

ESTIMATING THE ABUNDANCE OF CHRIST'S INDIAN PAINTBRUSH (*CASTILLEJA CHRISTII*) USING DISTANCE SAMPLING METHODOLOGY



Idaho Conservation
Data Center
Idaho Department of
Fish and Game
PO Box 25
Boise, Idaho
83707



Beth Colket
Gillian Crymes

2006



US Fish and Wildlife Service

ABSTRACT

Christ's Indian paintbrush (*Castilleja christii*) was designated a candidate for listing under the Endangered Species Act in 1999. The global distribution of Christ's Indian paintbrush is restricted to 0.81 km² at the top of Mount Harrison in south-central Idaho, entirely within the Sawtooth National Forest. Population estimates traditionally consisted of counting all detectable plants, but this method produced results with high rates of error. Distance sampling is an alternative method that produces a density estimate with confidence intervals that allows direct statistical analyses between years and individual transects. The objectives of this study were to: 1) evaluate the use of distance sampling for Christ's Indian paintbrush population trend analysis and 2) use distance sampling to acquire an accurate estimate of the overall population size of Christ's Indian paintbrush. Three transects were established in each of the 3 communities (graminoid, mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), and snowbed), for a total of 9 transects. We estimated the density of Christ's Indian paintbrush using 0.50-m cluster distances at all 9 transects and with 0.25-m cluster distances at a subset of these transects. Distance sampling worked best in the graminoid and snowbed communities, probably because of the uniform distribution of associated vegetation. Distance sampling did not work well at some of the mountain big sagebrush distance sampling transects, likely caused by the obstruction of plants by mountain big sagebrush. Both the 0.25- and 0.50-m cluster distances worked well in most cases, although the 0.25-m cluster distance produced narrower confidence intervals and better probability detection models. We recommend continuing distance sampling at the 9 transects using the 0.25-m cluster distance. The predicted population size across all three communities was 819,126-1,716,033 plants, but there are several limitations in this calculation that could likely be resolved with more refined data for the spatial extent of the communities within the distribution of Christ's Indian paintbrush. These results represent the baseline for distance sampling of Christ's Indian paintbrush and should provide information from which to objectively measure population trends.

KEY WORDS

Christ's Indian paintbrush, *Castilleja christii*, distance sampling, monitoring, abundance, rare plant conservation, Idaho.

SUGGESTED CITATION

Colket, B., and G. Crymes. 2006. Estimating the abundance of Christ's Indian paintbrush using distance sampling methodology. Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise, Idaho. 19 pp. plus appendices.

COPYRIGHT

Publications authored by government employees are in the public domain. The Idaho Conservation Data Center, Idaho Department of Fish and Game retain copyright.

TABLE OF CONTENTS

Abstract	i
Keywords	i
Suggestion Citation	ii
Copyright.....	ii
Table of Contents.....	iii
List of Tables.....	iii
List of Figures.....	iii
List of Appendices	iv
Introduction	1
Study Area	1
Methods	2
Results	2
Discussion and Recommendations	4
Acknowledgments	5
Literature Cited.....	5

LIST OF TABLES

Table 1. 2005 estimated abundance of Christ's Indian paintbrush at distance sampling transects.....	7
Table 2. 2005 estimated rangewide abundance of Christ's Indian paintbrush based on extrapolation of distance sampling data	8

LIST OF FIGURES

Figure 1. Christ's Indian paintbrush distance sampling transects within EO 1.....	9
Figure 2. Photographs of distance sampling transects established within graminoid, mountain big sagebrush, and snowbed communities.....	10
Figure 3. Probability of detecting Christ's Indian paintbrush at transect 01 at increasing distances from the line transect using the 0.5-m cluster distance sampling method	11
Figure 4. Probability of detecting Christ's Indian paintbrush at transect 02 at increasing distances from the line transect using the 0.25- and 0.50-m cluster distance sampling method.....	12
Figure 5. Probability of detecting Christ's Indian paintbrush at transect 03 at increasing distances from the line transect using the 0.50-m cluster distance sampling method	13
Figure 6. Probability of detecting Christ's Indian paintbrush at transect 04 at increasing distances from the line transect using the 0.50-m cluster distance sampling method	14
Figure 7. Probability of detecting Christ's Indian paintbrush at transect 05 at increasing distances from the line transect using the 0.50-m cluster distance sampling method	15

Figure 8. Probability of detecting Christ’s Indian paintbrush at transect 06 at increasing distances from the line transect using the 0.25- and 0.50-m (bottom) cluster distance sampling methods.....	16
Figure 9. Probability of detecting Christ’s Indian paintbrush at transect 07 at increasing distances from the line transect using the 0.25- and 0.50-m (bottom) cluster distance sampling methods.....	17
Figure 10. Probability of detecting Christ’s Indian paintbrush at transect 08 at increasing distances from the line transect using the 0.50-m cluster distance sampling method	18
Figure 11. Probability of detecting Christ’s Indian paintbrush at transect 09 at increasing distances from the line transect using the 0.50-m cluster distance sampling method	19

LIST OF APPENDICES

Appendix A. GPS locations of distance sampling transects	Disc 1
Appendix B. GIS layer of distance sampling transects	Disc 1
Appendix C. Photographs of distance sampling transects	Disc 1
Appendix D. Distance sampling data.....	Disc 1
Appendix E. Distance sampling transect re-location directions	Disc 1

INTRODUCTION

Christ's Indian paintbrush (*Castilleja christii*) was designated a candidate for listing under the Endangered Species Act in 1999 (U.S. Fish and Wildlife Service 1999). The global distribution of Christ's Indian paintbrush is restricted to 0.81 km² at the top of Mount Harrison in south-central Idaho, entirely within the Sawtooth National Forest. This population is tracked as element occurrence (EO) 1 in the Idaho Conservation Database (2006), the only Christ's Indian paintbrush EO. An EO is a specific geographic location where "a species is, or was, present" (NatureServe 2002).

Population estimates traditionally consisted of counting all detectable plants, but this has been inadequate for estimating population trends and the overall population size. The variable distribution of Christ's Indian paintbrush across such a large area has made it difficult to consistently estimate its overall population size. Population trends have also been estimated at 20 permanent monitoring transects by counting the number of plants in 20 1-m² quadrats (Moseley 1996, Moseley 1997, Mancuso 2003, Motychak and Pierson 2005). However, the relatively small total area sampled (400 m²) and lack of independent samples (quadrats) makes it difficult to statistically analyze population trends at each transect or extrapolate these data to estimate overall population size.

Distance sampling is an alternative well designed for estimating population trends of certain plant species. This method appears to work best for estimating continuously distributed populations with >100 individuals, and is especially suited for showy species such as Christ's Indian paintbrush (Colket and Church 2005). Distance sampling involves measuring the perpendicular distance to the objects detected by an observer moving along a randomly located transect. A density estimate with confidence intervals is calculated that allows direct statistical analyses between years and individual transects. Distance sampling also reduces the observer bias associated with traditional counts. Distance sampling produces a detection probability that allows for some objects to go undetected and for detectability to decrease with increasing distance from the transect line. The objectives of this study were to: 1) evaluate the use of distance sampling in estimating Christ's Indian paintbrush abundance and 2) use distance sampling to acquire an accurate estimate of the overall population size of Christ's Indian paintbrush.

STUDY AREA

The study area is located in Cassia County, Idaho at the top of Mount Harrison (2632-2804 m; Fig. 1). Three communities occur within the study area: graminoid, mountain big sagebrush, and snowbed (Moseley 1993; Fig. 2). The graminoid community is dominated by Idaho fescue (*Festuca idahoensis*) and bearded wheatgrass (*Elymus caninus*). The mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) community is associated with Idaho fescue, and is distributed in a biscuit and swale pattern. The snowbed community is dominated by forbs and snow persists later than in the other communities (Moseley 1993).

METHODS

We randomly selected 9 transect locations within EO 1 using a GIS-based random points generator. All sampling occurred during the week of 25-29 July 2005. Once at the transect location, we randomly selected a transect azimuth from the GPS point. *A priori* transect location criteria required that at least 100 Christ's Indian paintbrush flowering plants were present. We permanently established a 20-m long transect and recorded the transect start and end points with a GPS unit (Appendices A and B). Sampling occurred on the transect side with the minimum required number of plants, or was randomly selected if both sides were similar. Distance sampling was truncated 20 m from the transect.

Three transects were established in each of the 3 communities (graminoid, mountain big sagebrush, and snowbed) occurring within EO 1, for a total of 9 transects. We estimated the density of Christ's Indian paintbrush using 0.50-m cluster distances at all 9 transects. We also estimated density using 0.25-m cluster distances at 3 of these transects, 1 in each community. Christ's Indian paintbrush and putative hybrids sharing more characteristics of Christ's Indian paintbrush than Wyoming Indian paintbrush (*Castilleja linariifolia*) were counted for the distance sampling. Hybrids that shared more characteristics of Christ's Indian paintbrush were typically characterized by a lighter orange flower color and fleshier and thicker leaves (K. Pierson, pers. comm. 2005). Photographs were taken at the start and end points of each transect (Appendix C). All distance sampling data are provided in Appendix D. Directions for distance sampling transect re-location are in Appendix E.

We used Distance Version 4.1 Release 2 to generate density estimates (Thomas et al. 2003). Results were assessed primarily on the models showing probability of detecting Christ's Indian paintbrush at increasing distances from the transect. Additional factors contributing to better density estimates were a lower Akaike's Information Criterion (AIC) value and fewer model parameters (Buckland et al. 1993). The final detection function model was based on half-normal cosine parameters and no distance truncation. Land area of the graminoid, mountain big sagebrush, and snowbed communities within EO 1 was used to predict population size using the estimated density of Christ's Indian paintbrush at the distance sampling transects.

RESULTS

Overall

The probability detection models had good fits for most of the 9 transects sampled (Table 1; Figs. 3-11). The mountain big sagebrush community generally had the poorest model fits, due to the physical obstruction of mountain big sagebrush. Based on the 0.50-m cluster distance, Christ's Indian paintbrush density across all three communities was 1.1-2.3 plants/ m² (Table 2). Density estimates were not different between the 3 communities (Table 2).

Graminoid

Transects 03, 07, and 09 were in the graminoid community (Table 1; Figs. 2, 5, 9, and 11). The probability detection models for the graminoid community transects all had good fits using the 0.50-m cluster distance, although the 0.25-m cluster distance was better at transect 07. Based on the 0.50-m cluster distance, Christ's Indian paintbrush density in the graminoid community was 1.4-3.4 plants/m² (Table 2).

Mountain big sagebrush

Transects 01, 06, and 08 were in the mountain big sagebrush community (Table 1; Figs. 2, 3, 10). The probability detection model for the mountain big sagebrush community had a good fit at transect 06. The probability detection models at transects 01 and 08 had the poorest fits of the 9 transects. AIC values were low with 1 model parameter using 0.50-m cluster distances, indicating model stability despite the poor distribution patterns of probability detection. The problems with the probability detection models at transects 01 and 08 were likely because of the visual obstruction by the mountain big sagebrush, making it easier to see Christ's Indian paintbrush individuals farther away than closer. Based on the 0.50-m cluster distance, Christ's Indian paintbrush density in the mountain big sagebrush community was 0.8-1.8 plants/m² (Table 2).

Snowbed

Transects 02, 04, and 05 were in the snowbed community (Table 1; Figs. 2, 4, 6, 7). The probability detection models for the snowbed community were good fits at transects 02 and 05, and a fair fit at transect 04. All probability detection models had 1 model parameter and relatively low AIC values, especially using the 0.50-m cluster distance. Based on the 0.50-m cluster distance, Christ's Indian paintbrush density in the snowbed community was 1.0-1.9 plants/m² (Table 2).

Comparison of 0.25- and 0.50-m cluster distances

The 0.25-m cluster distance produced better probability detection models than the 0.50-m cluster distance (Figs. 4, 8, and 9), although the AIC values were typically lower for the 0.50-m cluster distance (Table 1). Confidence intervals produced by the 0.25-m cluster distance were narrower than for the 0.50-m cluster distance, due to the greater number of observations associated with the 0.25-m cluster distance.

Christ's Indian paintbrush population size

The mean density of Christ's Indian paintbrush plants was extrapolated to predict the total number of plants within each community and across the entire EO. The predicted population size across all three communities was 819,126-1,716,033 plants (Table 2). Most of the population occurred in the snowbed community because of its greater overall land area. There are several limitations to using the rangewide population estimates for Christ's Indian paintbrush that are discussed below.

DISCUSSION AND RECOMMENDATIONS

Distance sampling for Christ's Indian paintbrush was relatively replicable, easy, and robust. This method provides confidence intervals that would not be possible by simply counting the number of plants within the same 9 400-m² areas where the distance sampling transects occurred. The Christ's Indian paintbrush monitoring program does involve counting plants within 20 1-m² quadrats at 20 permanently marked monitoring transects (Moseley 1996, Moseley 1997, Mancuso 2003, Motychak and Pierson 2005). This is a repeatable method that has been used to evaluate population trends at monitoring transects for 10 years, but distance sampling has several advantages. The monitoring transect quadrats are not independent of each other, so the variance of the number of plants can not be estimated for individual transects. Furthermore, the number of plants counted at distance sampling transects cover a much larger area than the monitoring transects (9x greater). The large time span (10 years) and repeatable methodology of the monitoring transects nevertheless continues to be useful for evaluating population trend of Christ's Indian paintbrush. However, the distance sampling transects provide many advantages not otherwise possible with the monitoring transects.

Distance sampling worked best in the graminoid and snowbed communities, probably because of the uniform distribution of associated vegetation. Distance sampling did not work well at some of the mountain big sagebrush distance sampling transects, likely caused by the obstruction of plants by mountain big sagebrush. Both the 0.25- and 0.50-m cluster distances worked well in most cases, although the 0.25-m cluster distance produced narrower confidence intervals and better probability detection models. Some of the problems associated with transects in the mountain big sagebrush community could potentially be minimized if the 0.25-m cluster distance was used instead of the 0.50-m cluster distance. Both cluster distances took similar amounts of time, but it was easier to keep track of the large number of plants at some transects with the 0.25-m cluster distance. We recommend that the 0.25-m cluster distance be used in the future for monitoring Christ's Indian paintbrush population trends.

Land area was used to predict Christ's Indian paintbrush population size within each community and rangewide (Table 2). These predictions have limitations that should be considered before being applied. Distance sampling methodology requires that there be a minimum number of plants present. Many potential transects were eliminated because they had few or zero plants, so the distance sampling transects are not completely representative of population distribution patterns of Christ's Indian paintbrush. This means that the population size predictions for Christ's Indian paintbrush were likely overestimated. Also, the land area calculations for each community are based on 1993 estimates that could be further delineated with GPS and GIS tools (Moseley 1993, Moseley 1996).

Distance sampling is replicable and generates a population estimate with confidence intervals that facilitate tests for statistical significance among individual transects and years. We recommend continuing distance sampling for assessing population trends at the 9 transects using the 0.25-m cluster distance. If the 0.25-m cluster distance does

not ameliorate the problems at transects 01 and 08, we recommend re-locating these transects elsewhere within the mountain big sagebrush community. Applying distance sampling to predict the rangewide population size of Christ's Indian paintbrush has limitations that could likely be overcome by updating spatial information about the distribution of Christ's Indian paintbrush within each community. Updated vegetation mapping data within the distribution of Christ's Indian paintbrush would be useful to further refine rangewide population size estimates presented in this report. The other main limitation to extrapolating total population abundance is that the population extrapolations are more relevant for those areas with >100 plants. These results represent the baseline for distance sampling of Christ's Indian paintbrush and should provide information from which to objectively measure long-term population trends.

ACKNOWLEDGMENTS

This project was greatly improved by the assistance of Kim Pierson. We also gratefully acknowledge Michael Mancuso and Kevin Church for reviewing and providing constructive criticism.

LITERATURE CITED

- Buckland, S.T., D.R. Anderson, K.P. Burnham and J.L. Laake. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London, UK.
- Colket, B., and K. Church. 2005. A comparison of traditional counts and distance sampling methods for estimating the abundance of Ute ladies' tresses (*Spiranthes diluvialis*). Idaho Department of Fish and Game, Idaho Conservation Data Center, Boise. 11 pp.
- Holmgren, N.H. 1973. Five new species of *Castilleja* (Scrophulariaceae) from the Intermountain region. Bulletin of the Torrey Botanical Club 100(2): 83-93.
- Idaho Conservation Data Center. 2006. Idaho Conservation Data Center, Idaho Department of Fish and Game. BIOTICS data system database, Boise.
- Mancuso, M. 2003. A fifth year of monitoring Christ's Indian paintbrush (*Castilleja christii*) on the Sawtooth National Forest: 2002 results. Conservation Data Center, Idaho Department of Fish and Game, Boise. 18 pp. plus appendices.
- Moseley, R.K. 1993. The status and distribution of Christ's Indian paintbrush (*Castilleja christii*) and Davis' wavewing (*Cymopterus davisii*) in the Albion Mountains, Sawtooth National Forest and City of Rocks National Reserve. Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise. 18 pp. plus appendices.

- Moseley, R.K. 1996. Christ's Indian paintbrush (*Castilleja christii*) monitoring on the Sawtooth National forest: transect establishment and baseline data. Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise. 16 pp. plus appendices.
- Moseley, R.K. 1997. Christ's Indian paintbrush (*Castilleja christii*) monitoring on the Sawtooth National Forest: Second-year results Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise. 8 pp. plus appendices.
- Motychak, J. and K. Pierson. 2005. A ten-year summary of monitoring Christ's Indian paintbrush (*Castilleja christii*) on Mount Harrison, Sawtooth National Forest (1995-2005).
- NatureServe. 2002. Element occurrence data standard. NatureServe in cooperation with the Network of Natural Heritage Programs and Conservation Data Centers, Rosslyn, VA. 201 pp.
- Thomas, L., J.L. Laake, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley, J.H. Pollard and J.R.B. Bishop. 2003. Distance 4.1 Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.
<http://www.ruwpa.st-and.ac.uk/distance>.
- U.S. Fish and Wildlife Service. 1999. 50 CFR 17. Endangered and threatened wildlife and plants; review of plant and animal taxa that are candidates or proposed for listing as endangered or threatened; annual notice of findings on recycled petitions; annual description of progress on listing actions; proposed rule. Federal Register 64:57533.

Table 1. 2005 estimated abundance of Christ's Indian paintbrush at distance sampling transects.

Transect	Community	Sampling method	Parameters ¹	N^2	AIC ³	ESW ⁴	LCL ⁵	UCL ⁶
01	Mountain big sagebrush	0.50 m cluster	1	91	545.4	19.8	210	437
02	Snowbed	0.25 m cluster	1	201	1126.1	10.7	480	699
		0.50 m cluster	1	99	570.3	12.5	388	750
03	Graminoid	0.50 m cluster	1	146	859.8	14.2	583	1083
04	Snowbed	0.50 m cluster	1	136	812.6	17.7	538	1034
05	Snowbed	0.50 m cluster	1	101	598.9	15.8	231	452
06	Mountain big sagebrush	0.25 m cluster	2	205	1176.3	10.7	520	883
		0.50 m cluster	1	103	613.1	16.1	343	755
07	Graminoid	0.25 m cluster	1	336	1981.6	14.5	1094	1610
		0.50 m cluster	3	77	448.4	11.6	536	1846
08	Mountain big sagebrush	0.50 m cluster	1	90	583.7	11.9	388	935
09	Graminoid	0.50 m cluster	1	141	833.1	14.8	597	1140
Sum	-	0.50 m cluster	-	-	-	-	3814	8432

¹Parameters=number of parameters.

² N =number of observations.

³AIC=Akaike's Information Criterion.

⁴ESW=effective strip width.

⁵LCL=lower confidence limit.

⁶UCL=upper confidence limit.

Table 2. 2005 estimated rangewide abundance of Christ's Indian paintbrush based on extrapolation of distance sampling data. Land area of each community is based on Moseley (1996).

Community	Land area (km ²)	Mean density (plants/m ²)			Estimated number of plants		
		LCL ¹	MEAN	UCL ²	LCL ¹	MEAN	UCL ²
Graminoid	0.15	1.4	2.4	3.4	208351	351198	494044
Mountain big sagebrush	0.16	0.8	1.3	1.8	126957	206962	286968
Snowbed	0.50	1.0	1.4	1.9	483819	709420	935021
Sum	0.81	1.1	1.7	2.3	819126	1267580	1716033

¹LCL=lower confidence limit.

²UCL=upper confidence limit.

Figure 1. Christ's Indian paintbrush distance sampling transects within EO 1. MAP NOT SHOWN.



Figure 2. Photographs of distance sampling transects established within graminoid (left), mountain big sagebrush (center), and snowbed communities (right).

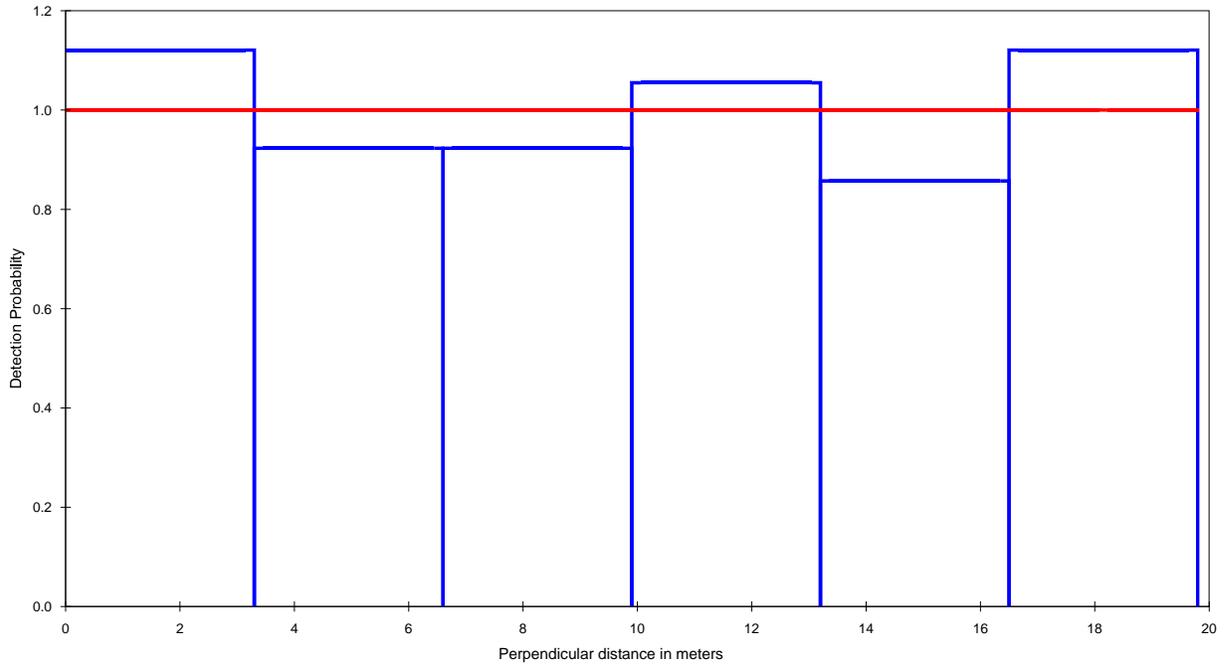


Figure 3. Probability of detecting Christ's Indian paintbrush at transect 01 at increasing distances from the line transect using the 0.5-m cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.

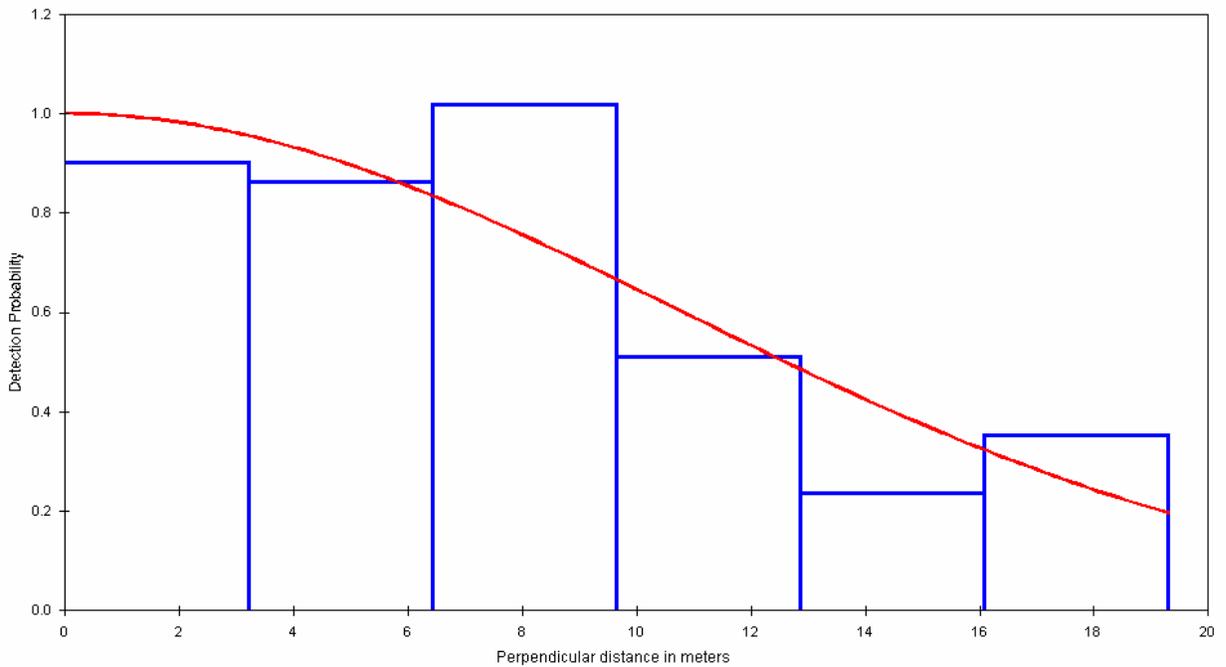
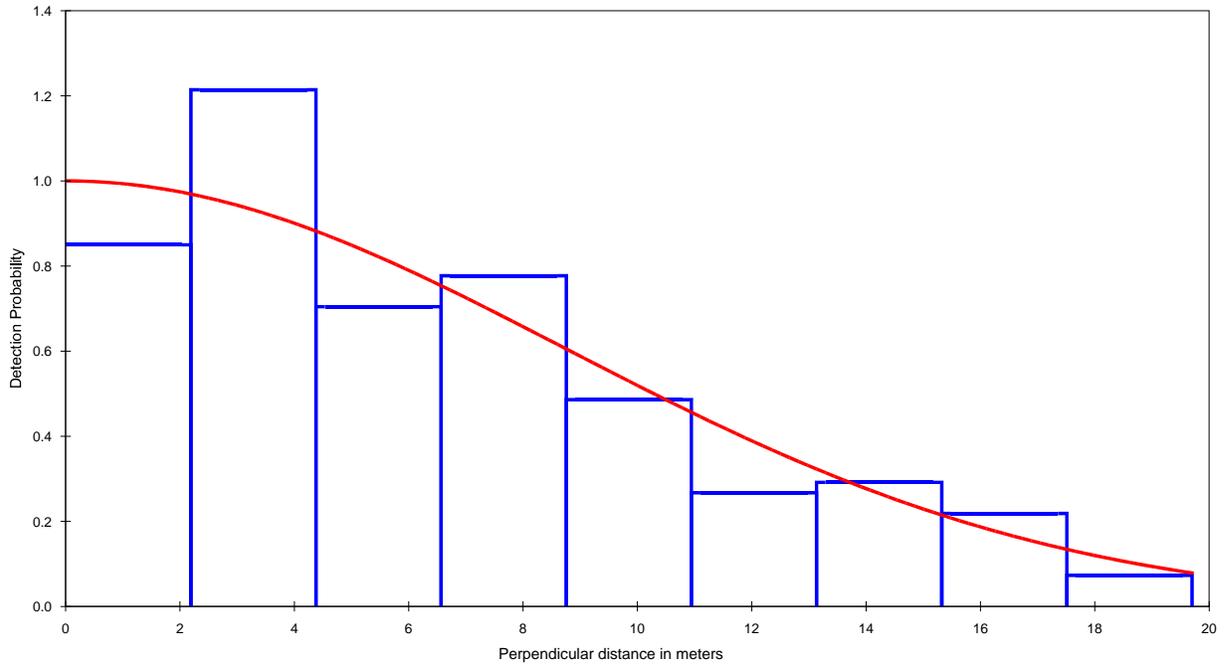


Figure 4. Probability of detecting Christ's Indian paintbrush at transect 02 at increasing distances from the line transect using the 0.25- (top) and 0.50-m (bottom) cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.

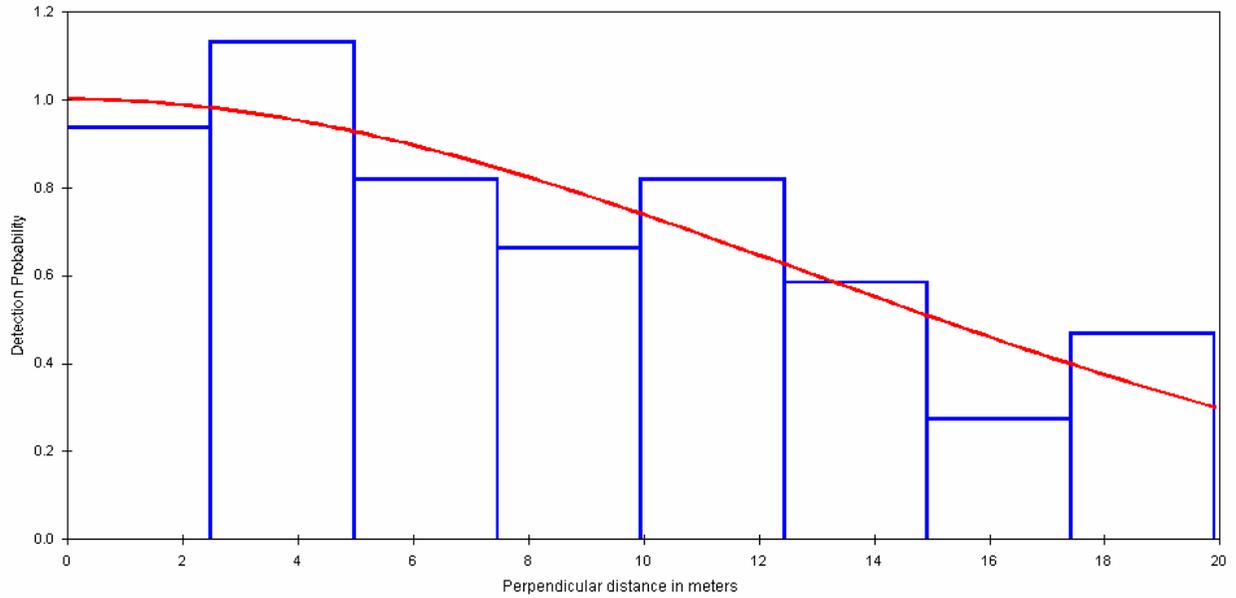


Figure 5. Probability of detecting Christ's Indian paintbrush at transect 03 at increasing distances from the line transect using the 0.50-m cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.

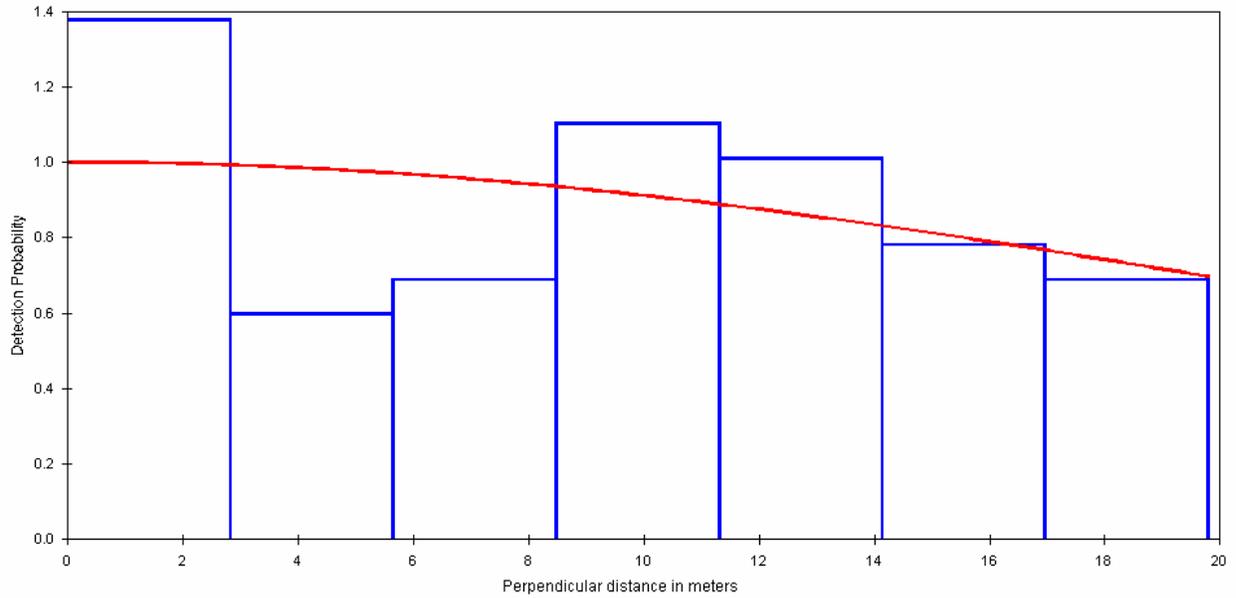


Figure 6. Probability of detecting Christ's Indian paintbrush at transect 04 at increasing distances from the line transect using the 0.50-m cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.

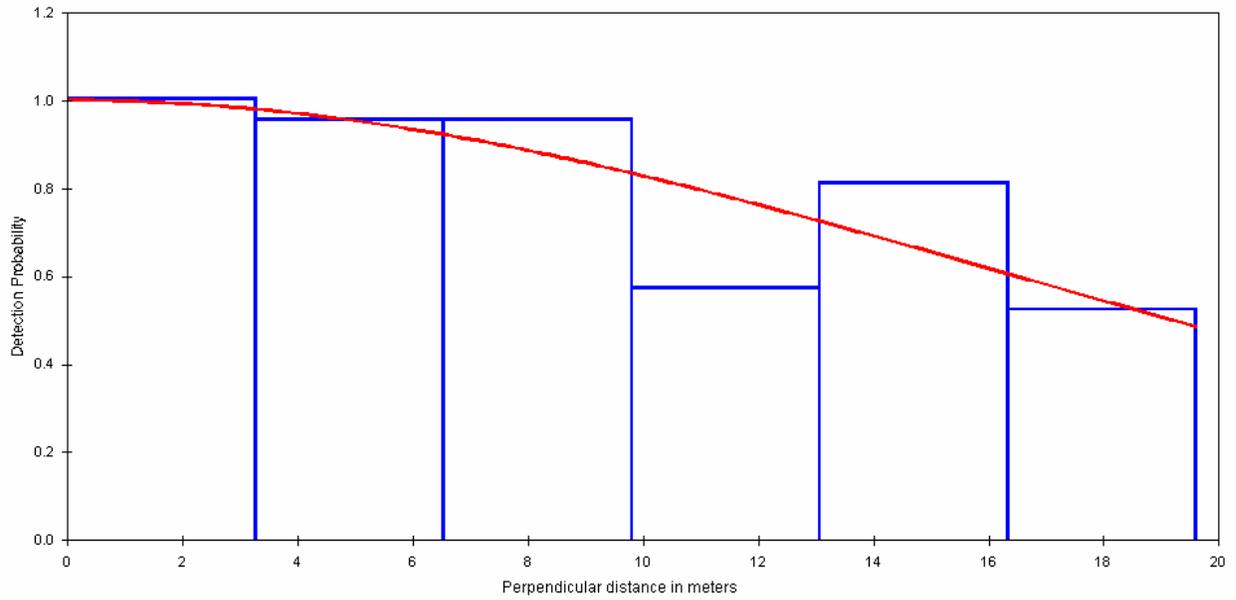


Figure 7. Probability of detecting Christ's Indian paintbrush at transect 05 at increasing distances from the line transect using the 0.50-m cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.

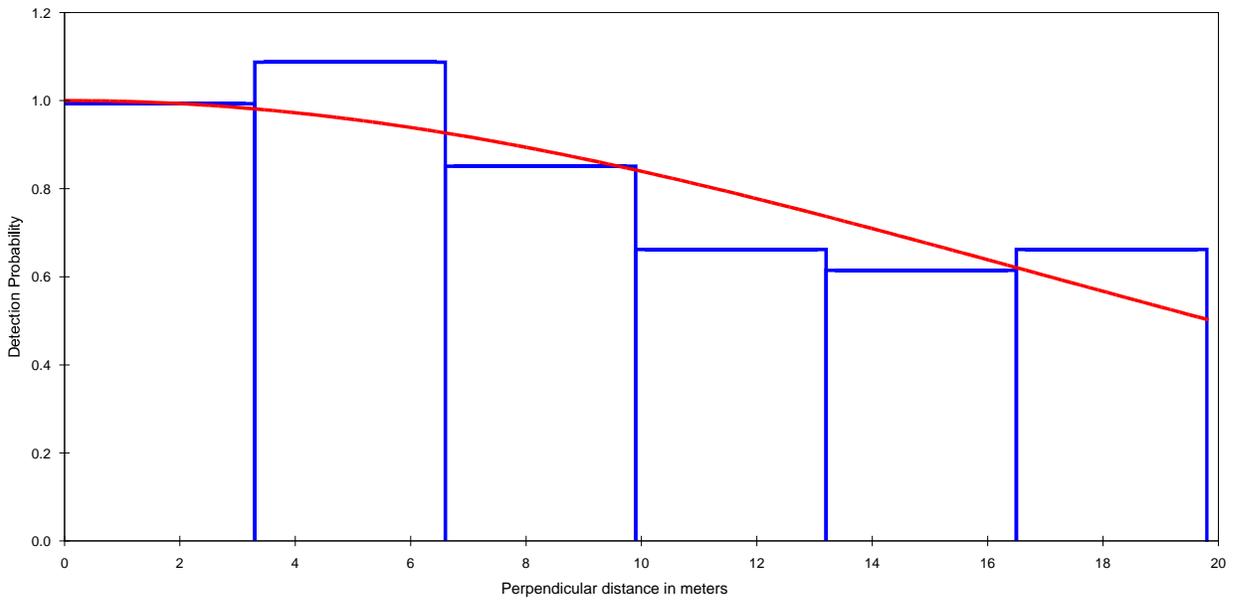
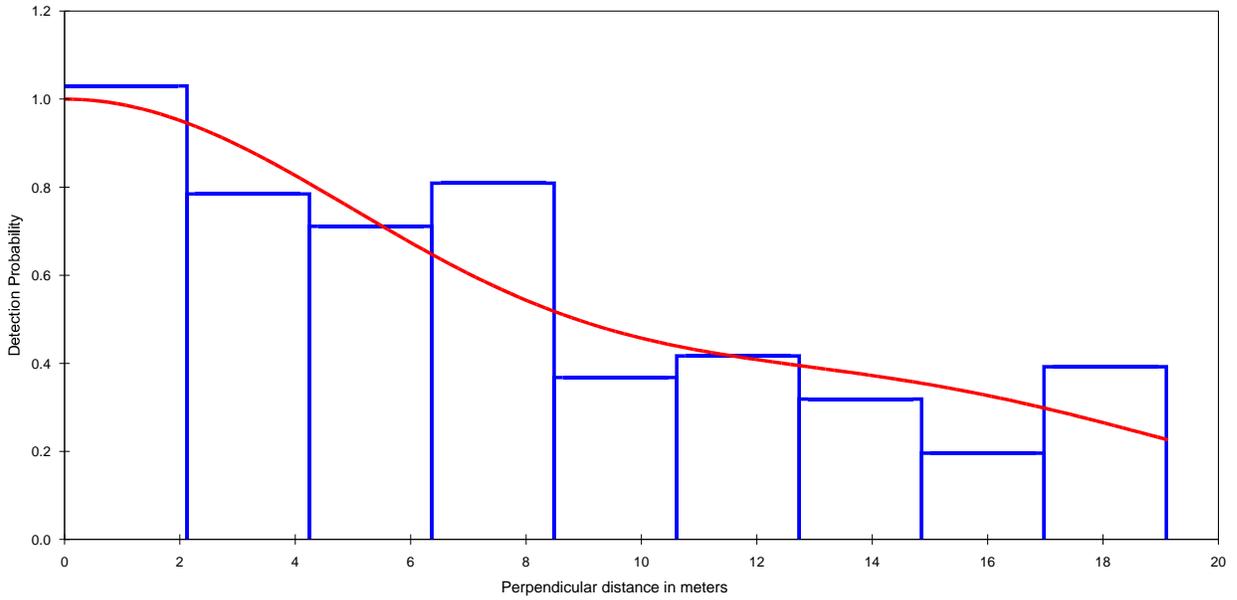


Figure 8. Probability of detecting Christ’s Indian paintbrush at transect 06 at increasing distances from the line transect using the 0.25- (top) and 0.50-m (bottom) cluster distance sampling methods. The detection function model was based on half-normal cosine parameters and no distance truncation.

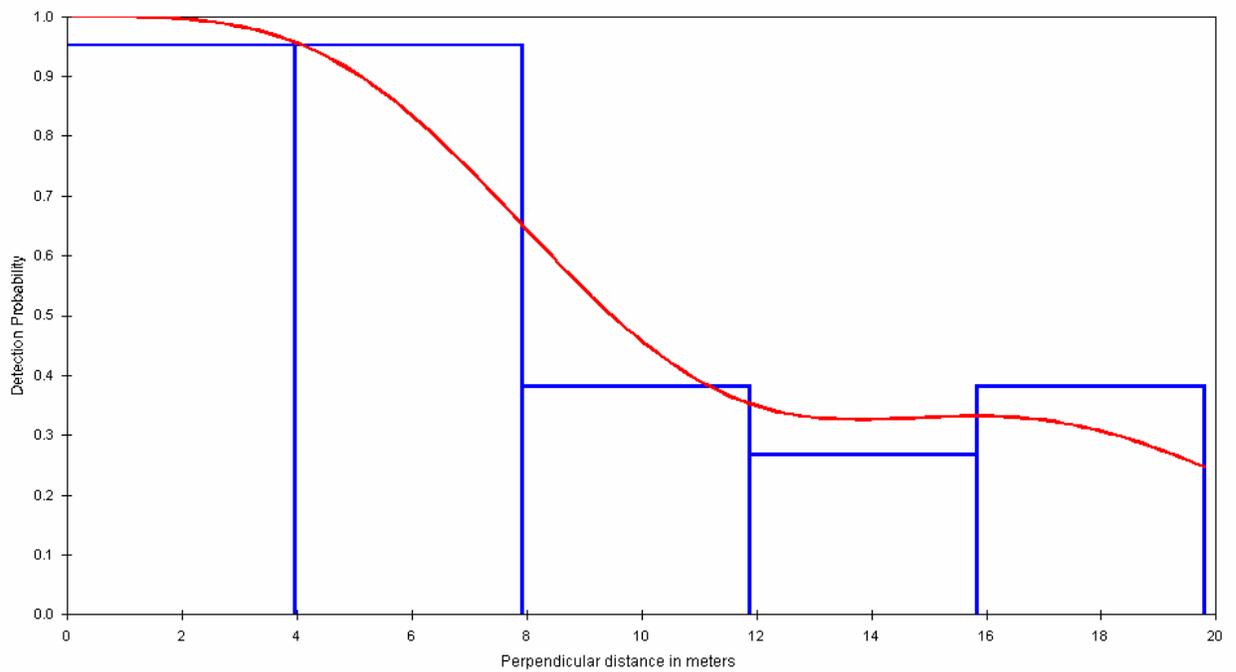
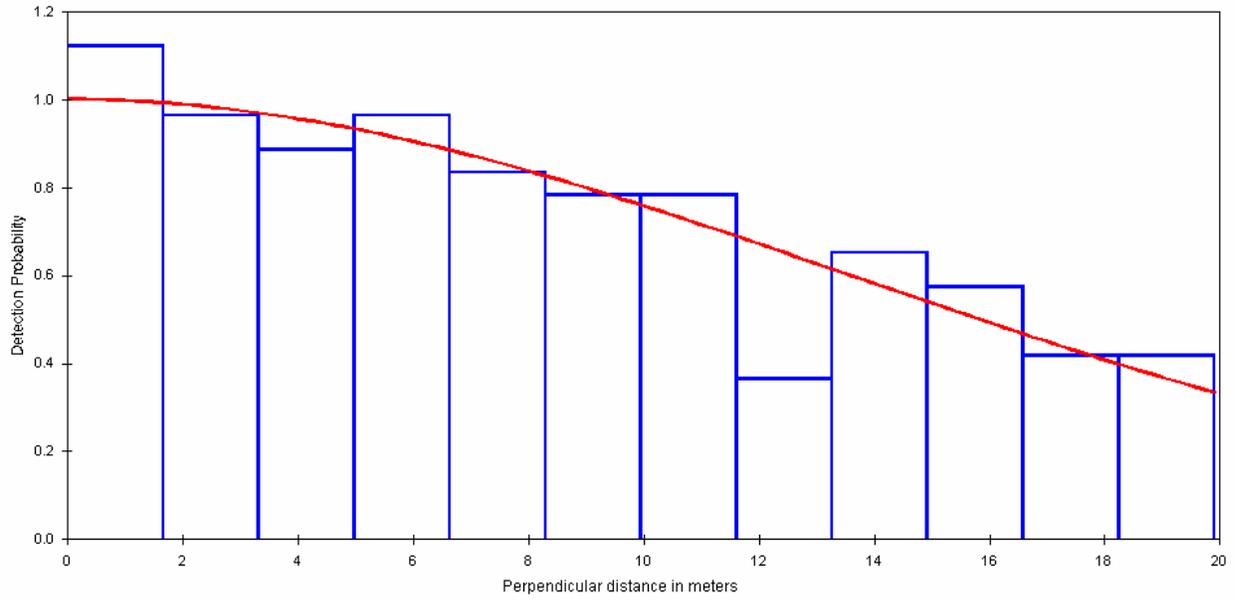


Figure 9. Probability of detecting Christ's Indian paintbrush at transect 07 at increasing distances from the line transect using the 0.25- (top) and 0.50-m (bottom) cluster distance sampling methods. The detection function model was based on half-normal cosine parameters and no distance truncation.

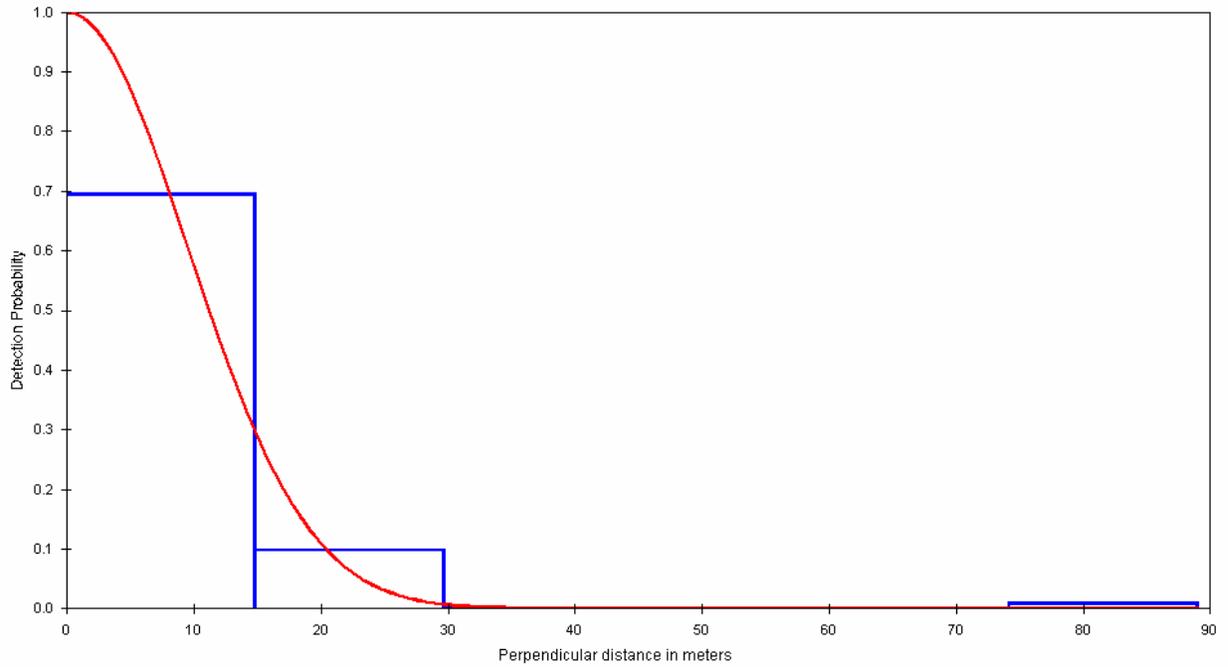


Figure 10. Probability of detecting Christ's Indian paintbrush at transect 08 at increasing distances from the line transect using the 0.50-m cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.

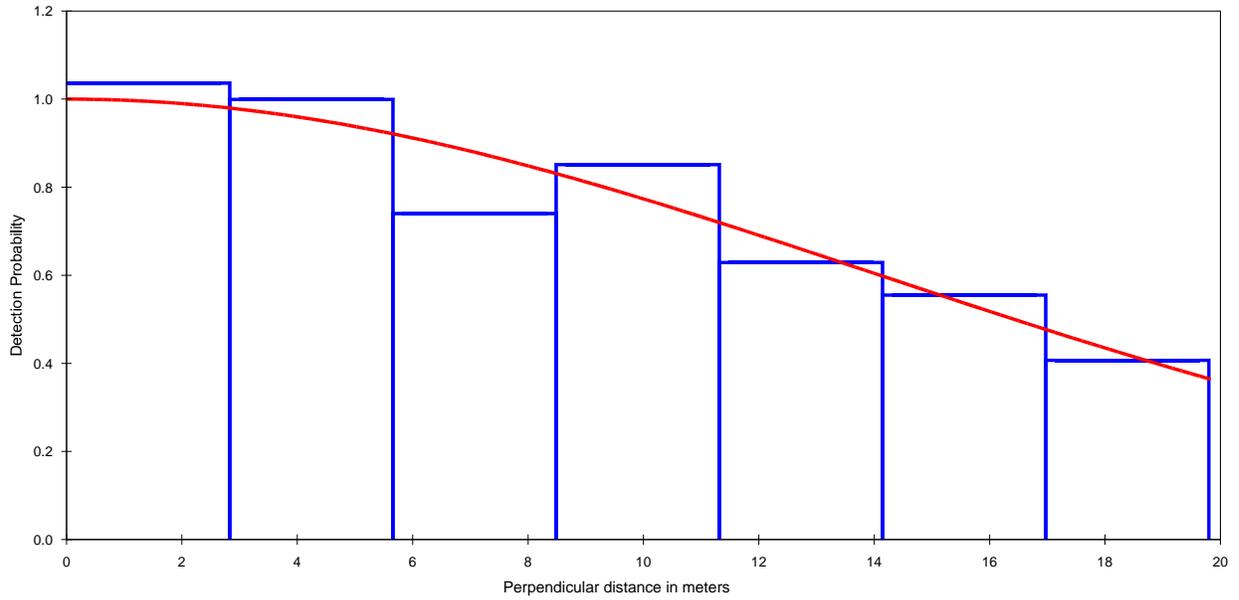


Figure 11. Probability of detecting Christ's Indian paintbrush at transect 09 at increasing distances from the line transect using the 0.50-m cluster distance sampling method. The detection function model was based on half-normal cosine parameters and no distance truncation.