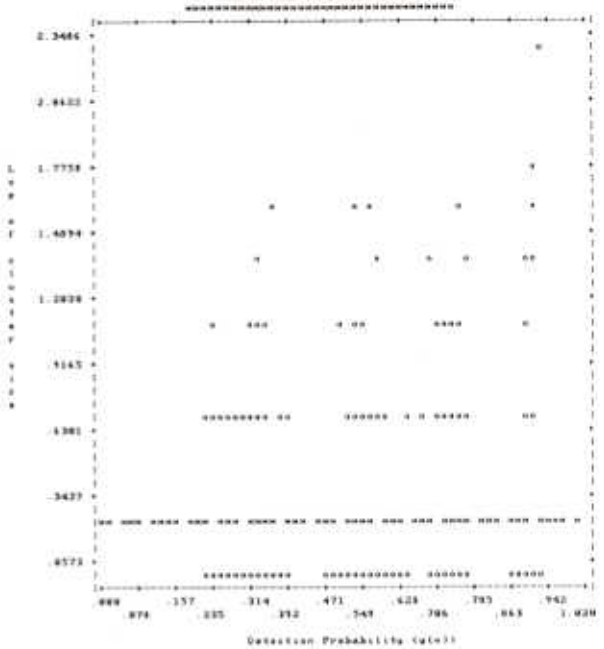
Cluster Size Regression Plot



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Expected Cluster Size Estimation

Effort : 334.0000
samples : 14
Width : 220.0000
observations: 285

Model
Hazard Rate key, k(y) = 1 - Exp(-(y/A(1))**-A(2))

Expected cluster size estimated based on regression of: log(s(i)) on g(x(i))

Regression Estimates

Slope	=	.3989878E-01	Std error	=	.101983
Intercept	=	.212726	Std error	=	.6883648E-01
Correlation:		.0233	Students-t	=	.391536
DF	=	283	Pr(T < t)	=	.652152

Expected cluster size = 1.4225 Standard error = .394778E-01

Mean cluster size = 1.4421 Standard error = .5547AE-01

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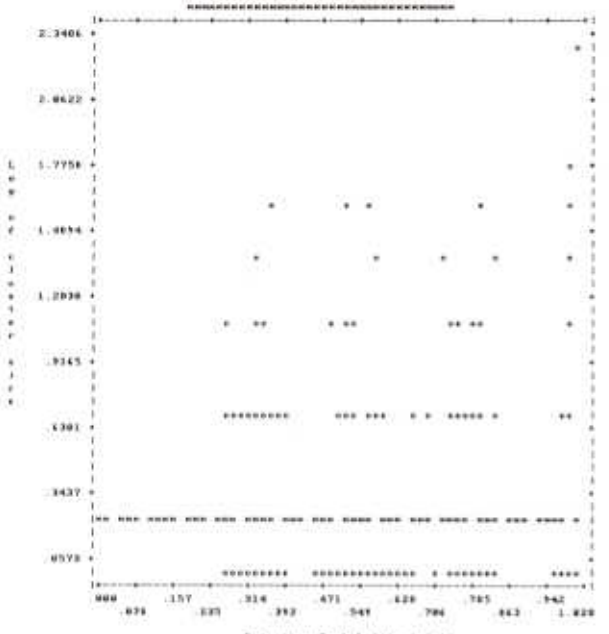
Cluster Size Regression Plot



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Density Estimation Results

Effort : 334.0000
samples : 14
Width : 220.0000
observations: 285

Model 1
Uniform key, h(y) = 1/w
Cosine adjustments of order(s) : 1, 2, 3

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
f(0)	.922770E-02	.114538E-02	13.52	.627138E-02	.187755E-01
p	.55121	.339468E-01	13.52	.48489	.63693
ESW	121.54	16.919	13.92	92.648	159.46
n/L	.85829	.11745	13.76	.63472	1.1471
DS	5.4493	1.1859	19.58	3.8279	8.3374
E(s)	1.4273	.394938E-01	2.77	1.3518	1.5071
D	8.8634	1.5943	19.77	5.4458	11.941
N	9257.8	1838.2	19.77	6270.8	13768

Measurement Units

Density: Numbers/SQ. MILES
ESW: METERS

Component Percentages of Var(D)

Detection probability	49.6
Encounter rate	48.5
Cluster size	1.8

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Density Estimation Results

Effort : 334.0000
samples : 14
Width : 220.0000
observations: 285

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

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
f(0)	.790327E-02	.381504E-03	5.25	.634559E-02	.984262E-02
p	.62138	.326506E-01	5.25	.56861	.68894
ESW	142.17	7.4704	5.25	128.27	157.58
n/L	.85829	.11745	13.76	.63472	1.1471
DS	4.8295	.71154	14.73	3.5458	6.5795
E(s)	1.4195	.391844E-01	2.77	1.3398	1.4934
D	6.8316	1.0041	14.99	4.9544	9.3442
N	7977.8	1348.9	14.99	5758.8	10774.

Measurement Units

Density: Numbers/SQ. MILES
ESW: METERS

Component Percentages of Var(D)

Detection probability	12.8
Encounter rate	84.2
Cluster size	3.4

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Density Estimation Results

Effort : 334.0000
samples : 14
Width : 220.0000
observations: 285

Model 1
Half-normal key, h(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	
f(0)	.688553E-02	.749448E-03	9.36	.544539E-02	.911432E-02
p	.54034	.511231E-01	9.36	.45468	.63567
ESW	124.91	11.697	9.36	104.81	148.82
n/L	.85829	.11745	13.76	.63472	1.1471
DS	5.4967	.91587	16.65	3.9178	7.7119
E(s)	1.4265	.395644E-01	2.77	1.3518	1.5062
D	7.8418	1.3233	16.88	5.5659	11.046
N	9141.8	1525.9	16.84	6417.8	12936.

Measurement Units

Density: Numbers/SQ. MILES
ESW: METERS

Component Percentages of Var(D)

Detection probability	30.8
Encounter rate	66.5
Cluster size	2.7

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Density Estimation
Results

Effort	334.0000
# samples	14
Width	220.0000
# observations	285

Model 1
Negative Exponential key, h(y) = Exp(-y/A(1))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
f(0)	.875258E-02	.754528E-03	8.68	.743875E-02	.104858E-01
p	.95786	.827664E-01	8.68	.810806	.58819
ESW	113.73	9.7845	8.68	96.118	134.58
n/L	.85329	.11745	13.76	.63472	1.1471
DS	6.8376	.98001	14.33	4.8298	8.4154
E(S)	1.4268	.39477E-01	2.78	1.3511	1.5067
D	8.6140	1.4187	16.47	6.1538	12.058
N	9532.8	1635.7	16.47	7805.6	13983.

Measurement Units

Density: Numbers/SQ. MILES
ESW: METERS

Component Percentages of Var(D)

Detection probability	27.3
Encounter rate	69.7
Cluster size	2.9

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Density Estimation
Results

Effort	334.0000
# samples	14
Width	220.0000
# observations	285

Model 1
Hazard Rate key, h(y) = 1 - Exp(-(y/A(1))**-A(2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
f(0)	.839218E-02	.120788E-02	14.39	.633956E-02	.111095E-01
p	.92881	.745487E-01	14.39	.39343	.68941
ESW	119.14	17.139	14.38	90.018	157.74
n/L	.85329	.11745	13.76	.63472	1.1471
DS	5.7622	1.1471	19.91	3.8815	8.5548
E(S)	1.4225	.39477E-01	2.78	1.3472	1.5028
D	8.1567	1.4476	20.18	5.5815	12.211
N	9451.8	1699.7	20.18	6344.8	14088.

Measurement Units

Density: Numbers/SQ. MILES
ESW: METERS

Component Percentages of Var(D)

Detection probability	51.2
Encounter rate	46.5
Cluster size	1.9

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Estimation Summary
Encounter rates

Pooled Estimates:

	Estimate	%CV	df	95% Confidence Interval	
n	285.00				
k	14.000				
L	334.00				
n/L	.85329	13.76	13	.63472	1.1471

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Estimation Summary
Detection probability

Pooled Estimates:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine	n	1.0000				
	AIC	792.56				
	Chi-p	.13148				
	f(0)	.780337E-02	5.25	284	.634539E-02	.779625E-02
	p	.62138	5.25	284	.56861	.68074
	ESW	142.17	5.25	284	128.27	157.58
Uniform/Cosine	n	3.0000				
	AIC	763.53				
	f(0)	.822777E-02	13.92	282	.627138E-02	.107955E-01
	p	.53121	13.92	282	.40481	.69693
	ESW	121.54	13.92	282	92.648	159.46
Half-normal/Cosine	n	2.0000				
	AIC	762.13				
	Chi-p	.22226				
	f(0)	.680655E-02	9.36	283	.566539E-02	.961438E-02
	p	.54594	9.36	283	.45469	.65567
	ESW	124.91	9.36	283	104.01	150.02
Neg Exp/Cosine	n	1.0000				
	AIC	771.39				
	Chi-p	.48588				
	f(0)	.875258E-02	8.68	284	.743875E-02	.104858E-01
	p	.95786	8.68	284	.82884	.58819
	ESW	113.73	8.68	284	96.118	134.58
Hazard/Cosine	n	2.0000				
	AIC	761.64				
	Chi-p	.31851				
	f(0)	.839218E-02	14.38	283	.633956E-02	.111095E-01
	p	.92881	14.38	283	.39343	.68941
	ESW	119.14	14.38	283	90.018	157.74

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Estimation Summary
Expected cluster size

Pooled Estimates:

		Estimate	%CV	df	95% Confidence Interval	
Average cluster size						
	E(s)	1.4421	4.12	284	1.3302	1.5635
Uniform/Cosine						
	P	.206635E-01				
	P-P	.63584				
	E(s)	1.4145	2.77	283	1.3398	1.4934
Uniform/Cosine						
	P	.207775E-01				
	P-P	.68571				
	E(s)	1.4279	2.77	283	1.3518	1.5071
Half-normal/Cosine						
	P	.213750E-01				
	P-P	.68519				
	E(s)	1.4265	2.77	283	1.3516	1.5062
Neg Exp/Cosine						
	P	.226520E-01				
	P-P	.64832				
	E(s)	1.4264	2.78	283	1.3511	1.5067
Hazard/Cosine						
	P	.232648E-01				
	P-P	.65235				
	E(s)	1.4225	2.79	283	1.3472	1.5029

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Estimation Summary
Density/Abundance

Pooled Estimates:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	D1	4.8295	14.73	17	3.5458	6.5795
	D	6.8314	14.99	18	4.9544	9.3442
	N	7837.8	14.99	18	5758.8	10774.
Uniform/Cosine						
	D1	5.6493	19.56	51	3.8275	8.3374
	D	8.8634	19.77	53	5.6658	11.542
	N	9297.8	19.77	53	6278.8	13768.
Half-normal/Cosine						
	D1	5.4967	16.65	29	3.9178	7.7119
	D	7.8459	16.86	29	5.5659	11.046
	N	9061.8	16.86	29	6417.8	12734.
Neg Exp/Cosine						
	D1	6.0376	16.23	25	4.3388	8.4144
	D	8.6142	16.47	26	6.1539	12.058
	N	9932.8	16.47	26	7095.8	13903.
Hazard/Cosine						
	D1	5.7622	19.91	54	3.8815	8.5548
	D	8.1967	20.18	56	5.5819	12.211
	N	9451.8	20.18	56	6344.8	14084.