National Park Service
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Northeast Region
Philadelphia, Pennsylvania

Movement and Habitat Use of Sika and White-tailed Deer on Assateague Island National Seashore, Maryland

Technical Report NPS/NER/NRTR—2009/140

ON THE COVER
Top left: Radio-collared male white-tailed deer; photo taken by Sonja Christensen.
Bottom right: Sonja Christensen with a captured sika deer; photo taken by Wendy Vreeland.

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Duane R. Diefenbach[1], Sonja A. Christensen[2]

[1] U.S. Geological Survey
Pennsylvania Cooperative Fish and Wildlife Research Unit

[2] Pennsylvania Cooperative Fish and Wildlife Research Unit
The Pennsylvania State University

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Executive Summary

This research project was conducted to describe habitat use of sika deer (*Cervus nippon*) and white-tailed deer (*Odocoileus virginianus*) and possibly attribute the effects of ungulate herbivory to specific deer species, if spatial separation in habitat use could be identified. Sturm (2007) conducted an exclosure study to document the effect of feral horse (*Equus caballus*) herbivory, deer herbivory, and horse and deer herbivory combined on plant communities. Sturm (2007) found that ungulate herbivory reduced plant species richness, evenness, and diversity in the maritime forest and affected species composition in all habitats studied. Sturm (2007) also found that herbivory on some species could be directly attributable to either horse or deer. However, the effects of sika and white-tailed deer herbivory could not be separated via an exclosure study design because of the difficulty of passively excluding one deer species but not the other.

We captured white-tailed deer and sika deer in January–March of 2006 and 2007 throughout the Maryland portion of Assateague Island. Deer were fitted with radio-collars and their survival and locations monitored via ground telemetry. Up to four locations were acquired per deer each week during early (May–June) and late (August–September) growth periods for vegetation on the island. Also, we estimated deer locations during a dormant vegetation period (November–December 2006). We used these data to estimate survival and harvest rates, document movements, and model habitat use.

We captured and fitted 50 deer with radio-collars over the course of the study. Of these 50 deer, 36 were sika and 14 were white-tailed deer. Of the 36 sika deer, 10 were harvested, three were likely killed by hunters but not recovered, and one died of natural causes while giving birth. Of the 14 white-tailed deer, three were harvested, one was illegally killed, and two were censored because of study-related mortality.

Annual survival was 0.48 (95% CI = 0.16–0.82) for male white-tailed deer, 0.74 (95% CI = 0.44–0.91) for female white-tailed deer, 0.56 (95% CI = 0.35–0.75) for male sika deer, and 0.86 (95% CI = 0.70–0.94) for female sika deer. The harvest rate was 0.12 (95% CI = 0.04–0.27) for female sika deer, 0.44 (95% CI = 0.25–0.65) for male sika deer, 0.18 (95% CI = 0.05–0.51) for female white-tailed deer, and 0.38 (95% CI = 0.10–0.78) for male white-tailed deer. Annual survival rates for both species were similar to what has been observed in other populations. Unfortunately, small sample sizes for male white-tailed deer limited inferences about harvest and survival rates, but harvest rates of females for both species were similar to other published studies. Hunting was the primary cause of mortality, and outside the hunting season survival was 0.98–1.00 for all species and sexes.

We found that the home range area of sika deer was much greater than the home range area of white-tailed deer, but failed to detect any difference between sexes or among seasons. Sika deer also made long-distance movements and left the Maryland portion of Assateague Island. No sika deer left Assateague island during our study, but we did document the dispersal of a male white-tailed deer to the mainland. In their native range, sika deer have been able to readily expand populations and occupy vacant habitat (Kaji et al. 2000; Kaji et al. 2004). The long distance movements we observed on Assateague Island, especially relative to white-tailed deer, may reflect the ability of this species to exploit food resources that may be limited in quality or

quantity, or both. However, we did not collect data to assess use of food resources by sika deer and whether this may have influenced long distance movements.

We found both species of deer were less likely to use a habitat the further it was located from cover, which was defined as tall shrub or forest vegetation. For every 10 m (32 ft) from cover each species of deer was 1.23–1.38 times less likely to use any given habitat.

Patterns in use of vegetation classes were similar across species and seasons. Relative to forest habitat, both species avoided dune herbaceous, disturbed lands, sand, and water categories. Both species neither avoided nor preferred developed herbaceous, low shrub, marsh herbaceous, and tall shrub categories compared to the forest category.

However, there were consistent differences between the two species. During spring, white-tailed deer were more likely than sika deer to use forested, tall shrub, disturbed herbaceous, and sand areas, but were less likely to use all other habitats. During summer, habitat use was similar between the two species except that white-tailed deer tended to use forested habitat more. During winter, white-tailed deer were less likely to use dune herbaceous, low shrub, and forested habitats than sika deer.

Sturm (2007) identified differential browsing on plant species between horses and deer, but his experimental design did not permit detection of differential browsing between sika and white-tailed deer. Our study of habitat use did not provide information to identify plant species that may be differentially consumed by sika and white-tailed deer based on differences in habitat use. We envision two approaches to addressing the effects of deer browsing. One approach would be further research that identifies the food habits of both deer species at the plant species level. This would be similar to food habits research conducted by Keiper (1985) and others or could involve direct observation of food consumption by both species. However, both fecal analysis and direct observation would be time-consuming and not guaranteed to identify differences.

If the goal of ungulate population management is to protect the island ecosystem, another approach involving manipulation of deer abundance and monitoring the response of plant species known to be preferentially consumed by deer would be a more direct method of assessing effects of deer herbivory (Sturm 2007). Moreover, such an approach is not predicated on detecting differences between deer species. Direct manipulation of deer abundance could be incorporated into an adaptive management program (Williams et al. 2007) and may provide greater benefits to the management of ASIS in the long term. Harvest management decisions for white-tailed deer and sika deer are made on an ongoing basis and by coupling these decisions with a vegetative monitoring program it may be possible to reduce or minimize adverse effects of ungulate herbivory. Furthermore, management of feral horses could be incorporated into the decision process.

Acknowledgments

This project was made possible by the cooperation and assistance of the National Park Service, U.S. Geological Survey, and The Pennsylvania State University. We thank the numerous individuals who contributed their hands and minds, despite many a setback, to ensure the success of this project. Of these individuals, we would like to thank the Pennsylvania State University technicians, Eric Atkins, Shawn Miller, and Tom Gieder, and the Assateague Island National Seashore technician, Erin Dorsey, for their tireless field efforts and commitment. In particular, we would like to thank Pennsylvania State University graduate assistant Wendy Vreeland for her exceptional contribution to this project from the early planning stages and implementation in the field.

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Introduction

Concerns on behalf of National Park Service resource managers regarding ungulate herbivory on Assateague Island National Seashore (ASIS) prompted this descriptive study on the population ecology of both the native white-tailed deer (*Odocoileus virginianus*) and the nonnative sika deer (*Cervus nippon*) that inhabit the island. Assateague Island is a fragile and dynamic barrier island ecosystem that not only hosts white-tailed and sika deer, but also feral horses (*Equus caballus*). Herbivory by horses poses a threat to the island's vegetative communities (Furbish and Albano 1994).

To document the effect of ungulate herbivory on Assateague Island, Sturm (2007) conducted an exclosure study to document the effect of no ungulate herbivory, deer-only, and horse and deer herbivory on plant communities. Sturm (2007) found that ungulate herbivory reduced plant species richness, evenness, and diversity in the maritime forest and affected species composition in all habitats studied. Sturm (2007) also found that herbivory on some species could be directly attributable to either horse or deer. However, the effects of sika and white-tailed deer herbivory are not easily separated via exclosure work because of the difficulty of passively excluding one deer species but not the other. Thus, this research project was conducted to try and determine whether differences in habitat use between sika and white-tailed deer existed and could be used to identify species-specific effects of deer herbivory.

Deer overabundance only can be defined relative to the management objectives for a particular ecosystem and typically is observed when deer can be linked to the interference or limitation of another valued species (Healy et al. 1997). Deer browsing may adversely affect a variety of species from both plant and animal communities and several studies have demonstrated negative effects in forest ecosystems (Waller and Alverson 1997). Conversely, nonnative invasive plant species may thrive under high levels of deer herbivory in forest ecosystems, further stressing native plant communities (Sturm 2007; Eschtruth and Battles 2008). On Assateague Island, even limited ungulate herbivory may have substantial effects because there are relatively few plant species that are adapted to an ecosystem that is easily disturbed by wind and ocean storms. For example, the seabeach amaranth (*Amaranthus pumilus*) is a federally listed plant species on ASIS which is particularly vulnerable to herbivory (Lea et al. 2003; Sturm 2008a, b).

Sika deer are native to Japan, Taiwan, and the east-Asia mainland, but have been introduced around the world (Eyler 2001). In both native ranges and introduced ranges, sika deer prefer forested areas, but are highly adaptable to a variety of habitats (Feldhamer 1980). In North America, free-ranging populations of sika deer exist in Texas, Dorchester County, Maryland, and on Assateague Island (Eyler 2001). In regions such as New Zealand and the United Kingdom, sika deer are rapidly expanding their ranges and possibly competing and/or hybridizing with other ungulates (Davidson 1973; Manchester and Bullock 2000; Ward 2005). Two populations of sika deer, one in Japan and the other on James Island, Maryland, experienced a large population increase followed by a population crash (Christian et al. 1960; Kaji et al. 2004). In both cases, a combination of environmental factors (primarily weather conditions and available food resources) was the suspected cause of the population crash (Christian et al. 1960; Kaji et al. 2004). As with high-density populations of white-tailed deer, abundant sika deer have been found to negatively affect forest regeneration (Nomiya et al. 2002; Tsujino and Yumoto 2004).

Seven sika deer were introduced to ASIS in 1923 from a captive population in Cambridge, Maryland (Flyger 1960). These deer were presumably from the same genetic line that contributed to the James Island and Dorchester County populations in Maryland (Flyger 1960). Sika deer have since expanded throughout the island and have become a popular hunted species on Assateague Island. Management of white-tailed and sika deer on Assateague Island occurs through archery, shotgun, and muzzleloader hunting seasons.

Numerous studies have described habitat use and movements for white-tailed deer, indicating a wide range of habitats are suitable for white-tailed deer (e.g. Rongstad and Tester 1969; Beier and McCullough 1990). More recently, research has focused on the effect this species has on plant species and communities (McShea and Rappole 1997; Waller and Alverson 1997; Russell et al. 2001; Liang and Seagle 2002; Horsely et al. 2003). However, despite the abundance of literature on white-tailed deer, relatively little information exits on white-tailed deer in northeast Atlantic coastal environments (Cypher and Cypher 1988). O'Connell (1989) studied white-tailed deer on Fire Island, New York, but this island is inhabited by humans and deer have access to a wider variety of food resources than would be typically found on a barrier island.

Research on Assateague Island deer populations primarily took place in the 1980s when a series of projects estimated the abundance and studied the ecology of white-tailed deer and sika deer (Keiper and Hunter 1982; Davidson and Crow 1983; Keiper and Tzilkowski 1983; Tzilkowski and Brown 1984; Keiper 1985). At that time sika deer were estimated to outnumber white-tailed deer by approximately 4:1 (Keiper and Hunter 1982; Keiper and Tzilkowski 1983; Tzilkowski and Brown 1984). These studies also described habitat use by both species, using visual observation data and pellet-composition analysis, which indicated diet overlap (Keiper and Tzilkowski 1983; Tzilkowski and Brown 1984).

Davidson and Crow (1983) sampled sika deer and white-tailed deer from Dorchester County, MD, and Chincoteague National Wildlife Refuge (Assateague Island), and determined that sika deer had better body condition indices compared to white-tailed deer, particularly from Assateague Island. Sika deer are suspected to compete with white-tailed deer and exclude them from resources (Harmel 1980), but sika deer also may be better able to exploit resources on island ecosystems.

Hunting occurred on Assateague Island before it was designated a national seashore and hunting continues to be used as the method to manage sika and white-tailed deer populations on ASIS today. Population abundance was estimated for both species and overall harvest rates could be estimated in combination with harvest data collected during hunts; however, sex-specific harvest rates are unknown. The relatively large population of sika deer is potentially problematic because they have no natural predators, are exotic, and are known to be aggressive competitors with other deer species (Davidson 1973).

During the 2004–2005 deer hunt on Assateague, 155 deer were harvested from the Maryland portion of the island, 90.3% of which were sika deer because of harvest restrictions on white-tailed deer (NPS report 2005). White-tailed deer are native to Assateague Island but populations were estimated at approximately 113 animals (3 white-tailed deer per 100 ha [247 ac]) for the Maryland portion of the island (Sturm 2004). Previous studies have indicated a consistently lower and slightly declining white-tailed deer population on ASIS in comparison to the sika population, such that harvest restrictions were implemented to potentially allow a population increase (Tzilkowski and Brown 1984; Keiper 1985; Sturm 2004; MD DNR 2005). Sika deer populations, on the other hand, have been determined to be relatively abundant, with a recent population estimate of 368 animals (10 sika deer per 100 ha [247 ac]; Sturm 2004) on the Maryland portion of Assateague Island. Over the years, increased bag limits and season lengths have allowed greater opportunity for harvest of sika deer. In turn, harvest regulations for sika deer have attempted to increase the proportion of the harvest composed of females by requiring harvest of an antlerless deer before a second antlered deer may be harvested.

This study radio-collared sika deer and white-tailed deer to study their habitat use, movements, and survival and harvest rates on ASIS. Deer were captured in winter (January–April) and intensive radio-telemetry occurred in spring (May–June), summer (August–September), and winter (November–December) to document habitat use and movements. Weekly monitoring of the fates of radio-collared deer throughout the rest of the year provided information on annual survival and harvest rates during the hunting season. The primary objective of this study was to determine if differences in habitat use could be detected and described for sika deer and white-tailed deer.

Study Area

Assateague Island is a barrier island located on the Atlantic coast of Maryland and Virginia (Figure 1). The island is 59.2 km (approx. 37 mi) in length and is approximately 7,296 ha (18,029 ac) in area. This study focused on the Maryland portion of the island under the administration of the National Park Service, designated as Assateague Island National Seashore (3,234 ha [7,991 ac]), and the Maryland Park Service, Assateague State Park (368 ha [909 ac]). This portion of the island is approximately 35.5 km (22 mi) long from the north inlet to the state line; hereafter, we refer to this portion of the island as ASIS. The southern 3,694 ha (9,128 ac) of the island are managed by the U.S. Fish and Wildlife Service as the Chincoteague National Wildlife Refuge. The refuge portion of the island lies primarily within the state of Virginia.

The warmest month is July, when the average high and low temperatures are 28.9^{o}C (84^{o}F) and 19.4^{o}C (67^{o}F), respectively. The coldest month is January, when the average high and low temperatures are 6.7^{o}C (44^{o}F) and -2.2^{o}C (28^{o}F), respectively. Average monthly precipitation ranges from 7.2 cm (2.8 in) in June to 11.0 cm (4.3 in) in January.

Camping is allowed year round at designated camping sites and approximately eight structures exist on ASIS but none are permanent human dwellings. No agricultural activity occurs on ASIS and vegetation is typical of barrier islands of the east coast of North America. The ocean side beach is the furthest eastern component, followed by a primary dune system, an interdune meadow, and then a secondary set of dunes. The western side of the island typically contains woody shrubs and forested areas where it meets the salt marsh.

The most common plant species of the primary dunes is American beach grass (*Ammophila breviligulata*). The inner dune complex consists of American three-square (*Schoenoplectus pugens*) and coastal fimbry (*Fimbristylis castanea*), with bayberry (*Morella pensylvanica*) and waxmyrtle (*Morella cerifera*) at slightly higher elevations. The forest consists of loblolly pine (*Pinus taeda*) and red maple (*Acer rubrum*) with an understory primarily of poison ivy (*Rhus toxicodendron*), green-briar (*Smilax*), waxmyrtle, and grasses and forbs. Along the bay edge of the forest a shrub zone occurs that is primarily composed of waxmyrtle and marsh elder (*Iva fruscens*). The high salt marsh is interspersed with shrubs but primarily composed of salt hay (*Spartina patens*) and spikegrass (*Distichlis spicata*). The low salt marsh occurs only a few inches in elevation below the tall grass marsh but is composed of saltwater cordgrass (*Spartina alterniflora*). Most of the low salt marsh community is vegetated by saltwater cordgrass.

Figure 1. Map of Assateague Island indicating the location of Assateague Island National Seashore, Chincoteague National Wildlife Refuge, and Assateague State Park.

Methods

Deer Capture and Handling

We captured white-tailed and sika deer in January–March of 2006 and 2007 after the conclusion of the hunting season using modified Clover traps (Clover 1956), rocket nets (Beringer et al. 1996), and a chemical immobilant administered via a dart gun. Protocols were approved by The Pennsylvania State University Institutional Animal Care and Use Committee (IACUC No. 21758). We captured deer throughout the island and all captured deer were ear-tagged (Original Temple Tag, Temple, TX, USA; use of trade names does not imply endorsement by the federal government).

Deer captured in Clover traps were physically restrained, deer captured in rocket nets were administered xylazine hydrochloride intramuscularly (5.0 mg/kg body mass), and deer chemically immobilized were administered intramuscularly a mixture of ketamine hydrochloride (7.5 mg/kg body mass) and xylazine hydrochloride (1.5 mg/kg body mass). Tolazoline was administered intramuscularly (4.0 mg/kg body mass) to reverse the effects of the xylazine hydrochloride.

Both species and all sex and age (<1 year old, $\geq$1 year old) groups were fitted with a radio-collar (Advanced Telemetry Systems, Inc., Isanti, MN, USA). However, one female sika deer was fitted with a collar that obtained locations using global positioning system (GPS) satellites and transmitted data via satellite to a web-based interface. Data from this deer were used only for monitoring survival and were not used in movement and habitat use analyses. Radio-collars fitted to males and juveniles were equipped with an elastic, expandable section to accommodated changes in neck circumference. Deer that were captured but not radio-collared were ear-tagged and released; however, we did not use data from these deer in the analyses presented in this report because the movements and fates of these deer were not known unless they were recovered in the harvest or otherwise found dead.

Deer Monitoring

We monitored the locations of radio-collared deer via ground telemetry from time of capture through September 2007 and monitored survival and harvest through February 2008. Radio-collars transmitted signals via a faster pulse rate if they did not move for six hours. If such a signal was detected, we located the radio-collar as soon as possible and if the animal was found dead the carcass was examined to ascertain cause of death.

We obtained locations based on a systematic schedule between the hours of 4a.m. and 11p.m. (Appendix A). We sampled deer locations in this manner to minimize the effects of autocorrelation (Otis and White 1999). Up to four locations were acquired per deer each week during early (May–June) and late (August–September) growth periods for vegetation on the island. Also, we estimated deer locations during a dormant vegetation period (November–December 2006). Hereafter, we refer to these growth periods as the spring (May–June), summer (August–September), and winter (November–December) seasons. During the remainder of the year, we obtained locations as time and personnel allowed and so that survival was monitored at least every five days.

We used software LOAS (Location of a Signal, Ecological Software Solutions, Switzerland) to triangulate an estimated deer location with a 95% error ellipse of <1.0 ha (2.47 ac) using Andrew's estimator. We used the intersection of ≥3 telemetry bearings collected within 20 minutes of each other to reduce location error caused by animal movement.

Estimating Survival and Harvest Rates

We used known-fate models in software MARK (White and Burnham 1999) to estimate annual survival rates for white-tailed and sika deer and assess whether differences existed among sex, species, and age classes or over time. We developed models a priori and always included species and sex variables in models because harvest (season and bag limit) regulations differed by these groups (Table 1). All models combined data from both years (2006–2007 and 2007–2008) in which deer were monitored because of limited sample sizes. We included captured deer in the analysis if they were alive 30 days post capture and until they may have left ASIS. If a deer was classified as a juvenile upon capture in year 1 (<1 year old) it became an adult (≥1 year old) the following year on 1 February. Because hunting mortality often comprises the majority of cause-specific mortality in a free-ranging deer population and both species of deer were hunted on ASIS, we developed annual survival models in which survival differed between the hunting and non-hunting seasons.

We used Akaike's Information Criterion adjusted for small sample size (AICc), to select the most parsimonious model which best explained annual survival or harvest rates (Burnham and Anderson 2002). We estimated variances for survival and harvest rates using the delta method (Oehlert 1992).

We developed annual survival models in which survival varied at monthly intervals with the year beginning on 1 February. Also, we created models in which survival was constant during the non-hunting months (February–August) and different, but constant, during the hunting months (September–January). We estimated harvest rates on a monthly basis for five months beginning in September, which corresponded with the regulated hunting seasons.

Estimating Movement

For each two-month period of intensive locations (see *Deer monitoring*), we calculated the average distance between all possible pairs of locations for each individual deer for each season (Diefenbach et al. 2006) using the Multiresponse Permutation Procedure (MRPP) in program BLOSSOM (Cade and Richards 2005). This measure of dispersion is comparable to a home range estimator because it can be interpreted as approximately the radius of a home range if the home range has a single activity center (Conner and Leopold 2001). Deer with larger home ranges will have larger average distances between all possible pairs of locations.

We used this measure of dispersion to make inferences about deer movements within a home range rather than estimating a home range boundary with home range estimators (e.g., Seaman et al. 1998). Furthermore, home range boundaries provide no information about the distribution of locations within the home range. We used the average distance among all possible pairs of locations in a general linear model (PROC GLM, Statistical Analysis System, SAS, Inc., Cary, NC, USA) to test for differences among species, sex, age, and season.

Table 1. Notation, description, and number of parameters for known fate survival and harvest rate models used with data collected on sika and white-tailed deer captured on Assateague Island National Seashore, 2006–2007.

Notation	Analysis[a]	Description	k[b]
S(nonhunt/hunt*species*sex)	S	Survival was constant during Feb–Aug and different but constant during Sep–Jan, and differed by species and sex.	8
S(nonhunt/hunt*species*sex*age)	S	Survival was constant during Feb–Aug and different but constant during Sep–Jan, and differed by species, age, and sex.	16
H(month*species)	H	Harvest rate differs by species over time.	24
S(month*species*sex) H(month*species*sex)	S,H	Survival/harvest differs by species and sex over time.	48
S(month*species*sex*age) H(month*species*sex*age)	S,H	Survival/harvest differs by species and sex and age over time.	94

[a] Analysis where model used: S = annual survival rate, H = harvest rate.
[b] No. parameters in model.

Estimating Habitat Use

We modeled habitat use for both species of deer using a resource selection function (RSF) created from a use-availability design (Manly et al. 2002). To define available habitat we used a land-cover map provided by ASIS staff that could be manipulated in GIS (ArcView 3.2, Environmental Systems Research Institute. Redlands, California, USA). Because Assateague Island is separated from the mainland by a wide, natural water barrier, available habitat was defined by the perimeter of the island itself. This scale of resource selection analysis assumes the available area is the same for all deer (Thomas and Taylor 2006).

We divided the study area into approximately 360,000 resource units, each 10×10 m (36×36 ft). Each resource unit was assigned a vegetative land cover category (Sand, Low Shrub, Marsh Herbaceous, Tall Shrub, Dune Herbaceous, Forest, Disturbed Lands, Water, and Developed Herbaceous; Figures 2–5) based on the land cover type that covered the greatest area within each resource unit (Table 2). The land cover categories we used in this study represent a consolidation of cover types identified in the ASIS land cover map (TNC 1995).

Any classification of land cover is necessarily subjective but should be relevant to the research question of interest, the landscape context in which the research is being conducted, and the species being studied (Manly et al. 2002). In addition, there are some considerations with respect to the statistical analysis used, because if there are many different classes of habitat of which some represent a small proportion of the area (e.g., <3%), then it is unlikely the analysis is going to be able to accurately measure use of these habitats. Most studies of habitat use include 5–10 categories of habitat (e.g., Murphy et al. 1985; Manly et al. 2002).

We reduced the land cover types in consultation with M. Sturm (Ecologist, ASIS) to represent a set of habitat types relevant to white-tailed deer and sika deer on Assateague Island. We included

Figure 2. Vegetative land cover types used to model habitat use by sika and white-tailed deer for the northernmost portion of Assateague Island National Seashore, Maryland, USA.

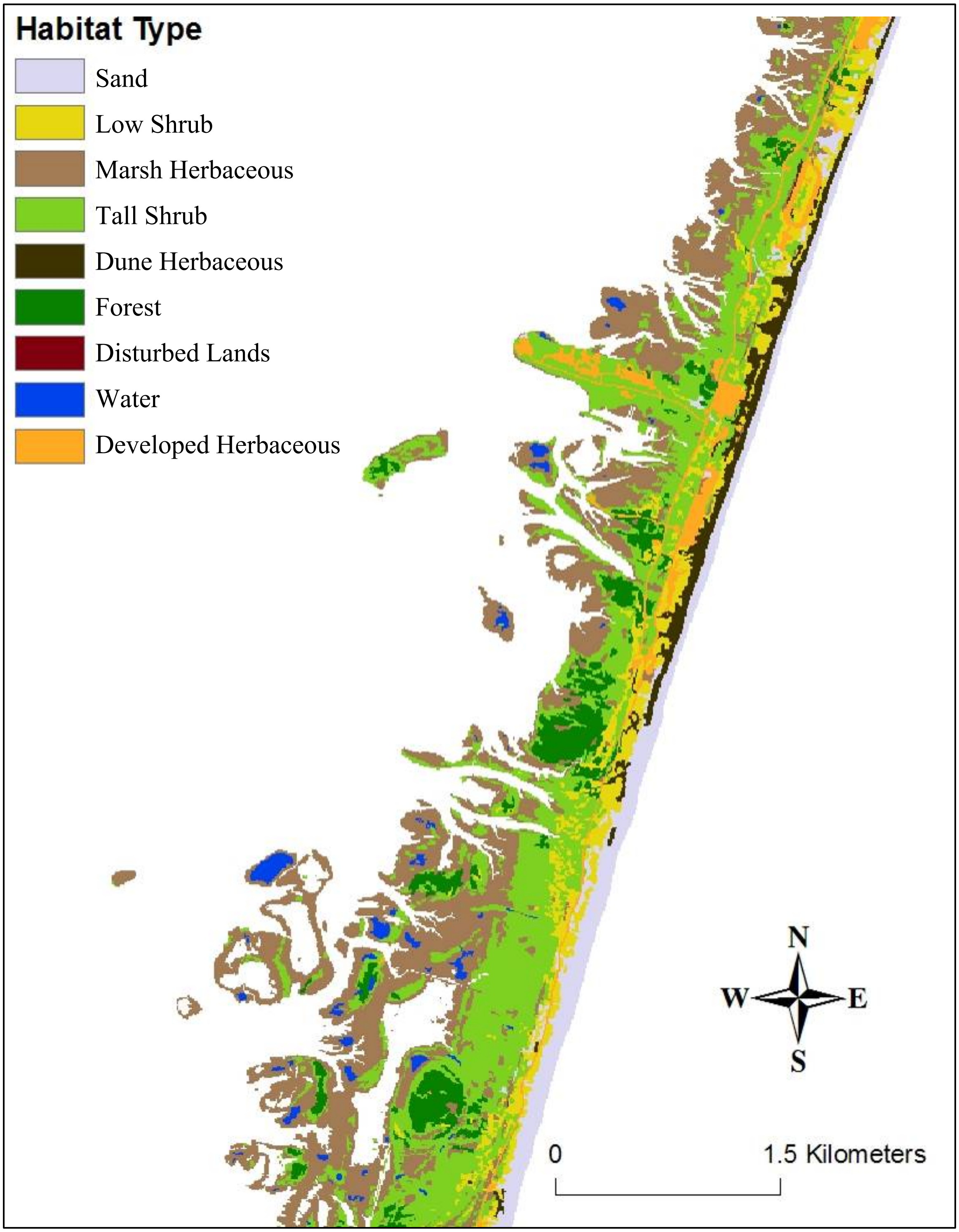

Figure 3. Vegetative land cover types used to model habitat use by sika and white-tailed deer immediately south of the northernmost portion of Assateague Island National Seashore, Maryland, USA.

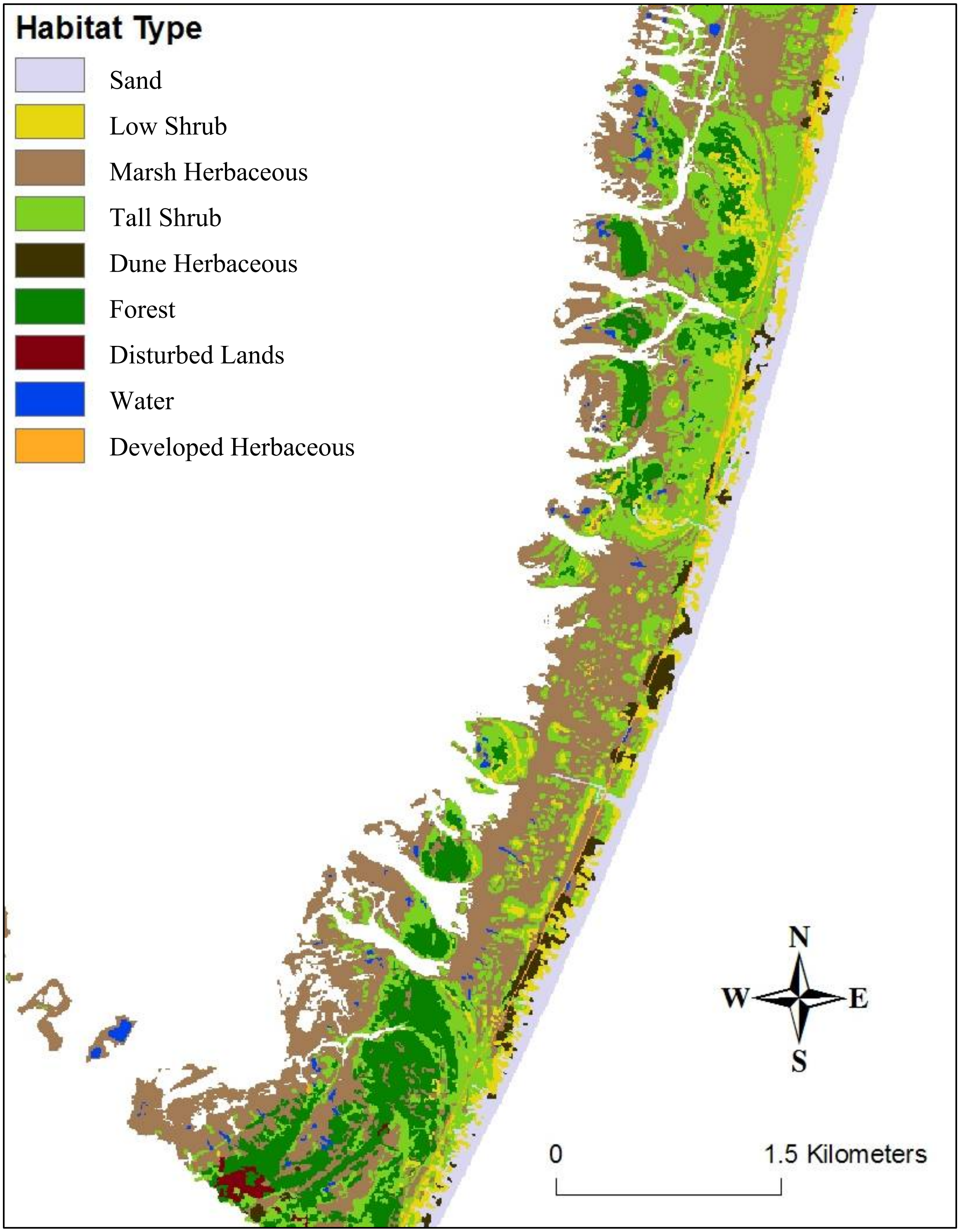

Figure 4. Vegetative land cover types used to model habitat use by sika and white-tailed deer immediately north of the southernmost portion of Assateague Island National Seashore, Maryland, USA.

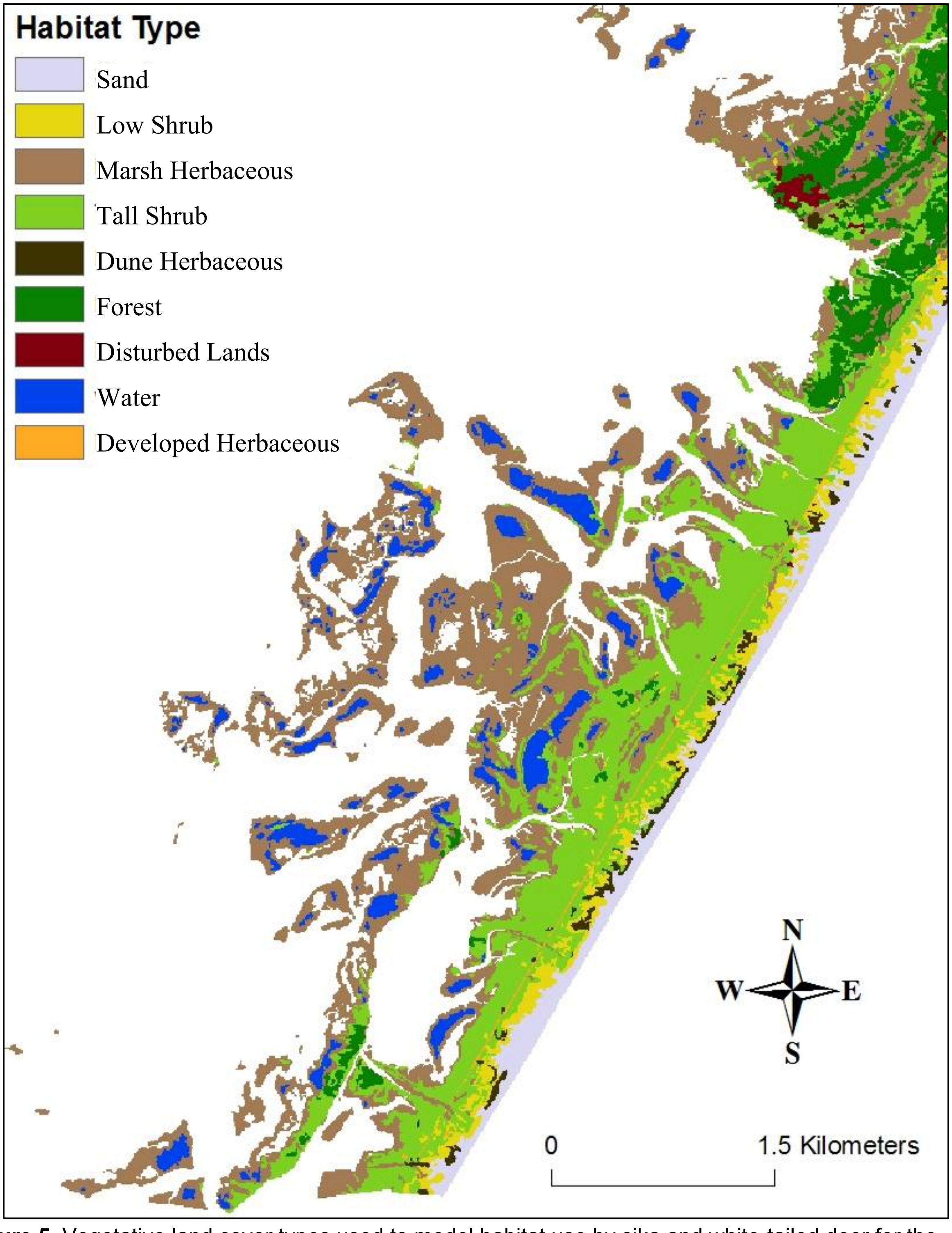

Figure 5. Vegetative land cover types used to model habitat use by sika and white-tailed deer for the southernmost portion of Assateague Island National Seashore, Maryland, USA.

Table 2. Vegetative cover types (and dominant species) as defined by the ASIS vegetative mapping program and corresponding habitat types as defined for classifying habitat use of sika and white-tailed deer in this study.

Vegetative cover type	Habitat category	Habitat type
Naturally occurring unvegetated areas	1	Sand
Dwarf-shrubland – *Hudsonia tomentosa, Panicum amarum, P. amarulum*	2	Low Shrub
Shrubland – *Morella pensylvanica, Diodia teres*	2	Low Shrub
Marsh herbaceous – *Schoenoplectus pungens, Fimbristylis castanea*	3	Marsh Herbaceous
Marsh herbaceous – *Phragmites australis*	3	Marsh Herbaceous
Marsh herbaceous – *Juncus roemerianus*	3	Marsh Herbaceous
Marsh herbaceous – *Typha angustifolia - Hibiscus moscheutos*	3	Marsh Herbaceous
Marsh herbaceous – *Spartina patens, Distichlis spicata, Borrichia frutescens*	3	Marsh Herbaceous
Marsh herbaceous – *Salicornia* spp., *Sarcocornia perennis, Spartina alterniflora*	3	Marsh Herbaceous
Algae, no data, or unidentified marsh herbaceous	3	Marsh Herbaceous
Shrubland tall shrub – *Baccharis halimifolia, Iva frutescens, Spartina patens*	4	Tall Shrub
Shrubland tall shrub – *Morella cerifera, Baccharis halimifolia, Spartina patens*	4	Tall Shrub
Shrubland tall shrub – *Smilax glauca, Toxicodendron radicans*	4	Tall Shrub
Shrubland tall shrub – *Morella cerifera, M. pensylvanica, Vaccinium corymbosum*	4	Tall Shrub
Sparse shrubland tall shrub – *Myrica pensylvanica, Schizachyrium scoparium, Eupatorium hyssopifolium*	4	Tall Shrub
Forest tall shrub – *Prunus serotina, Myrica cerifera, Smilax rotundifolia*	4	Tall Shrub
Shrubland high shrub – *Morella cerifera, Hydrocotyle* spp.	4	Tall Shrub
Dune herbaceous vegetation – *Panicum virgatum, Spartina patens*	5	Dune Herbaceous
Dune herbaceous vegetation – *Ammophila breviligulata, Panicum amarum, P. amarulum*	5	Dune Herbaceous
Dune herbaceous vegetation – *Spartina patens, Schoenoplectus pungens, Solidago sempervirens*	5	Dune Herbaceous
Forest – *Pinus taeda, Hudsonia tomentosa*	6	Forest
Forest – *Pinus taeda, Morella cerifera, Osmunda regalis, Vitis rotundifolia*	6	Forest
Forest – *Acer rubrum*	6	Forest
Built-up areas (unvegetated)	7	Disturbed Lands
Water	8	Water
Dead vegetation	9	Developed herbaceous
Undifferentiated dry grasses	9	Developed herbaceous

sand, disturbed lands, and water habitat types because they each represented 1–12% of the study area. Forest, tall shrub, and low shrub habitats all provided visual and thermal cover for deer but contained sufficiently different habitat structure and plant species composition to be separate categories. The dune herbaceous and marsh herbaceous habitats represented habitats that contained no visual or thermal cover for deer and contained different plant communities.

For each resource unit we calculated the nearest distance to edge, which we defined as the nearest boundary of the combined Tall Shrub and Forest categories (Figures 6–9). Also, we calculated a distance to nearest cover and we defined cover as areas classified as Tall Shrub or Forest (Figures 10–13).

Of the available resource units, we extracted every 25th resource unit (4%) to create a dataset of available habitat. For each deer, a resource unit was defined as "used" and included in the dataset if $\geq$1 estimated location fell within the boundaries of the resource unit. A given resource unit should be classified as either used or available, but because few resource units (<1%) were classified as both used and available this had little effect on parameter estimates (Manly et al. 2002), so we did not attempt to prevent this from occurring.

We incorporated error in estimating the location of deer in the habitat use analysis using methods described by Samuel and Kenow (1992). We used empirical estimates of error in estimating azimuths to the known location of a signal (SD = 11.71) by estimating azimuths to radio-collars of dead deer and comparing them to the coordinates obtained from a global positioning system. For each deer location, we generated each of 49 additional locations by multiplying a unit-normal random variate (truncated to the interval [-2,2]) by 11.71 and adding this value to each azimuth. If all 50 locations (the estimated location and 49 simulated locations) occurred inside the study area boundary then each of the 50 locations was assigned a weight of 1/50. Otherwise, the weight was the inverse of the number of locations that occurred inside the study area boundary.

For each deer and season we used logistic regression (PROC LOGISTIC, Statistical Analysis System, SAS Institute, Inc., Cary, NC, USA) to estimate parameters of the RSF. We estimated the probability a resource unit was used weighted by the sum of locations that occurred in each resource unit. We calculated AICc for each model (see Table 3) and selected the model that had the lowest AICc value summed across all deer for a given species.

When we used Vegclass in the model the Forest cover type was the reference value. Consequently, if the coefficient for a given Vegclass was <0 then that habitat type was used less relative to forest habitat. Similarly, when the coefficient for a given Vegclass was >0 that habitat type was used more relative to forest habitat.

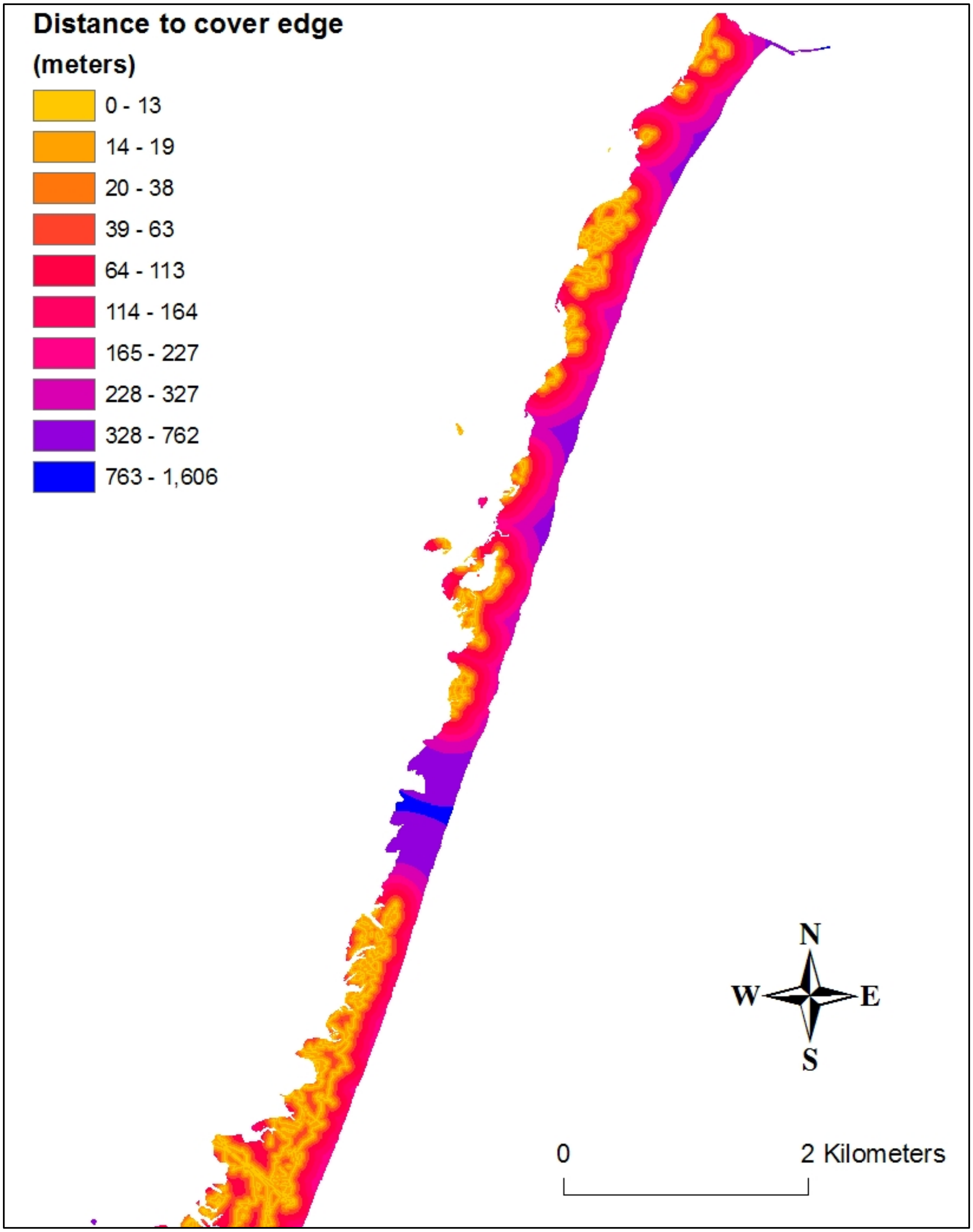

Figure 6. Map of the distance to edge (border of the combined tall shrub and forest habitat types) for the northernmost portion of Assateague Island National Seashore, Maryland, USA.

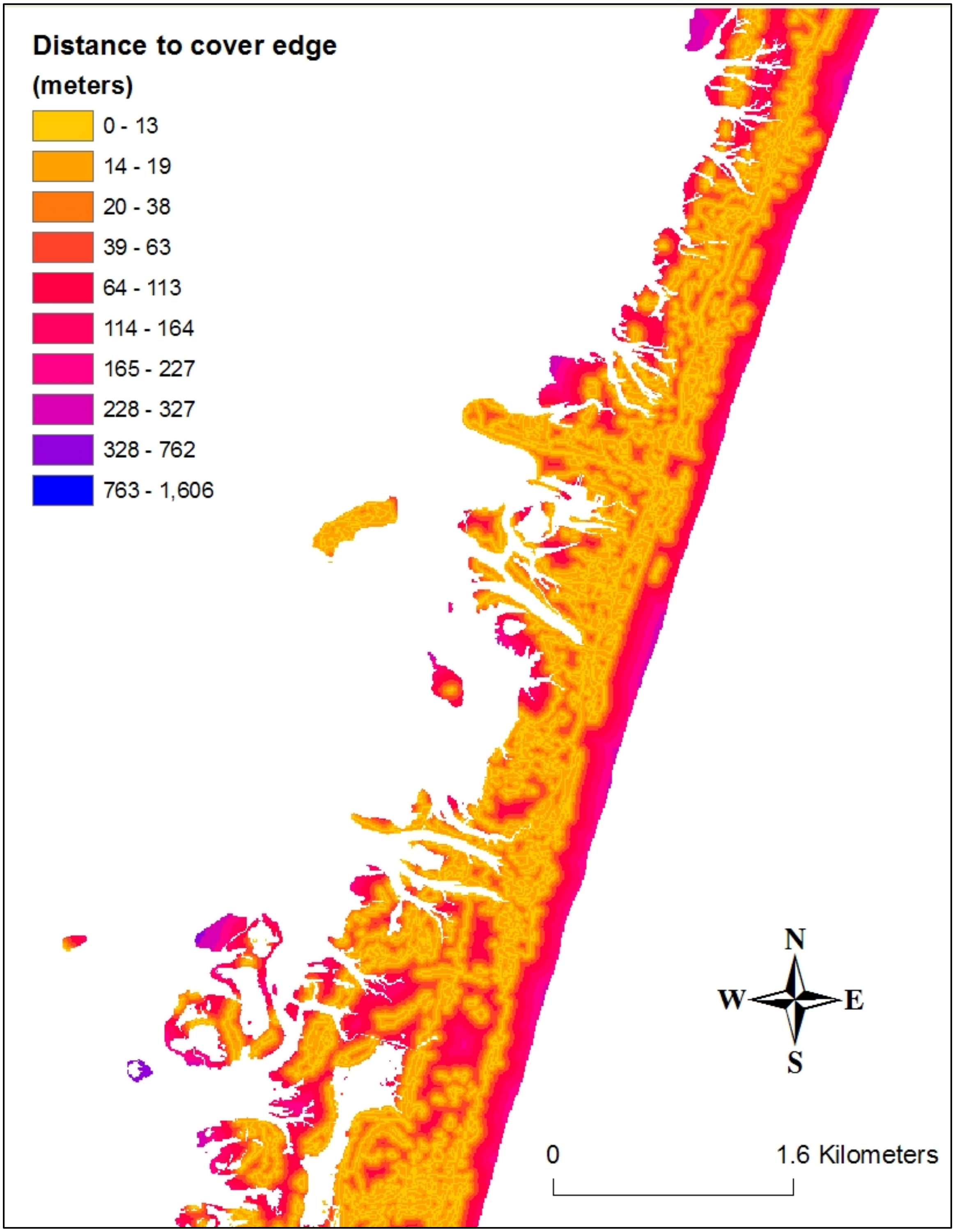

Figure 7. Map of the distance to edge (border of the combined tall shrub and forest habitat types) immediately south of the northernmost portion of Assateague Island National Seashore, Maryland, USA.

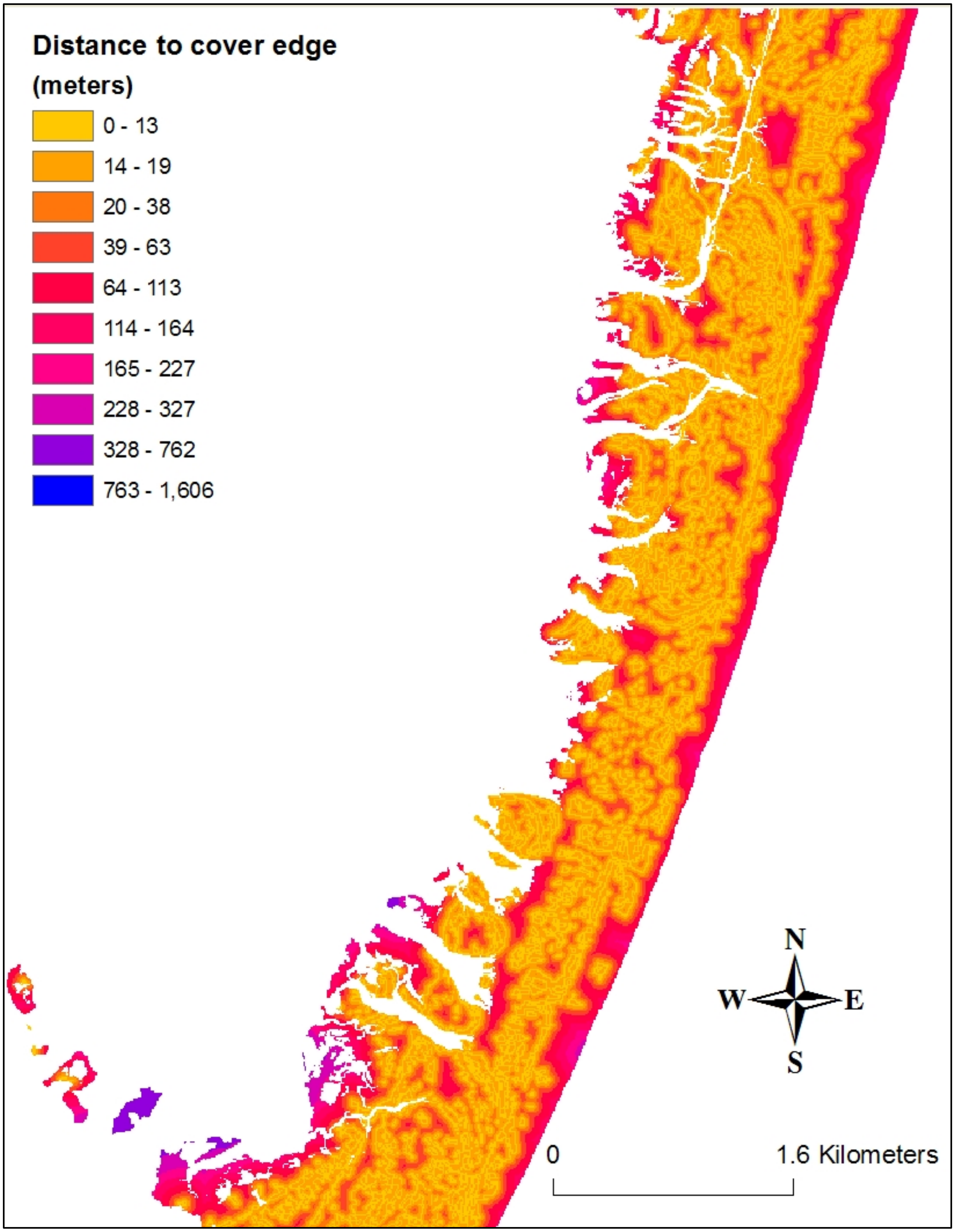

Figure 8. Map of the distance to edge (border of the combined tall shrub and forest habitat types) immediately north of the southernmost portion of Assateague Island National Seashore, Maryland, USA.

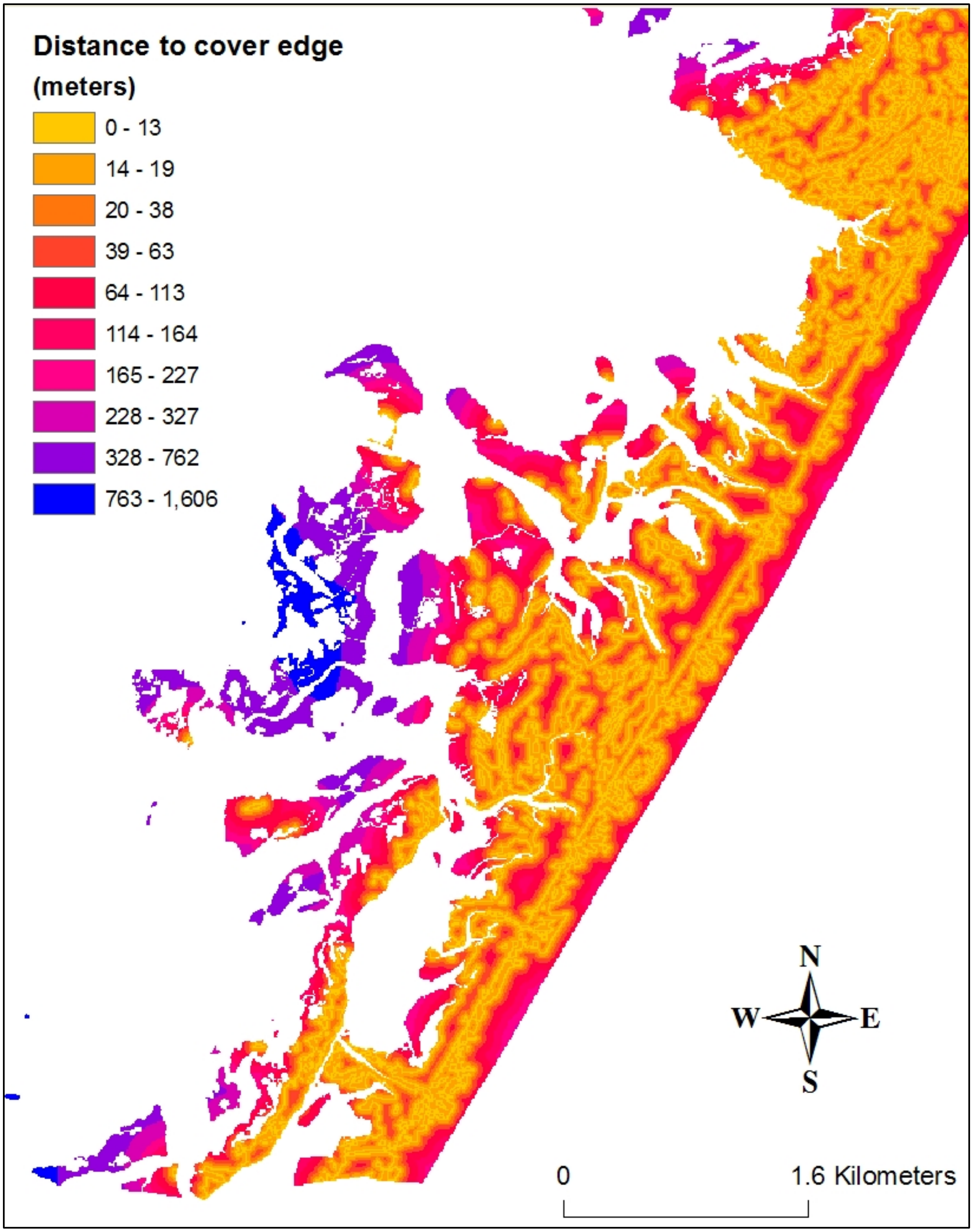

Figure 9. Map of the distance to edge (border of the combined tall shrub and forest habitat types) of the southernmost portion of Assateague Island National Seashore, Maryland, USA.

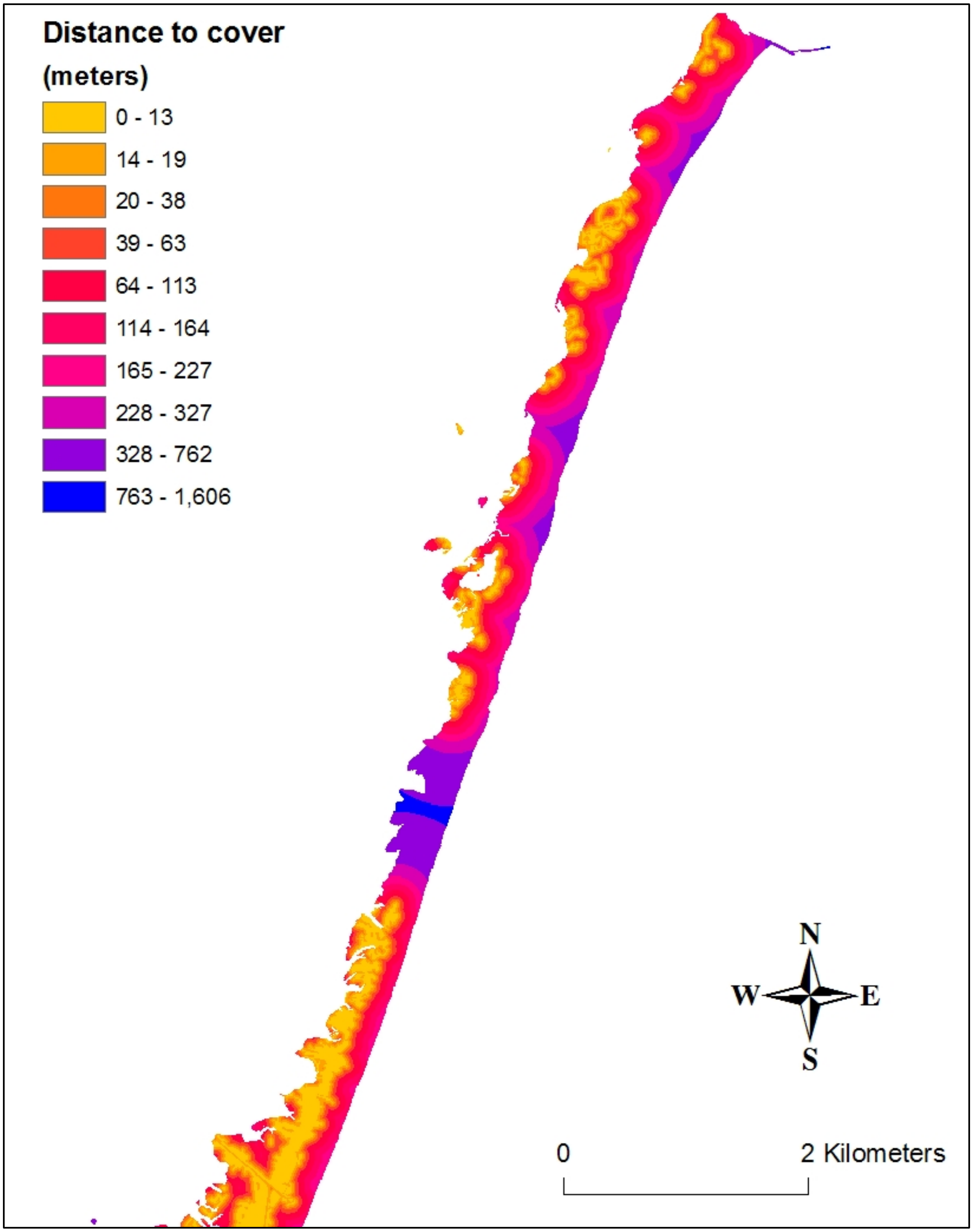

Figure 10. Map of the distance to cover (tall shrub or forest habitat types) for the northernmost portion of Assateague Island National Seashore, Maryland, USA.

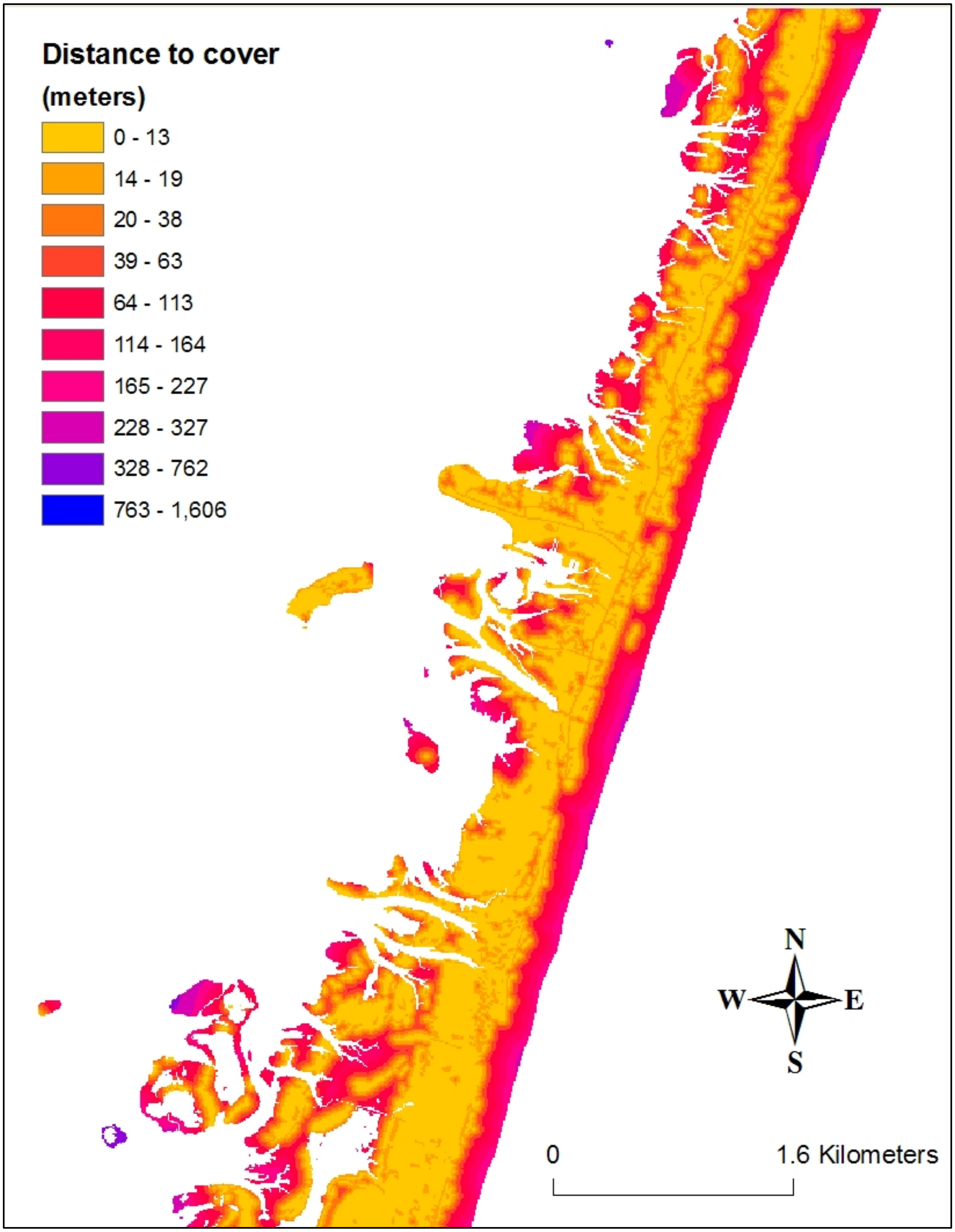

Figure 11. Map of the distance to cover (tall shrub or forest habitat types) immediately south of the northernmost portion of Assateague Island National Seashore, Maryland, USA.

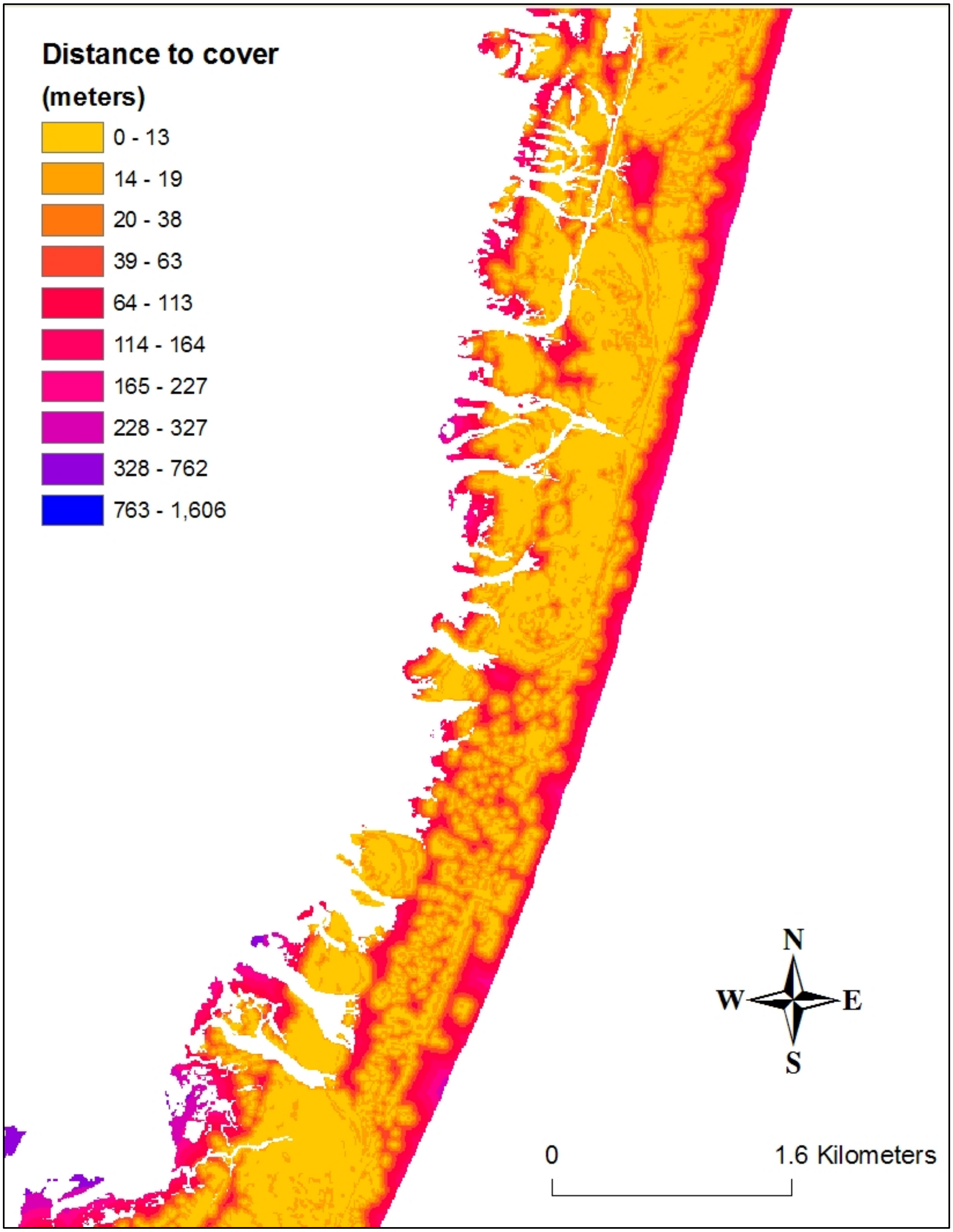

Figure 12. Map of the distance to cover (tall shrub or forest habitat types) immediately north of the southernmost portion of Assateague Island National Seashore, Maryland, USA.

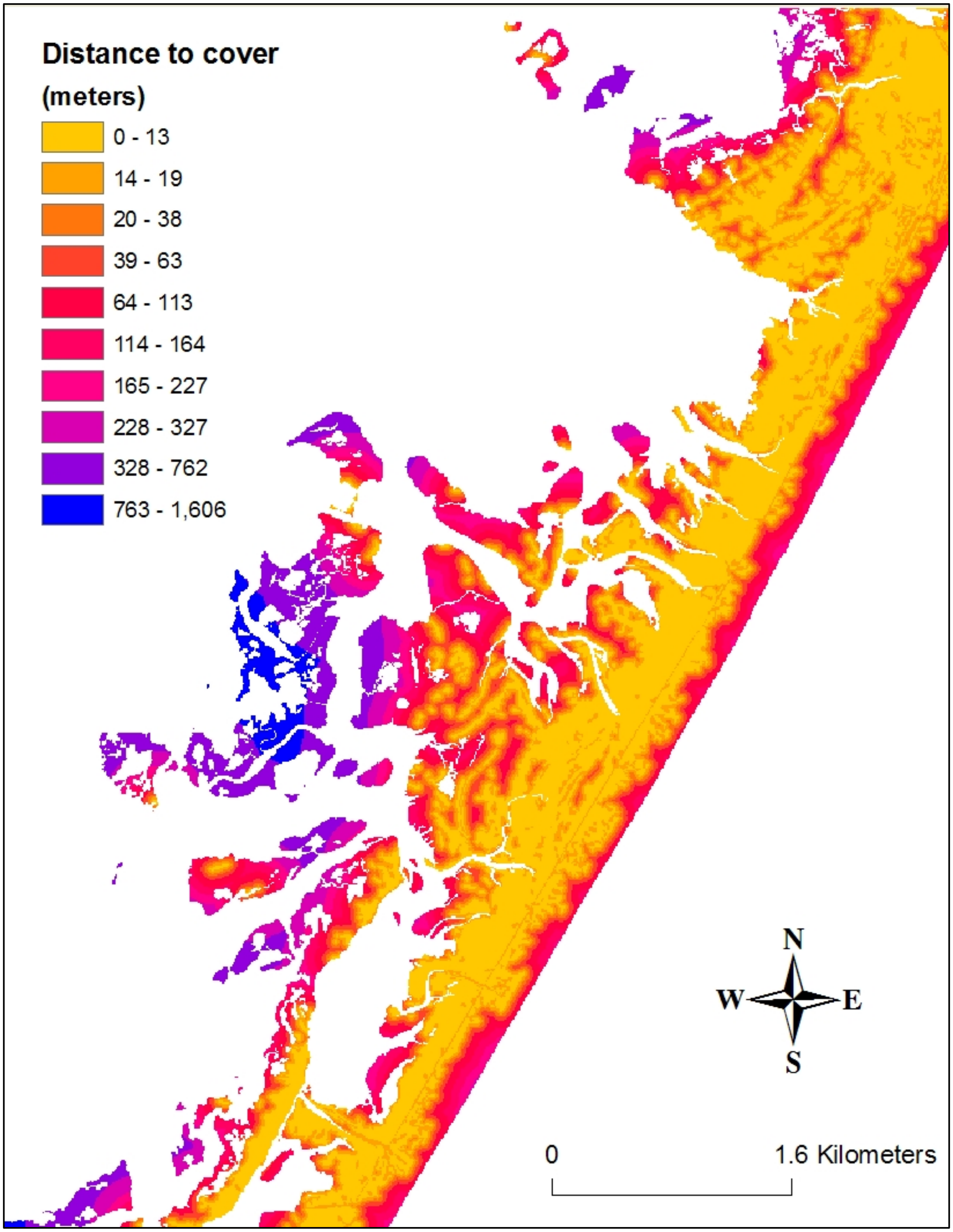

Figure 13. Map of the distance to cover (tall shrub or forest habitat types) for the southernmost portion of Assateague Island National Seashore, Maryland, USA.

Table 3. Model description and number of parameters for a suite of logistic regression models investigated to estimate the resource selection function for white-tailed and sika deer on Assateague Island National Seashore.

Model	Description	k^{a}
Null	Intercept only	1
Vegclass	Categorical habitat cover types	9
Distcov	Distance to cover	2
Distedge	Distance to the edge of cover	2
Distedge, vegclass	Distance to the edge of cover and habitat cover types	10
Distcov, vegclass	Distance to cover and habitat cover types	10

[a]No. parameters in model

For the best model, we averaged parameters across individual deer to account for heterogeneity among deer (Sawyer et al. 2006). We then used these averaged parameter estimates in a resource selection function (Manly et al. 2002):

$$\mathrm{RSF_i} = e^{\bar{\beta}_0 + \bar{\beta}_1 x_{1i} + \ldots + \bar{\beta}_{ji} x_{ji}} ,$$

where $\bar{\beta}_j$ is the average coefficient for habitat variable *j* and i indexes the resource units in the study area.

We then normalized the RSF values as

$$\overline{\overline{RSF_i}} = \frac{RSF_i - \overline{RSF}}{SD(RSF)} .$$

An $\overline{\overline{RSF}}$ value of 0 indicated the resource unit received average use and positive values indicated the resource unit received greater use than average and negative values indicated lesser use than average. We used normalized values so that when we mapped the difference in habitat use between white-tailed deer and sika deer ($\overline{\overline{RSF}}_{wtd} - \overline{\overline{RSF}}_{sika}$) a value of zero indicated both species used the habitat at their mean level. Positive values indicated that white-tailed deer used the given habitat more and negative values indicated that sika deer used the given habitat more (relative to each species' mean level of use).

A resource selection function based on a logistic regression model provides a relative measure of resource use by animals and does not provide information of use relative to availability. Although use relative to availability is not necessary to the objective of this study to identify differences in habitat use between sika and white-tailed deer, we created a graph of use versus availability to show which habitats were used more or less in proportion to the available habitat on the study area. This graphical representation of habitat use can differ from the RSF if the RSF includes additional variables to explain habitat use (e.g., distance to cover).

Results

We captured and fitted 50 deer with radio-collars over the course of the study. Of these 50 deer, 36 were sika and 14 were white-tailed deer. Of the 36 sika deer, 10 were harvested, three were likely killed by hunters but not recovered, and one died of natural causes while giving birth. Of the 14 white-tailed deer, three were harvested, one was illegally killed, and two were censored because of study-related mortality.

Survival and Harvest Rates

The best model for annual survival was one in which survival differed between the non-hunting and hunting months (Table 4). Most mortality occurring during the hunting season (Table 5).

The best model of the harvest rate indicated no differences over time or between age classes (Table 6). Harvest rates were greater for males than females, although precision of these estimates was poor (Table 7).

Movement

We found that the dispersion of locations for sika deer was greater than for white-tailed deer ($F_{1,149} = 3.98$, $P = 0.048$) but failed to detect any difference among sex ($F_{1,149} = 0.53$, $P = 0.467$), age ($F_{1,149} < 0.01$, $P = 0.951$), or season ($F_{1,149} = 0.18$, $P = 0.834$). Dispersion distances for white-tailed deer averaged 302–519 m (990–1,703 ft) among all seasons and sexes (Table 8). In contrast, sika deer of both sexes exhibited extreme variability within and among seasons: mean dispersion distances averaged 587–2,074 m (1,926–6,804 ft) across seasons and sexes. The smallest mean dispersion distances for sika deer occurred among females in the spring and winter seasons, but because of the variability among individuals within a season, we failed to detect any seasonal differences in our statistical analysis (Table 8).

Movement patterns for both sexes of sika deer varied among individuals. Fidelity to permanent home ranges was observed for 11 of 23 female sika deer and 3 of 13 male sika deer, but the majority of sika deer had large movements and shifts in home ranges (Figure 14). Many sika deer made relatively quick, long distance movements along the length of the island. These movements were ≤20 km (12 mi) within a 24-hour period. Some sika deer made long distance movements that were repeated on a seasonal basis, although the lack of continuous monitoring limited any firm conclusions regarding migratory behavior, which has been documented for this species (McCullough et al. 2009).

Despite the capacity to move long distances, we never located a sika deer off Assateague Island. In contrast, white-tailed deer did not exhibit long distance movements or shifts in home range location (Figure 15), except one yearling male white-tailed deer dispersed to the mainland.

Table 4. Model selection results for known-fate models of sika and white-tailed deer annual survival on Assateague Island National Seashore, 2006–2007 and 2007–2008.

Model	AICc	ΔAICc	AICc weights	Model likelihood	k^a
S(nonhunt/hunt*species*sex)	168.2	0.0	0.99	1.00	8
S(nonhunt/hunt*species*sex*age)	180.5	12.3	<0.01	<0.00	16
S(month*species*sex)	227.5	59.3	<0.01	<0.00	48
S(month*species*sex*age)	323.2	155.0	<0.01	<0.00	94

Table 5. Estimates of survival from all sources of mortality for sika and white-tailed deer on Assateague Island, Maryland, USA, 2006–2008. The model estimated constant monthly survival for the non-hunting (Feb–Aug) and hunting (Sep–Jan) periods.

Species **Sex**	**Non-hunting period**		**Hunting period**		**Annual**	
	$\hat{S}$	95% CI	$\hat{S}$	95% CI	$\hat{S}$	95% CI
White-tailed deer						
Male	1.000		0.864	0.65–0.96	0.480	0.16–0.82
Female	0.986	0.91–0.99	0.961	0.86–0.99	0.741	0.44–0.91
Sika deer						
Male	1.000		0.890	0.80–0.94	0.559	0.35–0.75
Female	0.995	0.97–1.00	0.976	0.94–0.99	0.856	0.70–0.94

Table 6. Model selection results for known-fate models of harvest rate of sika and white-tailed deer on Assateague Island National Seashore during the September-January hunting seasons, 2006–2007 and 2007–2008.

Model	**AICc**	**ΔAICc**	**AICc weight**	**Model likelihood**	***k***
H(species*sex)	132.9	0.0	0.70	1.00	4
H(species*sex*age)	134.5	1.7	0.30	0.44	8
H(month*species*sex)	147.6	14.8	<0.01	<0.01	20
H(month*species*sex*age)	178.7	45.9	<0.01	<0.01	40

Table 7. Estimates of harvest rates ($\hat{H}$), standard error ($\hat{SE}\left(\hat{H}\right)$ and 95% confidence intervals for sika and white-tailed deer on Assateague Island, Maryland, USA, 2006–2008.

Species **Sex**	$\hat{H}$	$\hat{SE}(\hat{H})$	**95% CI**
White-tailed deer			
Male	0.380	0.209	0.10–0.78
Female	0.180	0.116	0.05–0.51
Sika deer			
Male	0.441	0.108	0.25–0.65
Female	0.115	0.054	0.04–0.27

Table 8. Mean dispersion distance (m) and 95% CIs of sika and white-tailed deer for each sex and season on Assateague Island National Seashore, Maryland, USA, 2006–2007.

	Sika deer				White-tailed deer[a]			
	Male		Female		Male		Female	
Season	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Spring 2006	1,987	932–4,237	941	294–3,013	377	189–750	302	247–371
Summer 2006	2,016	891–4,562	1,969	824–4,703	333	220–505	366	266–505
Winter 2006	1,581	929–2,689	587	262–1,309			358	302–425
Spring 2007	2,074	1,001–4,296	666	256–1,735	390	272–558	519	314–859
Summer 2007	1,633	743–3,584	1,765	770–4,044	420	289–610	382	267–546

[a]insufficient data to estimate a mean dispersion distance where blank

Habitat Use

For seven of 10 season and species model comparisons, distance to cover (Distcover) and vegetation categories (Vegclass) were included in the best model of habitat selection (Table 8). For three season and species combinations the best model included the variable Distcover only. Therefore, for all seasons and both species, we used the model that included the parameters Distcover and Vegclass to calculate the RSF. Also, we averaged parameter estimates across years so that we had a single model for each season (spring, summer, and winter) and species.

All models indicated both species of deer were less likely to use a habitat the further it was located from cover, which was defined as tall shrub or forest vegetation (Table 9). We found that for every 10 m (33 ft) from cover each species of deer was 1.23–1.38 times less likely to use any given habitat (Table 10).

Patterns in use of vegetation classes were similar across species and seasons. Relative to forest habitat, both species avoided dune herbaceous, disturbed lands, sand, and water categories (Table 11). Both species neither avoided nor preferred developed herbaceous, low shrub, marsh herbaceous, and tall shrub categories compared to the forest category (Table 12).

A graph of habitat use versus availability (Figure 16) indicated both species exhibited greater use of forest, tall shrub, low shrub, and developed herbaceous habitats than were available. Sand, marsh herbaceous, and water habitats were used less than were available.

However, there were consistent differences between the two species. During spring, white-tailed deer were more likely than sika deer to use forested, tall shrub, disturbed herbaceous, and sand areas, but were less likely to use all other habitats (Figure 17). During summer, habitat use was extremely similar between the two species except that white-tailed deer tended to use forested habitat more (Figure 18). During winter, white-tailed deer were less likely to use dune herbaceous, low shrub, and forested habitats than sika deer (Figure 19).

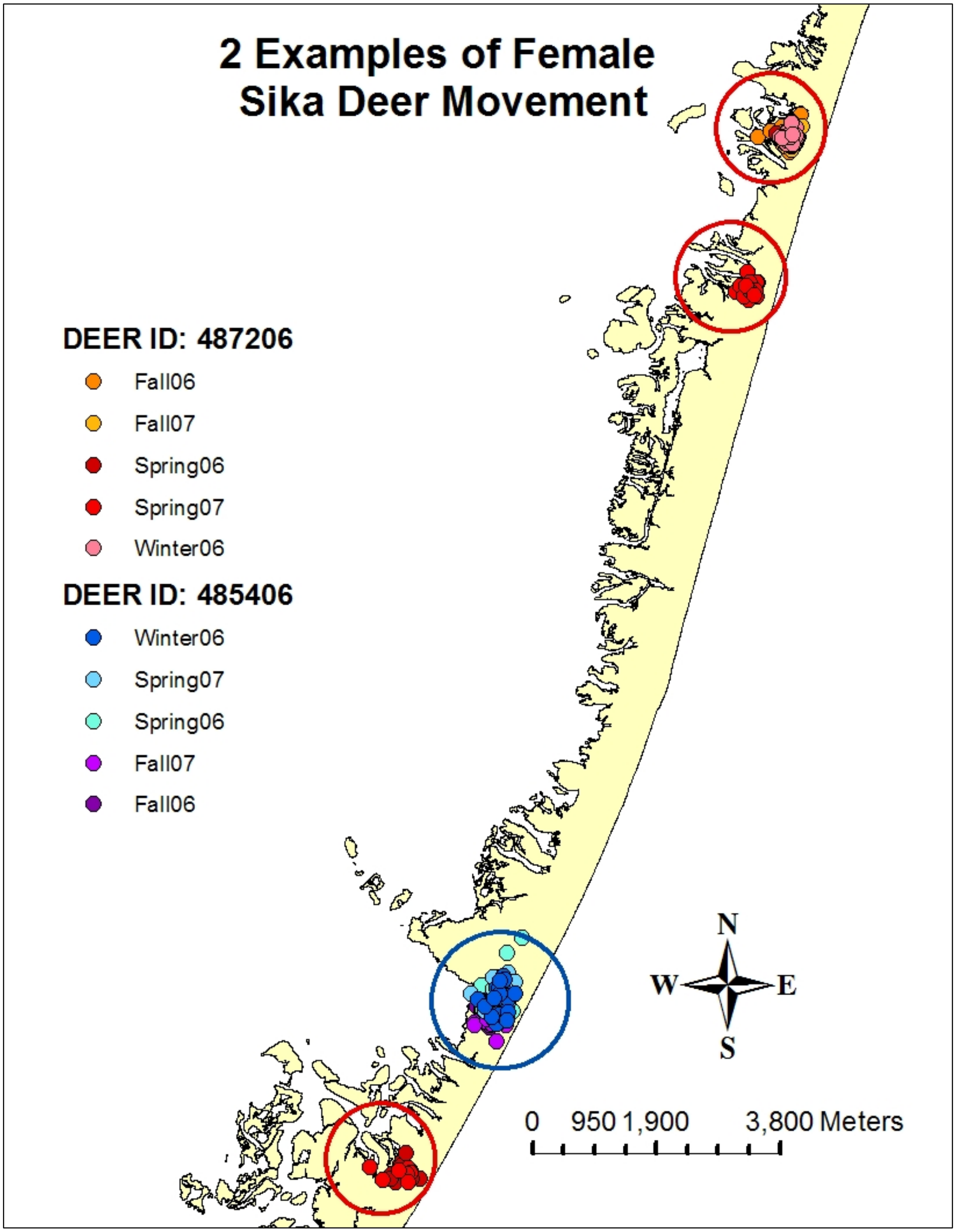

Figure 14. An example of the movements of two adult female sika deer on Assateague Island, Maryland, USA, 2006–2007. Both deer were monitored throughout the study. Deer ID represents the unique identifier for each deer, represented in shades of red and blue.

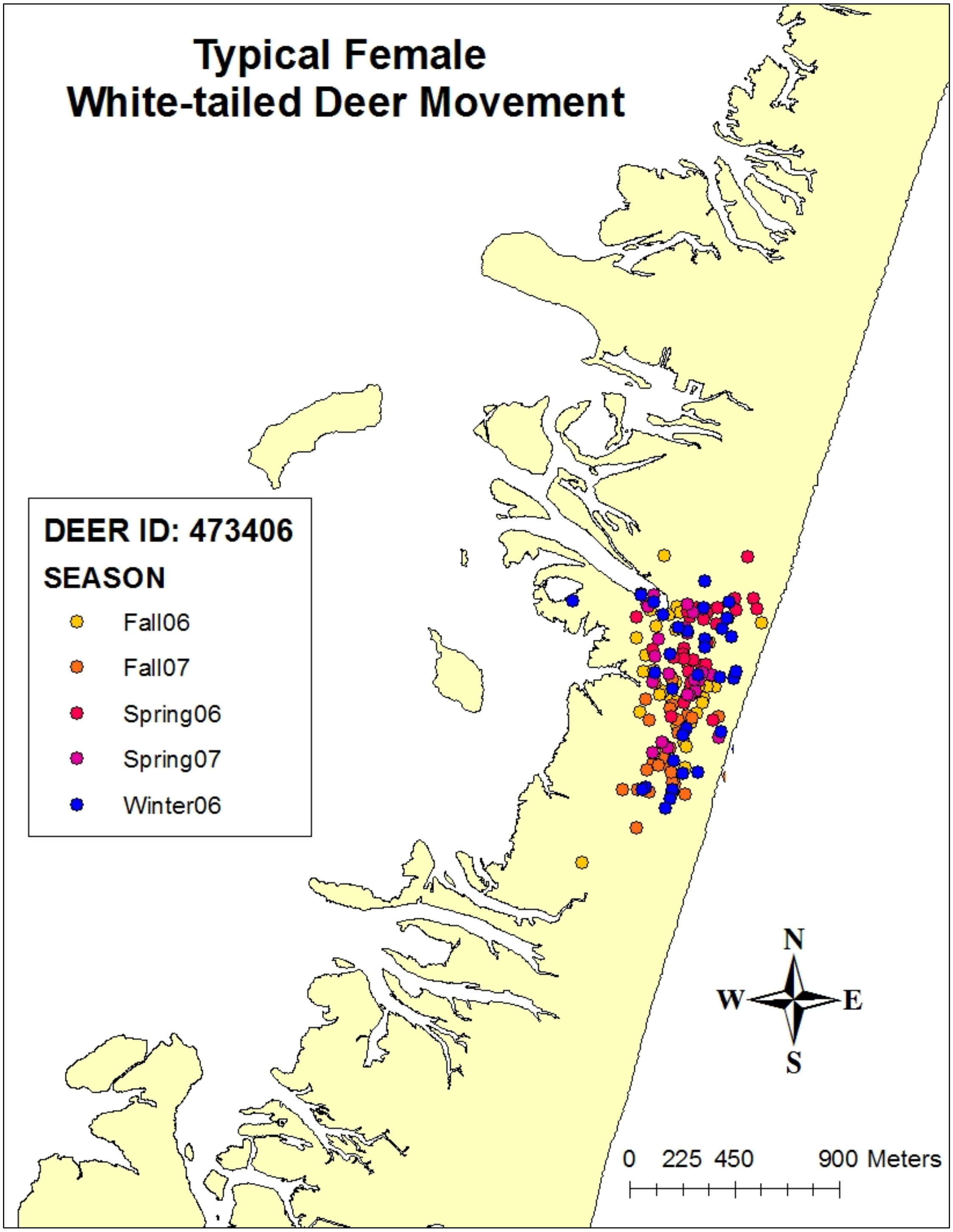

Figure 15. An example of the locations of a female white-tailed deer monitored throughout the study on Assateague Island, Maryland, USA, 2006–2007.

Table 9. Habitat use model selection ΔAICc values for sika and white-tailed deer on Assateague Island National Seashore, 2006–2007.

Season Species	Model Null	Distcov	Distedge	Vegclass	Distedge vegclass	Distcov vegclass
Spring 2006						
Sika deer	603.0	238.8	360.1	105.3	1.0	0.0
White-tailed deer	186.4	19.4	84.2	28.0	12.7	0.0
Summer 2006						
Sika deer	538.6	115.2	238.1	116.6	12.0	0.0
White-tailed deer	148.2	0.0	37.0	36.0	13.1	10.4
Winter 2006						
Sika deer	298.1	0.0	70.7	56.6	5.8	3.3
White-tailed deer	114.3	3.3	41.3	14.9	6.2	0.0
Spring 2007						
Sika deer	400.9	50.7	205.5	41.4	25.9	0.0
White-tailed deer	163.9	0.0	31.9	59.3	15.8	14.9
Summer 2007						
Sika deer	566.3	70.5	263.6	83.7	36.4	0.0
White-tailed deer	201.5	9.5	41.7	43.8	0.5	0.0

Table 10. Averaged coefficients for the resource selection function intercept and distance to cover parameters for sika and white-tailed deer on Assateague Island National Seashore, Maryland, USA, 2006–2007.

Species	Season	Intercept $\bar{\hat{\beta}}$	Intercept $\hat{SE}(\bar{\hat{\beta}})$	Distcov $\bar{\hat{\beta}}$	Distcov $\hat{SE}(\bar{\hat{\beta}})$	$\hat{OR}$ [a]	95% CI
Sika deer	Spring	-8.001	0.721	-0.028	0.004	1.32	1.22–1.43
White-tailed deer	Spring	-5.977	0.442	-0.032	0.004	1.38	1.27–1.49
Sika deer	Summer	-6.768	0.482	-0.032	0.004	1.38	1.27–1.49
White-tailed deer	Summer	-5.347	0.298	-0.026	0.005	1.30	1.17–1.43
Sika deer	Winter	-6.537	0.817	-0.021	0.004	1.23	1.14–1.34
White-tailed deer	Winter	-7.910	2.912	-0.021	0.007	1.23	1.07–1.47

[a] $\hat{OR}$ = Odds ratio, estimated odds a deer was *x* times less likely to use a habitat for every 10 meters from nearest cover.

Table 11. Averaged coefficients for the resource selection function for the habitat parameters that sika and white-tailed deer avoided compared to the forest category on Assateague Island National Seashore, Maryland, USA, 2006–2007.

Species	Season	Dune herbaceous $\bar{\hat{\beta}}$	Dune herbaceous SE	Disturbed lands $\bar{\hat{\beta}}$	Disturbed lands SE	Sand $\bar{\hat{\beta}}$	Sand SE	Water $\bar{\hat{\beta}}$	Water SE
Sika deer	Spring	-2.245	1.097	-7.761	1.005	-1.800	1.106	-5.969	1.074
White-tailed deer	Spring	-5.864	1.602	-10.312	1.103	-1.250	0.784	-7.115	1.594
Sika deer	Summer	-2.829	1.067	-9.150	0.872	-2.626	1.000	-8.474	0.937
White-tailed deer	Summer	-3.810	1.259	-9.258	1.265	-0.511	0.250	-9.085	1.590
Sika deer	Winter	-3.932	1.788	-10.805	1.278	-3.740	1.531	-9.391	1.387
White-tailed deer	Winter	-3.636	2.245	-6.842	2.827	-1.611	0.588	-1.236	3.780

Table 12. Averaged coefficients for the resource selection function for vegetation category parameters that sika and white-tailed deer used similarly to the forest category on Assateague Island National Seashore, Maryland, USA, 2006–2007.

		Developed herbaceous		Low shrub		Marsh herbaceous		Tall shrub	
Species	**Season**	$\hat{\beta}$	**SE**	$\hat{\beta}$	**SE**	$\hat{\beta}$	**SE**	$\hat{\beta}$	**SE**
Sika deer	Spring	-1.766	1.193	1.208	1.063	1.212	0.648	1.695	0.676
White-tailed deer	Spring	0.632	0.648	0.18	0.401	-0.398	0.371	-0.029	0.505
Sika deer	Summer	-0.89	0.819	0.429	0.794	0.477	0.466	0.771	0.428
White-tailed deer	Summer	0.255	0.493	0.085	0.163	-0.913	0.276	-0.419	0.342
Sika deer	Winter	-2.868	1.447	-0.016	1.238	0.06	0.744	0.385	0.696
White-tailed deer	Winter	2.423	3.264	-0.438	0.41	1.708	2.721	2.093	2.989

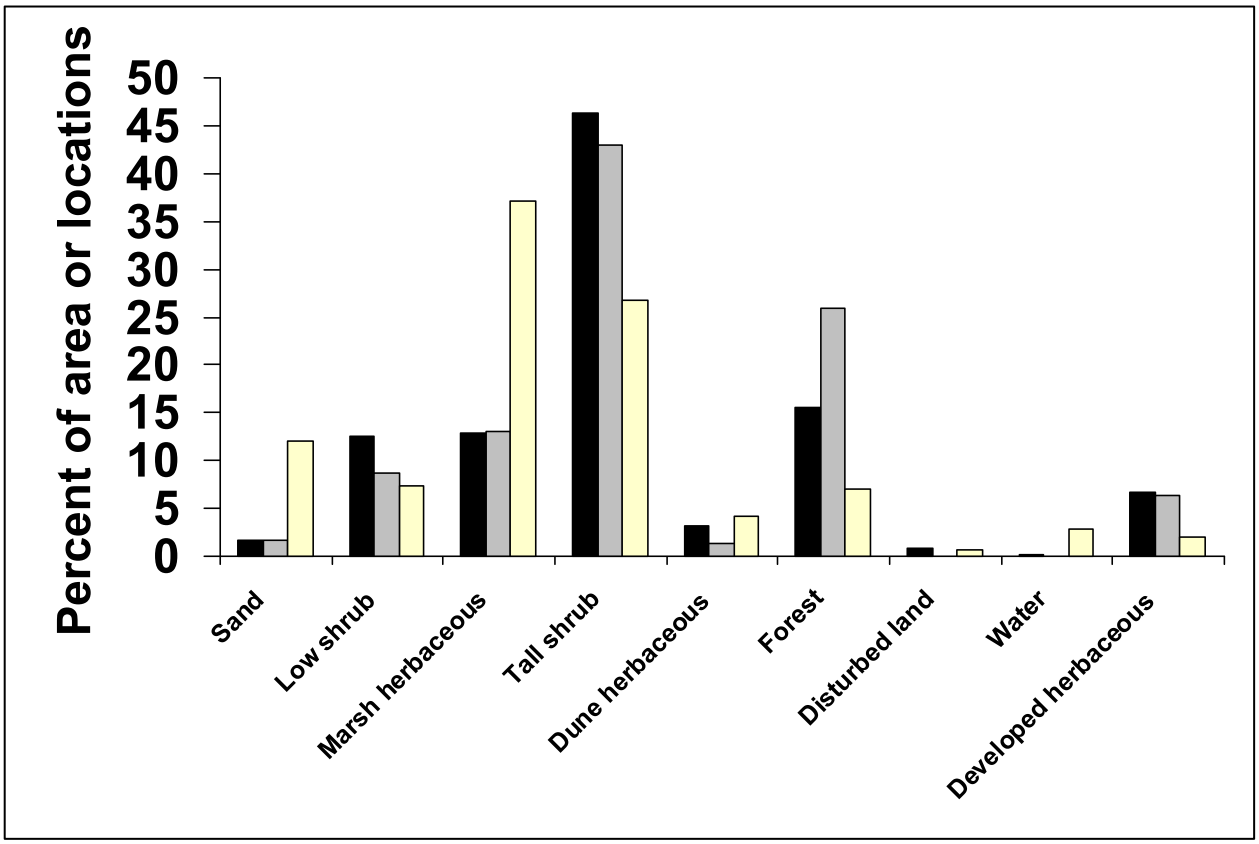

Figure 16. Proportion of locations of sika deer (black bars) and white-tailed deer (gray bars) in each habitat type compared to the area of each habitat type on the study area (yellow bars) , Assateague Island, Maryland, USA, 2006–2008.

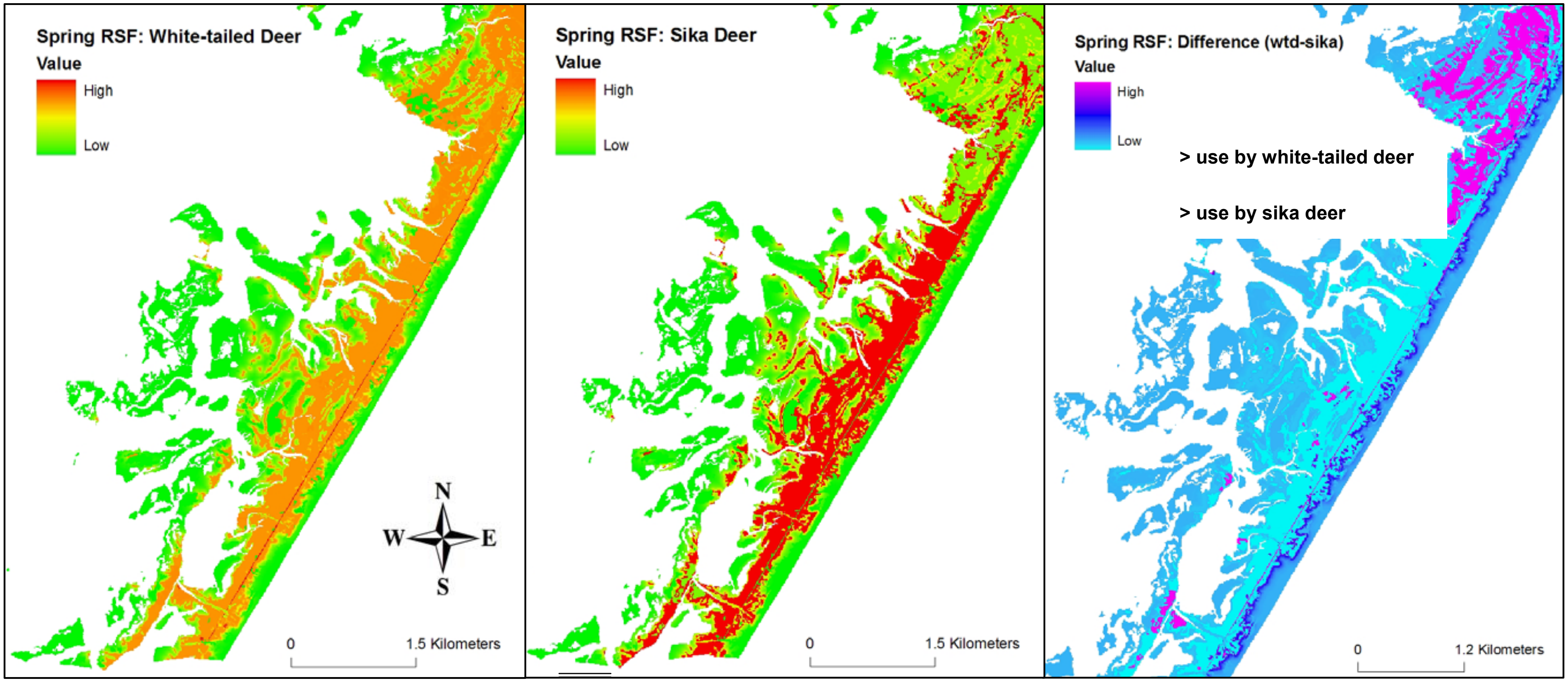

Figure 17. Normalized resource selection function (RSF) values during spring 2006–2007 for white-tailed deer (left), sika deer (middle) and the difference (white-tailed deer $\overline{\overline{RSF}}$ – sika $\overline{\overline{RSF}}$; right) for the southernmost section of Assateague Island National Seashore, Maryland, USA. See Appendix B for maps of the complete island.

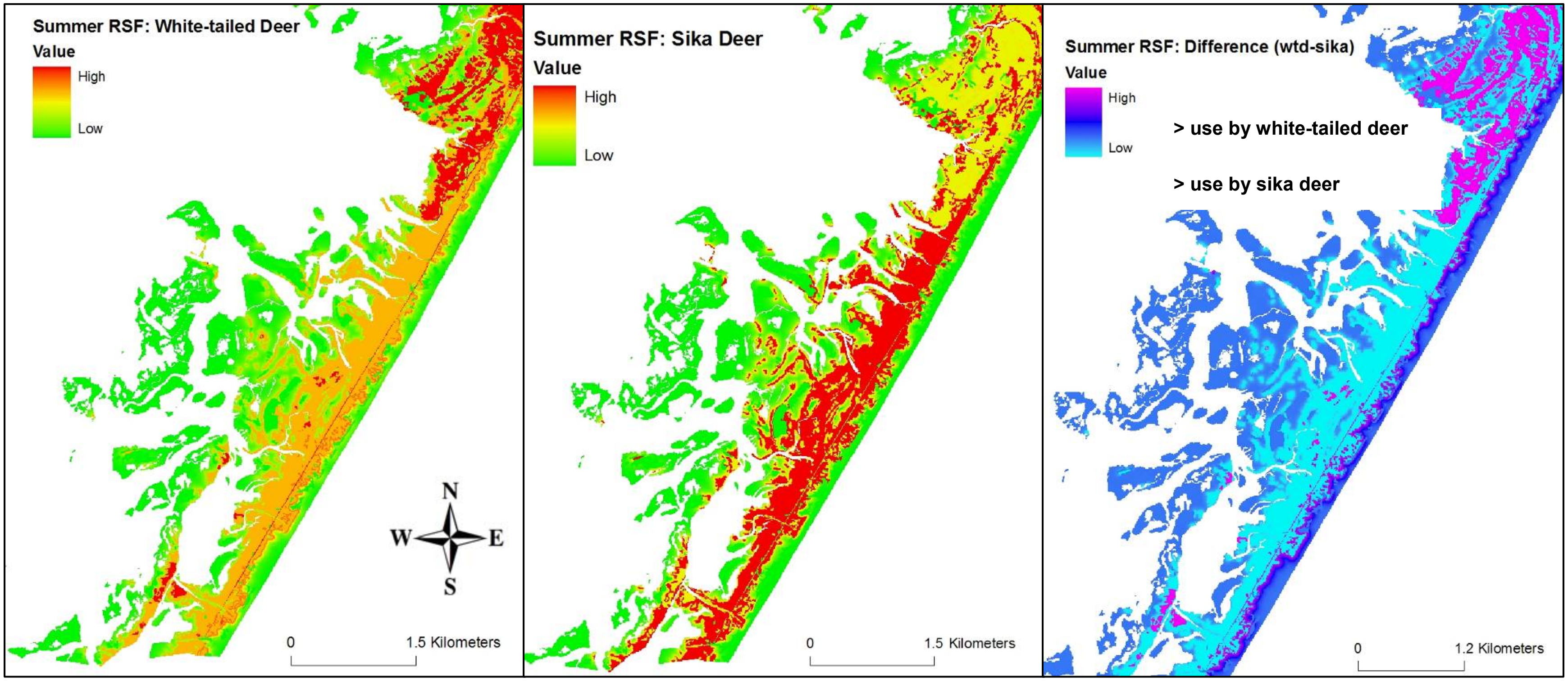

Figure 18. Resource selection function ($\overline{\overline{RSF}}$) values during summer 2006–2007 for white-tailed deer (left), sika deer (middle) and the difference (white-tailed deer $\overline{\overline{RSF}}$ – sika $\overline{\overline{RSF}}$; right) for the southernmost section of Assateague Island National Seashore, Maryland, USA. See Appendix C for maps of the complete island.

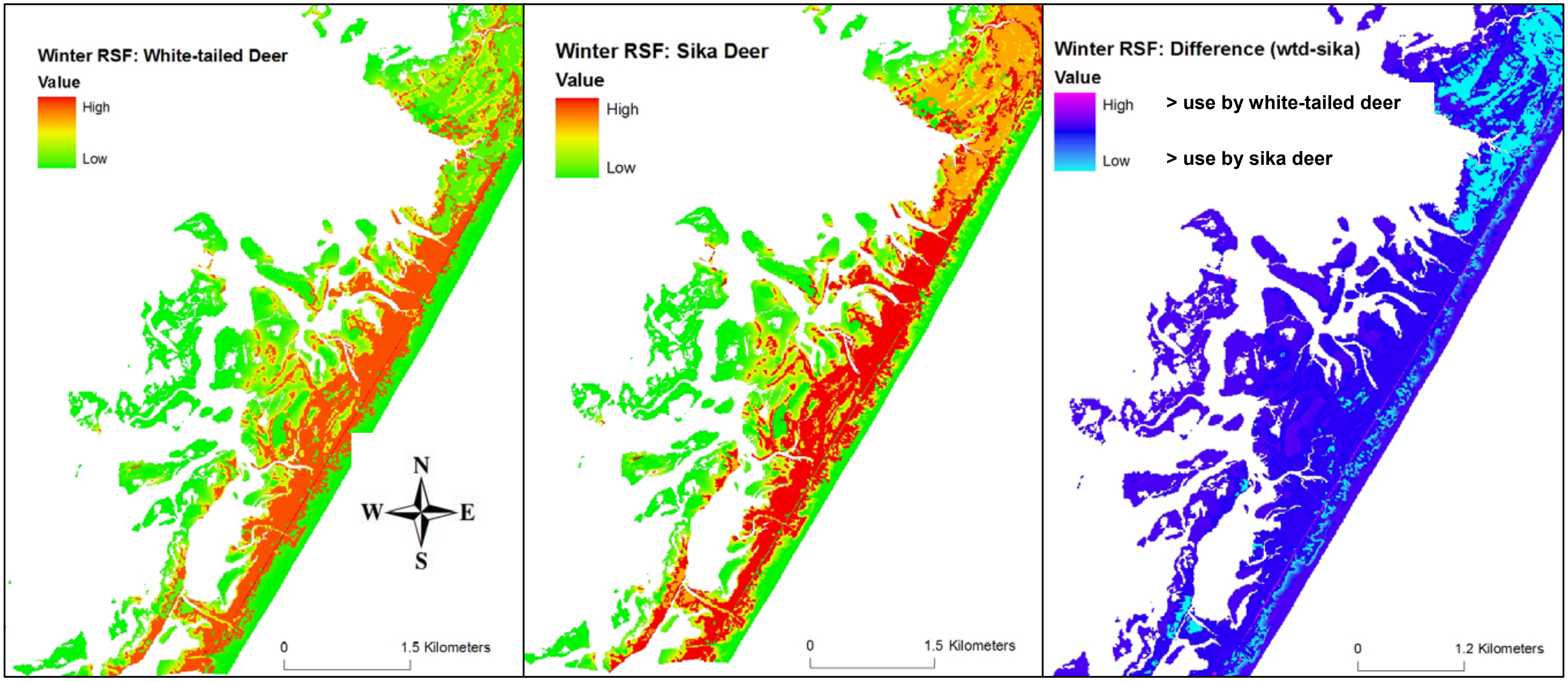

Figure 19. Resource selection function ($\overline{\overline{RSF}}$) values during winter 2006 for white-tailed deer (left), sika deer (middle) and the difference (white-tailed deer $\overline{\overline{RSF}}$ – sika $\overline{\overline{RSF}}$; right) for the southernmost section of Assateague Island National Seashore, Maryland, USA. See Appendix D for maps of the complete island.

Discussion

Survival and Harvest Rates

Hunting is the primary mortality factor for ungulates when populations do not greatly exceed carrying capacity of the habitat and severe environmental conditions do not occur (Gaillard et al. 1998). We observed such a pattern on Assateague Island in which survival rates for males and females of both species was 0.99–1.00 during the non-hunting period (Table 5). Uno and Kaji (2006) reported that annual survival for adult female sika deer on Hokkaido Island, Japan, was 0.78 (95% CI = 0.61–0.99), which was similar to our estimate of 0.86 (95% CI = 0.70–0.94; Table 5). Fuller (1990) reported annual survival rates for female white-tailed deer in Minnesota of 0.71 (95% CI = 0.63–0.80) in a declining population. In Pennsylvania, where white-tailed deer populations are stable, annual survival rates of female white-tailed deer varied from 0.61–0.90 depending on the location and whether land was publicly or privately owned (D. R. Diefenbach, unpublished data). These survival rates for deer in Pennsylvania are similar to the annual survival rates we estimated of 0.74 (Table 5) for female white-tailed deer on ASIS.

Unfortunately, small sample size did not permit precise estimates of harvest rates for white-tailed deer, but harvest rates for female sika deer (0.12, 95% CI = 0.04–0.27) were similar to the 0.12 (95% CI = 0.00–0.27) reported by Uno and Kaji (2006). Despite limited sample sizes, the patterns in harvest rates suggest deer hunters selectively harvest males. For white-tailed deer, female harvest is restricted via bag limit restrictions. For sika deer, harvest regulations require that an antlerless deer be harvested before a second antlered deer can be harvested. The sex ratio in the harvest is generally 50:50 (J. Kumer, National Park Service, personal communication), which means that if harvest rates are greater for males the population is composed of a greater proportion of females.

Movements

In their native range, sika deer have been able to readily expand populations and occupy vacant habitat (Kaji et al. 2000; Kaji et al. 2004). The long distance movements we observed on Assateague Island, especially relative to white-tailed deer, may reflect the ability of this species to exploit food resources that may be limited in quality or quantity, or both. However, we did not collect data to assess use of food resources by sika deer and whether this may have influenced long distance movements.

In Japan, sika deer have been reported to be migratory when deep winter snow conditions occur (Igota et al. 2009; Yabe and Takatsuki 2009), but otherwise sika deer are sedentary and have relatively small home ranges. Although sika deer have readily expanded their spatial distribution on Hokkaido Island, Japan (Kaji et al. 2000), we did not document any movements of sika deer off Assateague Island.

Eyler (2001) found no difference in home range area by species, year, or season among free-ranging sika deer and white-tailed deer in Dorchester County, Maryland. Eyler (2001) focused exclusively on female deer, although literature suggests male deer of both species typically have larger home ranges than female deer of the same species (Feldhamer et al. 1982; Marchinton and Hirth 1984; Yabe and Takatsuki 2009). Also, Eyler (2001) observed the use of bimodal home ranges by both female sika and white-tailed deer, which was observed in female sika deer in this study, but not female white-tailed deer.

The behavioral plasticity of sika deer relative to shifts in home range location seems to be a consistent finding among studies. Consequently, it is unlikely that localized population reduction of sika deer will create long-lasting areas of reduced deer density on ASIS. Management strategies to reduce sika deer population density likely will require population reduction to occur throughout the island.

In contrast to sika deer, white-tailed deer on Assateague Island with established home ranges did not exhibit long-distance movements by either males or females (Table 8). For both sexes and all seasons, the largest dispersion distance (mean distance between all possible pairs of locations) was approximately 1.4 km (0.9 mi) for white-tailed deer and >4 km (2.5 mi) for sika deer. However, a dispersing yearling male white-tailed deer left Assateague Island and was later observed on the mainland. Timing of dispersal in white-tailed deer is influenced by demographic population characteristics (Long et al. 2008), and yearling male deer are known to disperse greater distances in landscapes with less forested habitat (Long et al. 2005). However, too few yearling male white-tailed deer were monitored in this study to estimate dispersal rates and distances.

Habitat Use

We observed limited differences in habitat use between sika and white-tailed deer and our data do not suggest any spatial niche partitioning in terms of differential habitat use to reduce competition for resources. It is possible that because detailed habitat use information is more difficult to collect via VHF radio-collars compared to technology that uses GPS satellites we may have failed to detect habitat use differences between sika and white-tailed deer. However, the one sika deer fitted with a GPS collar exhibited similar habitat use to deer monitored via VHF radio-collars, in which this deer used forest and tall shrub in greater proportion and used all other habitat types in lesser proportion to what was available. Because of the large number of locations obtained for this deer (1,203 locations) it is to be expected that statistically every habitat type would be identified as either used more or less than it is available (i.e., a statistical analysis is likely to identify differences between use and availability for each habitat type even when differences are biologically unimportant). We believe it is unlikely that more intensive location data of deer would conflict with the conclusions reached in this study because model selection results were similar among deer (Tables 8).

Previous research on ASIS indicated substantial overlap in the diets of sika and white-tailed deer (Keiper 1985), although comparison of plant species consumption only could be studied at the genus level. Keiper (1985) noted the sika deer consume a greater variety of species and suggested they used freshwater and saltwater habitats more than white-tailed deer. Another study in Maryland reported sika deer selected marsh or wetland habitats, including wet woodlands, whereas white-tailed deer selected conifer stands and non-forested cover (Eyler 2001). However, unlike mainland Maryland, no agricultural component to the vegetation types exists on Assateague Island. In addition, available wetlands on Assateague Island had greater salinity and many were ephemeral, potentially making them less desirable than freshwater wetlands on the mainland.

We found relatively little difference between species in the proportion of time spent among habitat types, but that does not preclude the possibility of differential foraging. Takatsuki (2009) reported that food habits of sika deer differed by latitude and in other regions of the world sika deer consume a wide range of vegetation (Feldhamer 1980). In regions of Japan, sika deer have evolved as the sole cervid species among a wide variety of habitat types, which may explain their varying food habits (Takatsuki 2009). Sika deer appear to be well suited to exploit habitat resources on Assateague Island and in other native and introduced ranges.

Conclusions

The survival and harvest rate results of this study do not permit inferences regarding whether survival and harvest rates would result in declining, stable, or increasing populations because the precision of these estimates was insufficient and information on reproductive rates also is required. However, the results do not suggest these population parameters for deer on ASIS differ greatly from other free-ranging populations.

The results of this study suggest that habitat use by sika and white-tailed deer is not substantially different in terms of time spent in different habitats. Consequently, it is not possible to infer from our data whether these two deer species use different food resources or differentially use any given resource in the same habitat. Previous research has suggested substantial overlap in their diets (Keiper and Tzilkowski 1983; Tzilkowski and Brown 1984; Keiper 1985), although identifying species-specific differences in plant consumption would require more research. Such research could involve collecting more detailed information about diets via fecal analysis or direct observation of food consumption. However, it is not guaranteed that such research approaches necessarily would identify differences between sika and white-tailed deer.

If the goal of ungulate population management on ASIS is to protect the island ecosystem, or reduce herbivory on specific plant species, an adaptive management approach may be warranted (see Williams et al. 2007). Such an approach might involve manipulation of deer abundance and monitoring the response of plant species known to be preferentially consumed by deer. This potentially could be a more direct method of assessing effects of deer herbivory. Furthermore, by differentially manipulating sika deer and white-tailed deer densities it may be possible to assess if one species has a greater effect on specific plant species.

An adaptive management program (Williams et al. 2007) may provide greater benefits to the management of ASIS in the long term. Traditionally, many agencies make deer management decisions primarily based on harvest numbers or abundance, and rarely have habitat conditions been incorporated into the decision making process explicitly and in a quantitative manner (C. S. Rosenberry, Pennsylvania Game Commission, personal communication). Harvest management decisions for white-tailed deer and sika deer on ASIS are made on an ongoing basis and by coupling these decisions with a vegetative monitoring program it may be possible to more efficiently reduce or minimize the adverse effects of ungulate herbivory. Furthermore, management of feral horses could be incorporated into the decision making process.

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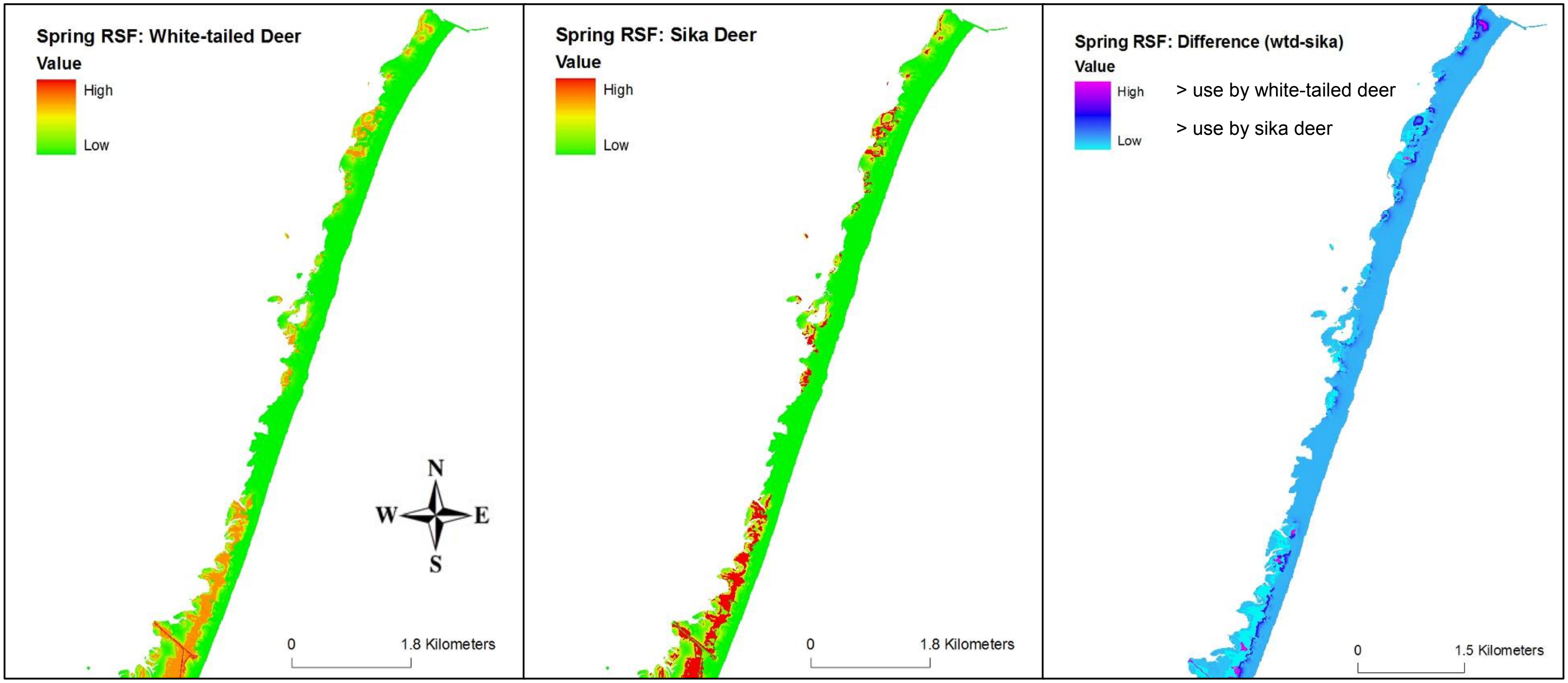
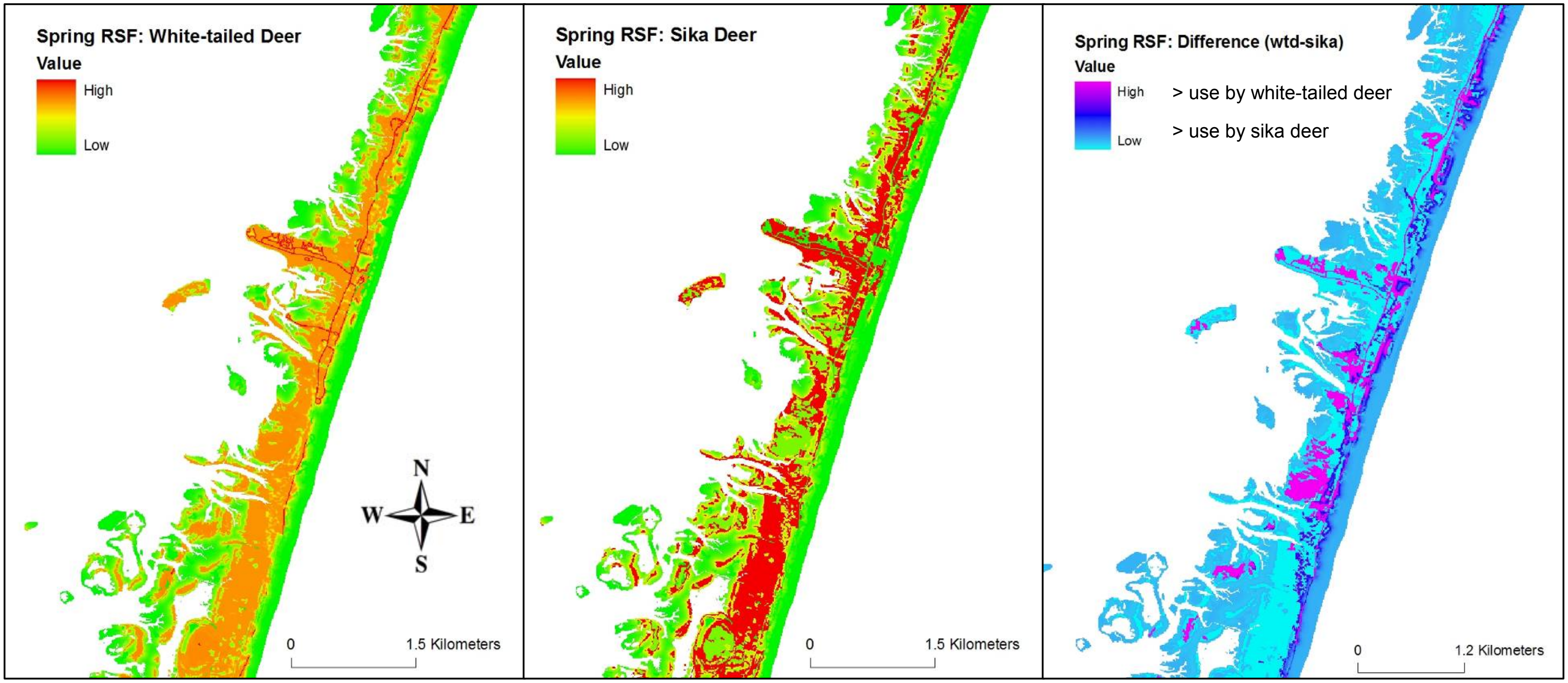
Appendix A. Telemetry monitoring schedule.

Deer were systematically monitored using ground-based radio telemetry techniques with the schedule below. The schedule was developed to allow one person to perform all the monitoring and still encompass as much of the 24-hr period as possible and sample all deer equally. The study area was divided into three zones (northern, middle, and southern third) and the day was divided into three time periods (AM: 4:00 am to 10:00 am; Mid-day: 10:00 am to 5:00 pm; PM: 5:00 pm to 11:00 pm). On any given day (excluding Saturday), one location was obtained for each deer that was present during the time periods and in the zone sampled (each deer was located four times/week). The recorded time of location within the specified time period was systematically shifted weekly to allow for location collections throughout the time period for each deer.

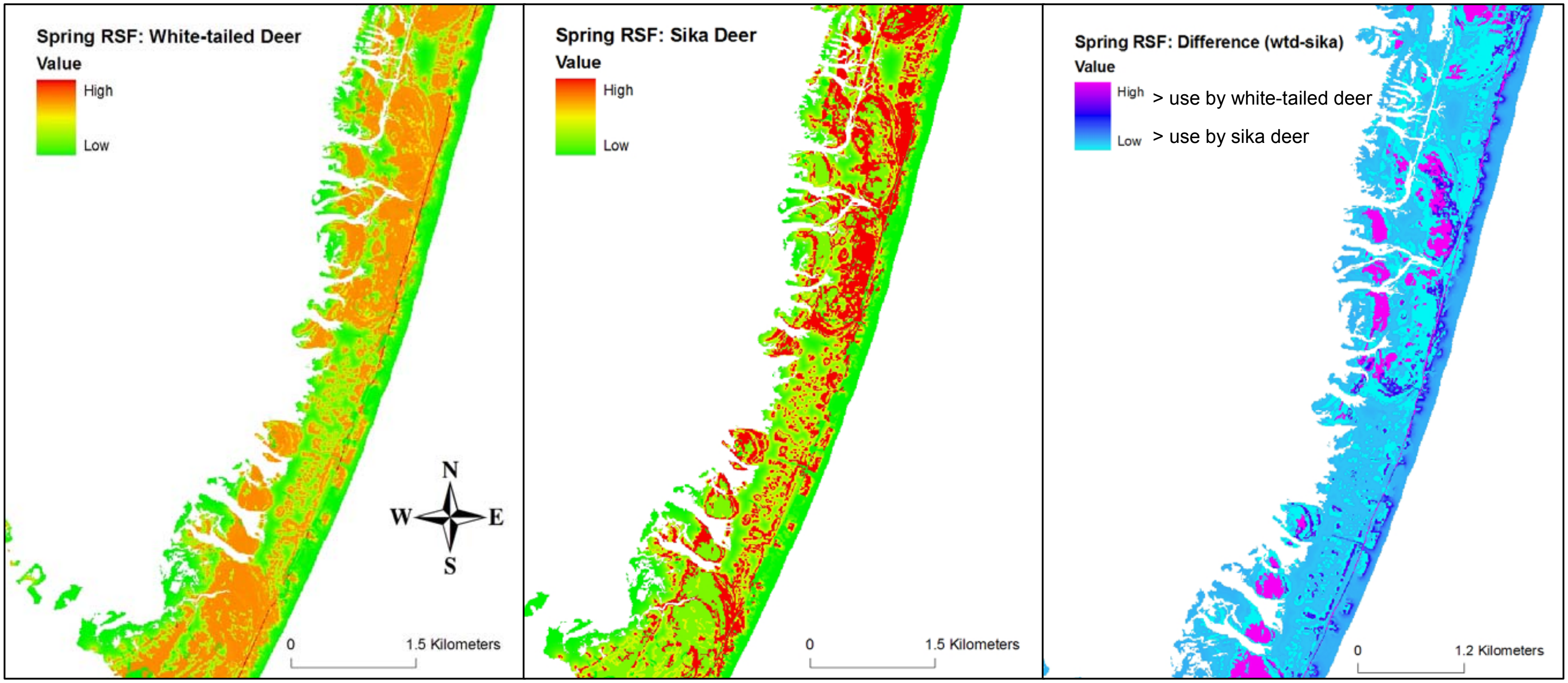
	Day of week					
Telemetry session	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Session 1	Mid-day Zone 2	Mid-day Zone 3	Mid-day Zone 1	AM Zone 2	AM Zone 3	AM Zone 1
Session 2	PM Zone 1	PM Zone 2	PM Zone 3	Mid-day Zone 1	Mid-day Zone 2	Mid-day Zone 3

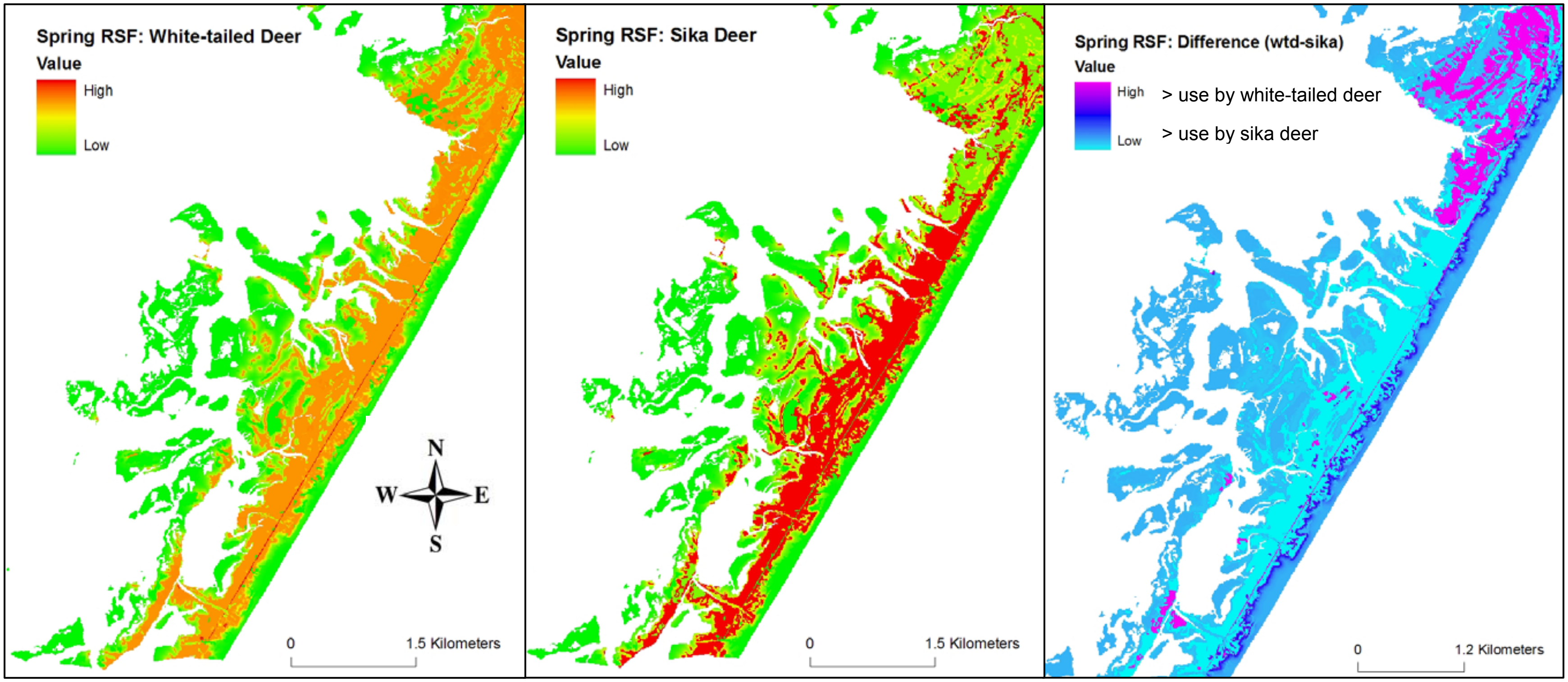
Appendix B. Resource selection function (RSF) maps during spring 2006–2007 for white-tailed deer, sika deer, and the difference (white-tailed – sika) on Assateague Island, Maryland, USA.


Spring RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.8 Kilometers
Spring RSF: Sika Deer
Value
High
Low
0
1.8 Kilometers
Spring RSF: Difference (wtd-sika)
Value
High
Low
> use by white-tailed deer
> use by sika deer
0
1.5 Kilometers

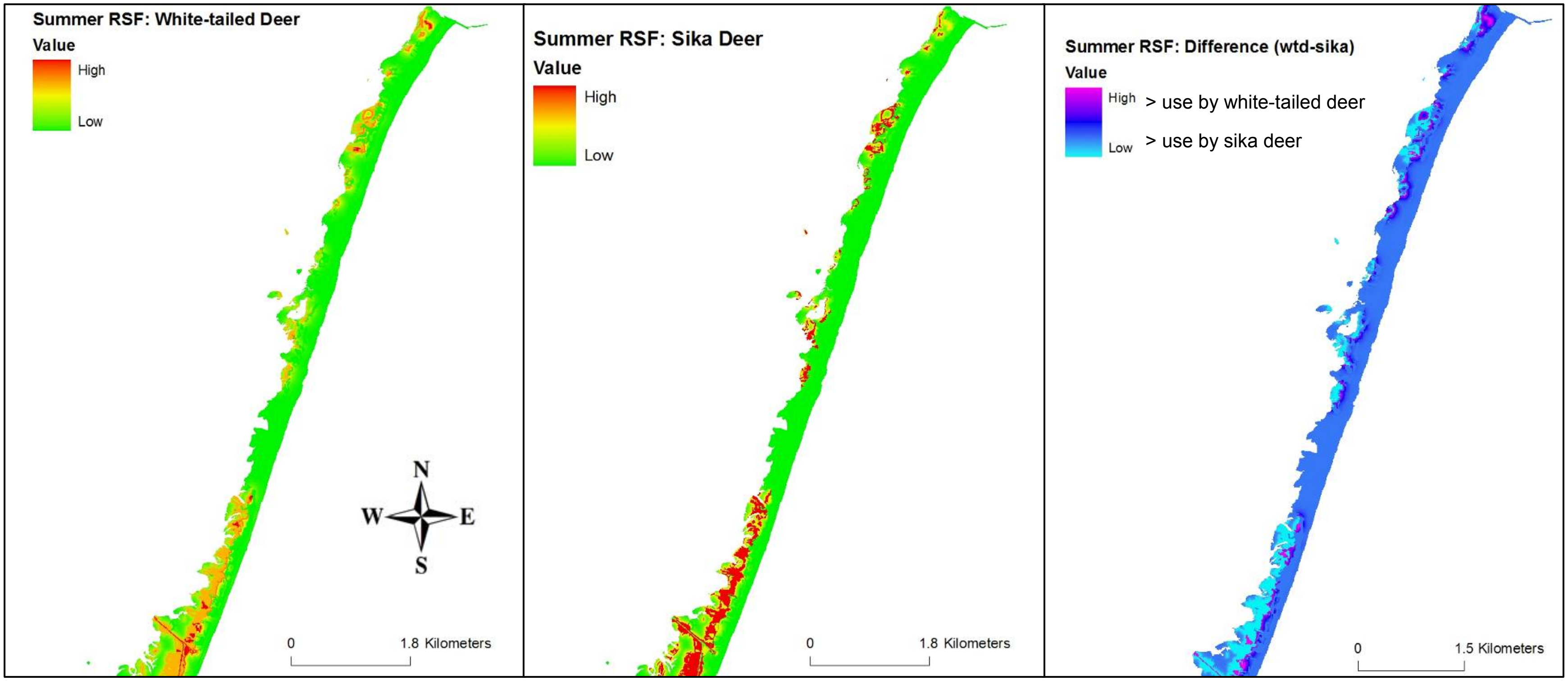


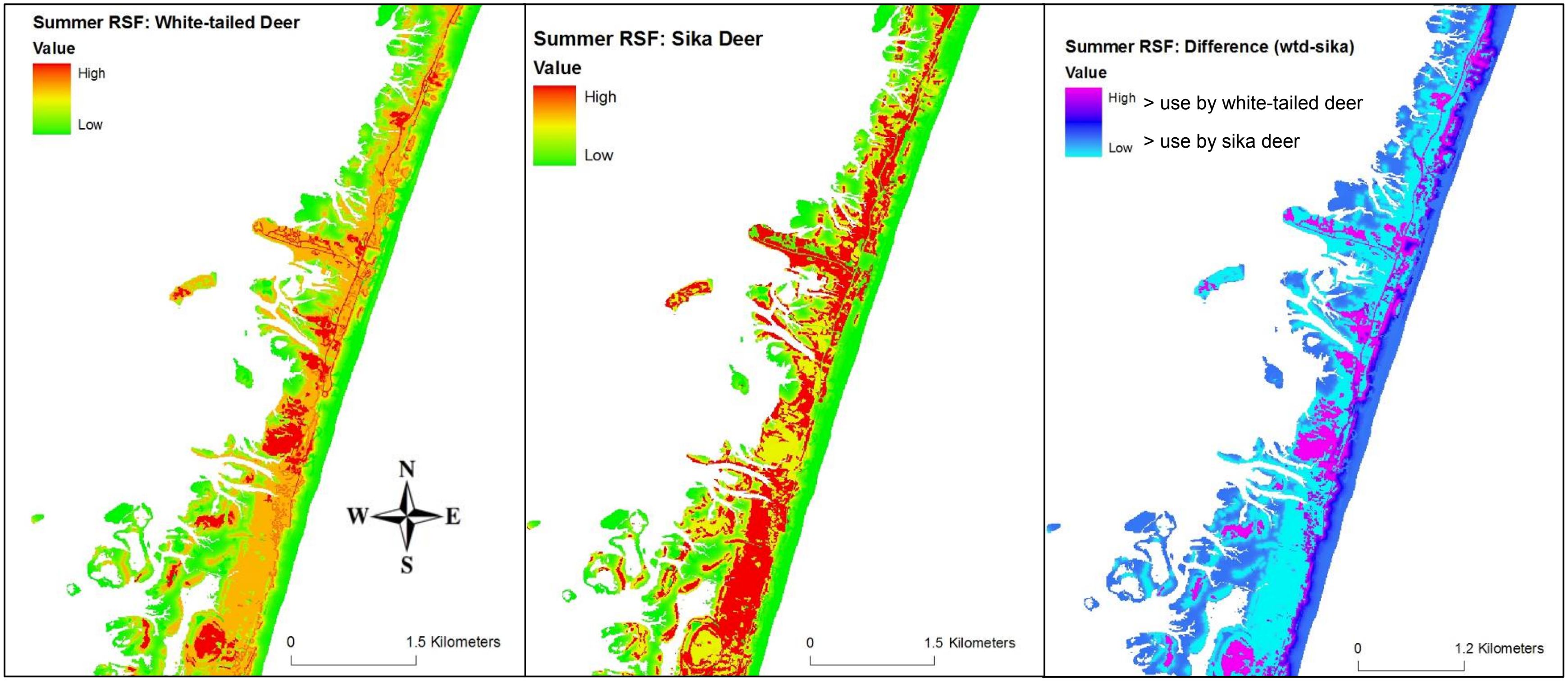
Spring RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Spring RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Spring RSF: Difference (wtd-sika)
Value
High
Low
> use by white-tailed deer
> use by sika deer
0
1.2 Kilometers


Spring RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Spring RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Spring RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.2 Kilometers

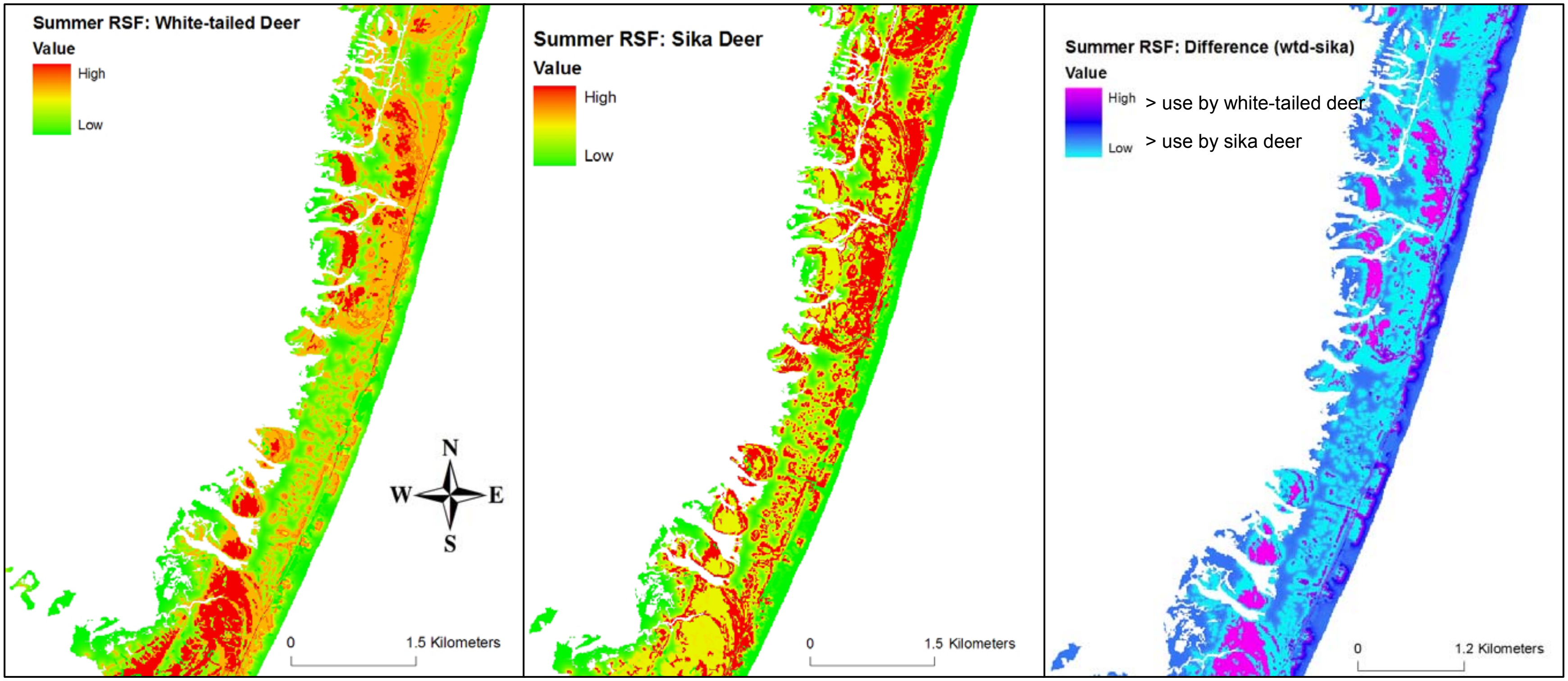

Spring RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Spring RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Spring RSF: Difference (wtd-sika)
Value
High
Low
> use by white-tailed deer
> use by sika deer
0
1.2 Kilometers

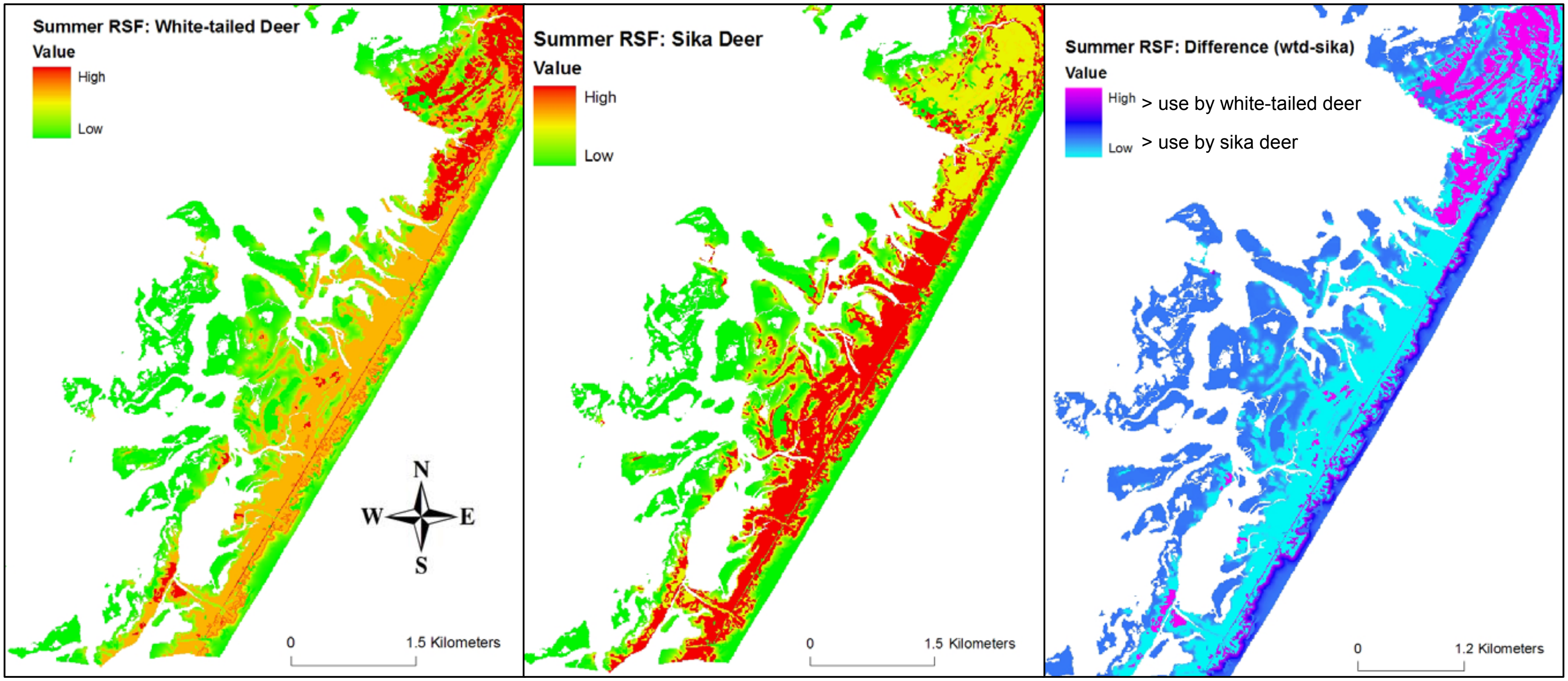
Appendix C. Resource selection function (RSF) maps during summer 2006–2007 for white-tailed deer, sika deer, and the difference (white-tailed – sika) on Assateague Island, Maryland, USA.


Summer RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.8 Kilometers
Summer RSF: Sika Deer
Value
High
Low
0
1.8 Kilometers
Summer RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.5 Kilometers



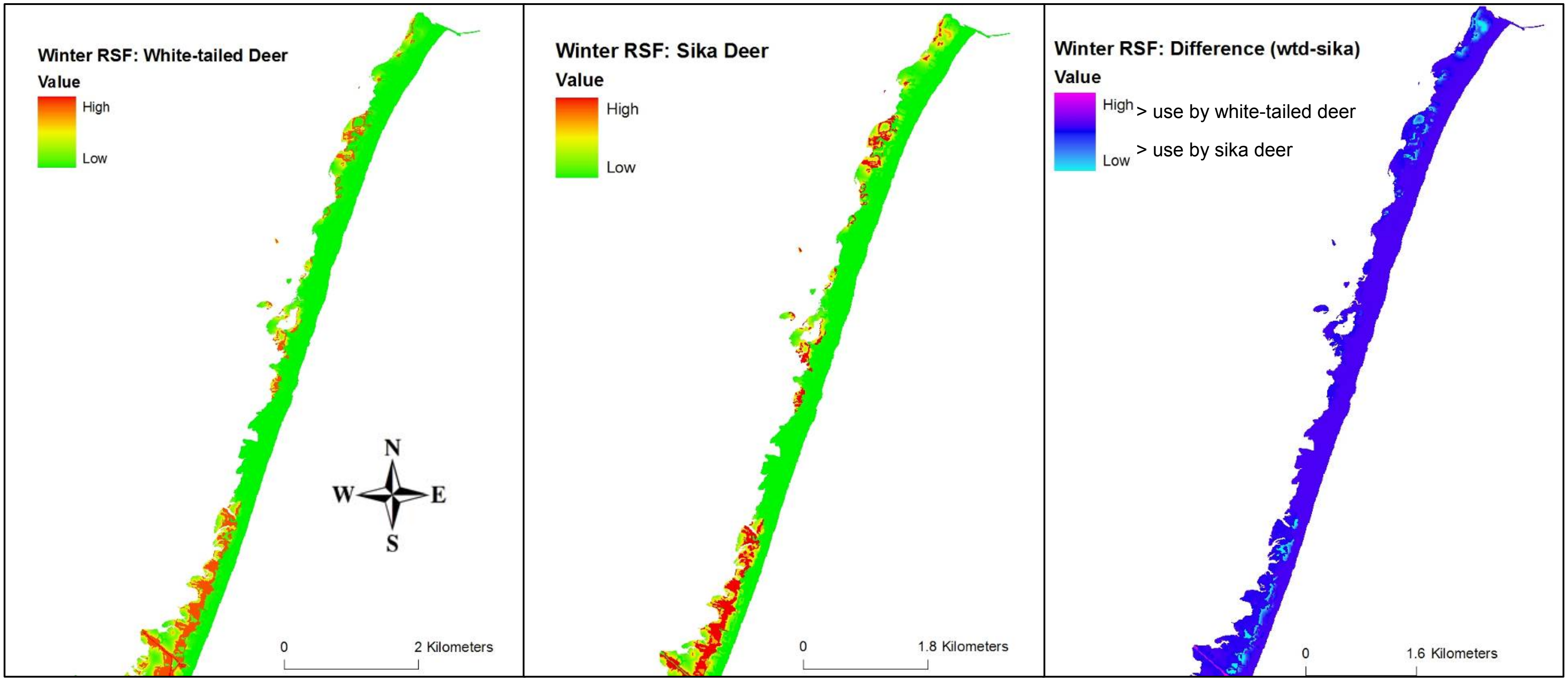
Summer RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Summer RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Summer RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.2 Kilometers

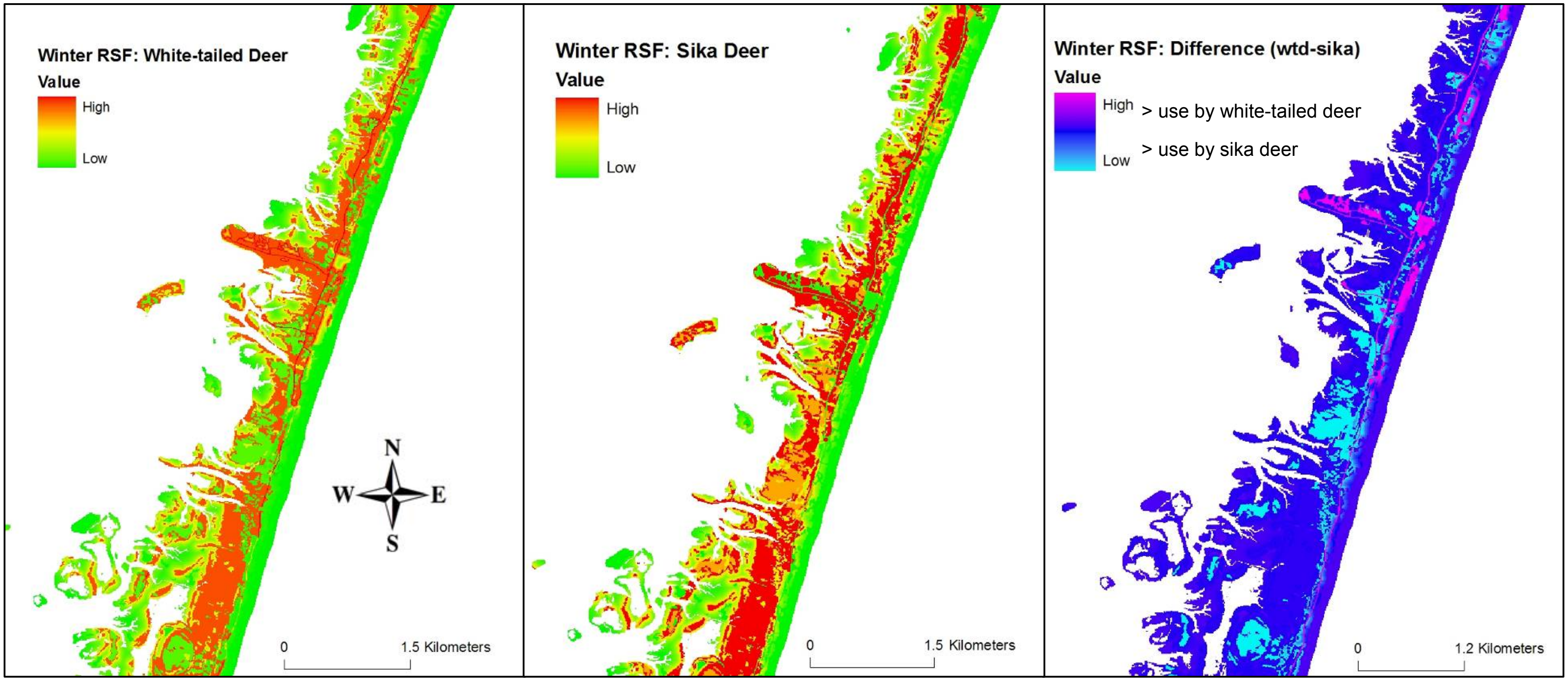

Summer RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Summer RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Summer RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.2 Kilometers

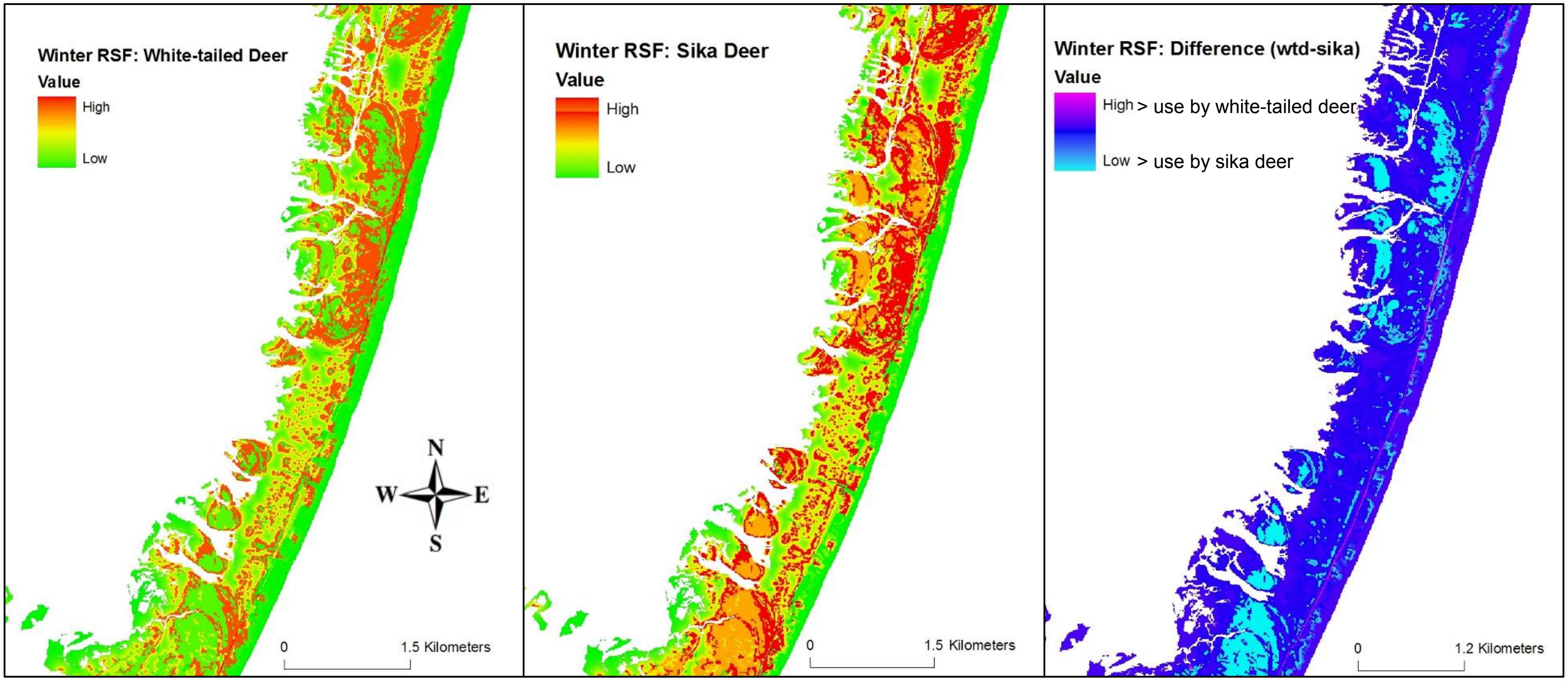


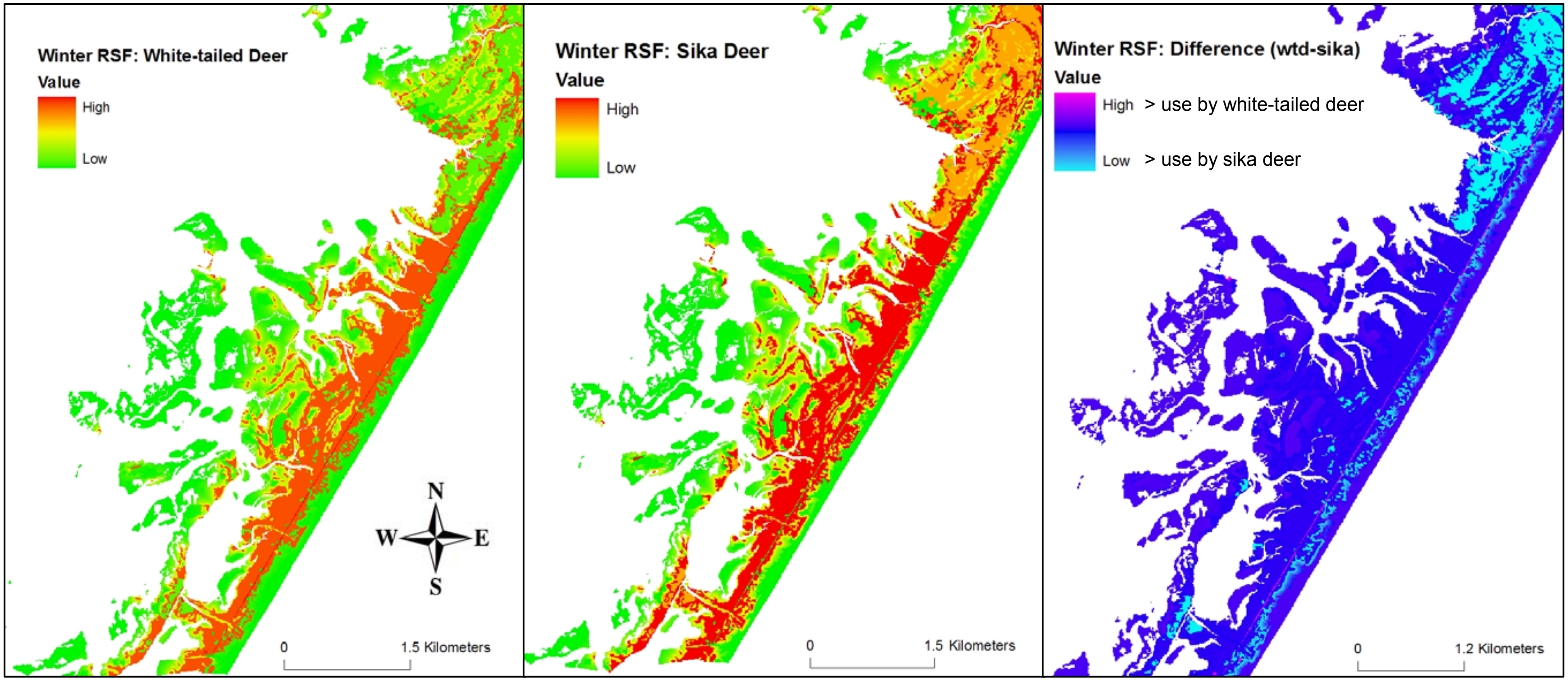
Summer RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Summer RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Summer RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.2 Kilometers

Appendix D. Resource selection function (RSF) maps during winter 2006 for white-tailed deer, sika deer, and the difference (white-tailed – sika) on Assateague Island, Maryland, USA.


Winter RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
2 Kilometers
Winter RSF: Sika Deer
Value
High
Low
0
1.8 Kilometers
Winter RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.6 Kilometers


Winter RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Winter RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Winter RSF: Difference (wtd-sika)
Value
High
> use by white-tailed deer
Low
> use by sika deer
0
1.2 Kilometers


Winter RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Winter RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Winter RSF: Difference (wtd-sika)
Value
High > use by white-tailed deer
Low > use by sika deer
0
1.2 Kilometers


Winter RSF: White-tailed Deer
Value
High
Low
N
W
E
S
0
1.5 Kilometers
Winter RSF: Sika Deer
Value
High
Low
0
1.5 Kilometers
Winter RSF: Difference (wtd-sika)
Value
High > use by white-tailed deer
Low > use by sika deer
0
1.2 Kilometers

Appendix E. Population estimates.

Lincoln-Petersen Estimator

The use of marked deer (e.g., radio-collared deer) can be used to estimate population abundance using the Lincoln-Petersen (L-P) estimator. On Assateague Island hunting occurs in autumn and the animals recovered in the harvest can be treated as data for the second sampling occasion (and provides recapture data). This estimator assumes (1) no mortality, births, emigration, or immigration occurs (i.e., the population is "closed" during the period between marking and recapture), (2) marks are not lost and are recorded correctly upon recapture, (3) all animals have the same probability of capture, (4) all animals have the same probability of being harvested, and (5) marking does not affect the probability of being harvested. Because we observed little natural mortality it would have been possible to include the recovery of ear-tagged only deer in these calculations; however, record keeping of ear-tagged deer at the hunter check station was not sufficiently accurate to include these data in our analyses.

The assumption that all deer have the same probability of capture and harvest is likely violated because we pooled data from males and females; consequently, resulting estimates of the variance of population size are likely underestimated. Also, even though deer are captured during January–April, because they are radio-collared it is possible to know the number of marked deer immediately prior to the hunting season to estimate the number of deer in the population. Ear-tagged only deer could be used, but one would have to assume no mortality between capture and the hunting season, and because births occurred after tagging the population estimate is still an estimate of population size immediately prior to the hunting season.

We used the Lincoln-Petersen estimator corrected for small sample size

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1,$$

where n_1 = no. marked deer, n_2 = number of harvested deer, and m_2 = number of marked deer harvested. We estimated the standard error of $\hat{N}$ as

$$\hat{S}E(\hat{N}) = \sqrt{\frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)(m_2 + 2)}}.$$

We estimated a 95% confidence interval by assuming the estimate of N was distributed log-normally and calculated

$$C = \exp\left[1.96 * \sqrt{\ln\left(1 + \frac{\hat{S}E(\hat{N})^2}{\hat{N}^2}\right)}\right]$$

so that the 95% lower bound was $\left(\hat{N} - (n_2 + n_1 - m_2)\right)/C + (n_2 + n_1 - m_2)$ and the upper bound was $\left(\hat{N} - (n_2 + n_1 - m_2)\right) \times C + (n_2 + n_1 - m_2)$.

Table E1. Estimates of the number of sika and white-tailed deer on Assateague Island, Maryland, USA, 2006–2007.

Year Species	Number marked deer	Number marked deer harvested	Number deer harvested	$\hat{N}$	$\hat{SE}(\hat{N})$	95% CI
2006						
White-tailed deer	6	1	8	31	13.56	21–53
Sika deer	23	5	148	595	191.12	398–959
2007						
White-tailed deer	11	3	31	95	32.79	68–147
Sika deer	30	7	87	340	93.35	246–500

Catch-Effort Estimator

We used a conditional likelihood approach to estimate *N* using catch-effort data (Gould and Pollock 1997) for antlered and antlerless sika deer during the 24 November – 8 December 2007 hunting season. Catch-effort models generally require a substantial portion of the population to be harvested before they can provide precise estimates of abundance. Also, changes in hunter behavior can introduce bias because a measure of hunter effort (e.g., hunter hours) may not accurately reflect true effort if, for example, some hunters forego harvesting antlerless deer until they have harvested an antlered deer. Similarly, harvest regulations that require hunters to harvest an antlerless deer before they can harvest a second antlered deer will adversely affect population estimates using catch-effort models.

We used the same analysis to estimate abundance of sika and white-tailed deer in which hunter effort and harvest were pooled by week and antlered and antlerless harvest data were combined. We restricted this analysis to the October 13–December 8 hunting seasons and multiplied effort by 3.0 during the muzzleloader and shotgun seasons.

Let N = the population size at the start of the regular rifle season (for antlered or antlerless deer), n_i = the number of deer killed during the ith day (i = 1, …, s), $x_i = \sum_{j=1}^{i-1} n_j$, the previous cumulative effort (i = 2, …, s+1; $x_1 = 0$; x_{s+1} = total annual harvest), f_i = number of half-day hunter trips on day i, k = harvest coefficient (harvest rate per unit of effort), $p_i = 1 - e^{-kf}$ = probability of harvest for a deer given f_i units of hunting effort, and $q_i = 1 - p_i = e^{-kf}$. This parameterization of probability of harvest assumes a Poisson process for sampling effort. Finally, $Q = (1 - p_1 - q_1 p_2 \cdots - q_1 q_2 \cdots q_{s-1} p_s)$, in which 1 – Q is the probability that a deer is harvested during one of the hunting days.

We used program SURVIV (White 1983) to maximize the likelihood of the total harvest (x_{s+1}) given the observed harvests (vector of n_i's):

$$L(x_{s+1} \mid \underline{n}) = \frac{x_{s+1}!}{\prod_{i=1}^{s} n_i!} \left[\frac{p_1}{1-Q}\right]^{n_1} \left[\frac{q_1 p_2}{1-Q}\right]^{n_2} \cdots \left[\frac{q_1 q_2 \cdots q_{s-1} p_s}{1-Q}\right]^{n_s} .$$

If we model the p_i's and q_i's in terms of the harvest quotient (termed 'catchability quotient' in the fisheries literature), *k*, then maximizing this likelihood provides an estimate of *k*, which can be used to estimate p_i, q_i, and *Q*. In turn, $\hat{N} = x_{s+1} / 1 - \hat{Q}$. Output from Program SURVIV is provided in Appendixes H–K.

Table E2. Summary results of catch-effort population estimates for antlered and antlerless sika deer using data from the 24 November–8 December 2007 hunting season, Assateague Island National Seashore.

Day of regular season	Effort[a]	Antlerless P(not harvested)	Antlered P(not harvested)
24 November	1.37	0.997689839	0.999999999
26 November	0.59	0.999004458	1
27 November	0.36	0.999392433	1
28 November	0.74	0.998751512	1
29 November	0.80	0.998650352	1
30 November	0.45	0.999240598	1
1 December	0.61	0.998970728	1
3 December	0.23	0.999611789	1
4 December	0.45	0.999240598	1
5 December	0.54	0.999088787	1
6 December	0.36	0.999392433	1
7 December	0.48	0.999189992	1
8 December	0.43	0.999274337	1
P(never harvested) = Q =		0.987568357	0.999999996
Reported harvest =		23	22
$\hat{N}$ =		1,850	5,176,725,611
$\hat{k}$ =		0.0016882	5.73521E-10
$\hat{SE}(\hat{k})$=		0.0980307	0.100218
GOF χ^2 =		18.061	8.933
df =		11	9
P =		0.0802	0.4435

[a] Effort measured in hundreds of half-day hunter trips.

Table E3. Summary results of catch-effort population estimates for sika deer and white-tailed deer using data from the 12 October–8 December 2007 hunting seasons, Assateague Island National Seashore.

Week of Hunting seasons	Effort[a]	Sika deer P(not harvested)	White-tailed deer P(not harvested)
12-Oct	5.25	0.978765796	0.722020606
19-Oct	1.82	0.992587142	0.893231147
26-Oct	0.25	0.99897848	0.984610054
02-Nov	0.50	0.997958003	0.969456959
09-Nov	0.43	0.998243631	0.973676163
16-Nov	0.64	0.997386991	0.961073321
23-Nov	4.14	0.9832174	0.773492755
30-Nov	7.92	0.968140259	0.611803499
07-Dec	2.73	0.988901346	0.844200856
P(never harvested) = Q =		0.907730396	0.230139574
Reported harvest =		67	27
$\hat{N}$ =		726	35
$\hat{k}$ =		0.00408817	0.0620384
$\hat{SE}(\hat{k})$ =		0.0183918	0.0305062
GOF χ^2 =		160.83	14.186
df =		7	7
P =		0.024	0.048

[a] Effort measured in hundreds of half-day hunter trips but multiplied by 3.0 during muzzleloader and shotgun seasons.

Gould, W. R., and K. H. Pollock. 1997. Catch-effort maximum likelihood estimation of important population parameters. Canadian Journal of Fisheries and Aquatic Sciences 54:890–897.

White, G. C. 1983. Numerical estimation of survival rates from band-recovery and biotelemetry data. Journal of Wildlife Management 47:716–728.

Appendix F. Input Data and Results of Survival Rate Analysis from Program MARK.

```
   Program  MARK  - Survival Rate Estimation with Capture-Recapture Data
   Compaq(Win32) Vers. 5.1 Apr 2007     29-May-2009 10:31:10    Page  001
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

  INPUT --- proc title Monthly Survival Final;

     Time in seconds for last procedure was 0.00

  INPUT --- proc chmatrix occasions=12 groups=15 etype=Known NoHist
  INPUT --- hist=390;

  INPUT ---    glabel(1)=Group 1;

  INPUT ---    glabel(2)=Group 2;

  INPUT ---    glabel(3)=Group 3;

  INPUT ---    glabel(4)=Group 4;

  INPUT ---    glabel(5)=Group 5;

  INPUT ---    glabel(6)=Group 6;

  INPUT ---    glabel(7)=Group 7;

  INPUT ---    glabel(8)=Group 8;

  INPUT ---    glabel(9)=Group 9;

  INPUT ---    glabel(10)=Group 10;

  INPUT ---    glabel(11)=Group 11;

  INPUT ---    glabel(12)=Group 12;

  INPUT ---    glabel(13)=Group 13;

  INPUT ---    glabel(14)=Group 14;

  INPUT ---    glabel(15)=Group 15;

  INPUT ---    time interval  1 1 1 1 1 1 1 1 1 1 1 1;

  INPUT ---    /*Known fate monthly survival model for Mark. Monthly
  INPUT ---    analysis: Month 1 = January 1st.Group 1 = SIKA AD FEMALE
  INPUT ---    06, Group 2 = SIKA JUV FEMALE 06, GROUP 3 = SIKA AD MALE
  INPUT ---    06, GROUP 4 = SIKA JUV MALE 06, GROUP 5 = WTD AD FEMALE 06,
```

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

INPUT ---    GROUP 6 = WTD JUV FEMALE 06, GROUP 7 = WTD JUV MALE 06,
INPUT ---    GROUP 8 = SIKA AD FEMALE 07, GROUP 9 = SIKA JUV FEMALE 07,
INPUT ---    GROUP 10 = SIKA AD MALE 07, GROUP 11 = SIKA JUV MALE 07,
INPUT ---    GROUP 12 = WTD AD FEMALE 07, GROUP 13 = WTD JUV FEMALE 07,
INPUT ---    GROUP 14 = WTD AD MALE 07, GROUP 15 = WTD JUV MALE 07*/
INPUT ---    Known   Fate Group=1;
INPUT ---       2 0;
INPUT ---       7 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 0;
INPUT ---       9 1;

INPUT ---    Known   Fate Group=2;
INPUT ---       2 0;
INPUT ---       3 0;
INPUT ---       5 0;
INPUT ---       5 0;
INPUT ---       5 0;
INPUT ---       5 0;
INPUT ---       5 0;
INPUT ---       5 0;
INPUT ---       5 1;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;

INPUT ---    Known   Fate Group=3;
INPUT ---       2 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 0;
INPUT ---       4 1;
INPUT ---       3 0;
```

```
 INPUT ---       3 0;

 INPUT ---    Known   Fate Group=4;
 INPUT ---       1 0;
 INPUT ---       3 0;
 INPUT ---       4 0;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 1;
 INPUT ---       4 1;
 INPUT ---       3 0;

 INPUT ---    Known   Fate Group=5;
 INPUT ---       1 0;
 INPUT ---       3 0;
 INPUT ---       3 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 1;

 INPUT ---    Known   Fate Group=6;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=7;
```

```
 INPUT ---       0 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 1;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=8;
 INPUT ---      12 0;
 INPUT ---      13 0;
 INPUT ---      15 0;
 INPUT ---      19 0;
 INPUT ---      20 1;
 INPUT ---      19 0;
 INPUT ---      19 0;
 INPUT ---      19 0;
 INPUT ---      19 0;
 INPUT ---      19 0;
 INPUT ---      19 1;
 INPUT ---      18 1;

 INPUT ---    Known   Fate Group=9;
 INPUT ---       0 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=10;
 INPUT ---       6 0;
 INPUT ---       7 0;
 INPUT ---       9 0;
```

```
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 1;
 INPUT ---       8 2;
 INPUT ---       6 1;
 INPUT ---       5 2;

 INPUT ---    Known   Fate Group=11;
 INPUT ---       0 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=12;
 INPUT ---       4 1;
 INPUT ---       3 0;
 INPUT ---       6 0;
 INPUT ---       6 0;
 INPUT ---       6 0;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 1;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;

 INPUT ---    Known   Fate Group=13;
 INPUT ---       0 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
```

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=14;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 1;
 INPUT ---       1 1;
 INPUT ---       0 0;

 INPUT ---    Known   Fate Group=15;
 INPUT ---       0 0;
 INPUT ---       0 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       1 0;

     Number of unique encounter histories read was 19.

     Number of individual covariates read was 0.
     Time interval lengths are all equal to 1.

     Data type is Known Fates.

    Time in seconds for last procedure was 0.09
```

```
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 INPUT --- proc estimate link=Sin varest=2ndPart ;

 INPUT --- model={S(nonhunt/hunt*species*sex)};

 INPUT ---    group=1 S rows=1 cols=12 Square Time=1;

 INPUT ---    group=2 S rows=1 cols=12 Square Time=1;

 INPUT ---    group=3 S rows=1 cols=12 Square Time=13;

 INPUT ---    group=4 S rows=1 cols=12 Square Time=13;

 INPUT ---    group=5 S rows=1 cols=12 Square Time=25;

 INPUT ---    group=6 S rows=1 cols=12 Square Time=25;

 INPUT ---    group=7 S rows=1 cols=12 Square Time=37;

 INPUT ---    group=8 S rows=1 cols=12 Square Time=1;

 INPUT ---    group=9 S rows=1 cols=12 Square Time=1;

 INPUT ---    group=10 S rows=1 cols=12 Square Time=13;

 INPUT ---    group=11 S rows=1 cols=12 Square Time=13;

 INPUT ---    group=12 S rows=1 cols=12 Square Time=25;

 INPUT ---    group=13 S rows=1 cols=12 Square Time=25;

 INPUT ---    group=14 S rows=1 cols=12 Square Time=37;

 INPUT ---    group=15 S rows=1 cols=12 Square Time=37;

 INPUT ---    design matrix constraints=48 covariates=8;
 INPUT ---             1 0 0 0 0 0 0 0;
 INPUT ---             1 0 0 0 0 0 0 0;
 INPUT ---             1 0 0 0 0 0 0 0;
 INPUT ---             1 0 0 0 0 0 0 0;
 INPUT ---             1 0 0 0 0 0 0 0;
 INPUT ---             1 0 0 0 0 0 0 0;
 INPUT ---             1 0 0 0 0 0 0 0;
```

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

INPUT ---             0 1 0 0 0 0 0 0;
INPUT ---             0 1 0 0 0 0 0 0;
INPUT ---             0 1 0 0 0 0 0 0;
INPUT ---             0 1 0 0 0 0 0 0;
INPUT ---             0 1 0 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 1 0 0 0 0 0;
INPUT ---             0 0 0 1 0 0 0 0;
INPUT ---             0 0 0 1 0 0 0 0;
INPUT ---             0 0 0 1 0 0 0 0;
INPUT ---             0 0 0 1 0 0 0 0;
INPUT ---             0 0 0 1 0 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 1 0 0 0;
INPUT ---             0 0 0 0 0 1 0 0;
INPUT ---             0 0 0 0 0 1 0 0;
INPUT ---             0 0 0 0 0 1 0 0;
INPUT ---             0 0 0 0 0 1 0 0;
INPUT ---             0 0 0 0 0 1 0 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 1 0;
INPUT ---             0 0 0 0 0 0 0 1;
INPUT ---             0 0 0 0 0 0 0 1;
INPUT ---             0 0 0 0 0 0 0 1;
INPUT ---             0 0 0 0 0 0 0 1;
INPUT ---             0 0 0 0 0 0 0 1;

INPUT ---    blabel(1)=;

INPUT ---    blabel(2)=;
```

```
 INPUT ---    blabel(3)=;

 INPUT ---    blabel(4)=;

 INPUT ---    blabel(5)=;

 INPUT ---    blabel(6)=;

 INPUT ---    blabel(7)=;

 INPUT ---    blabel(8)=;

 INPUT ---    rlabel(1)=S;

 INPUT ---    rlabel(2)=S;

 INPUT ---    rlabel(3)=S;

 INPUT ---    rlabel(4)=S;

 INPUT ---    rlabel(5)=S;

 INPUT ---    rlabel(6)=S;

 INPUT ---    rlabel(7)=S;

 INPUT ---    rlabel(8)=S;

 INPUT ---    rlabel(9)=S;

 INPUT ---    rlabel(10)=S;

 INPUT ---    rlabel(11)=S;

 INPUT ---    rlabel(12)=S;

 INPUT ---    rlabel(13)=S;

 INPUT ---    rlabel(14)=S;

 INPUT ---    rlabel(15)=S;

 INPUT ---    rlabel(16)=S;
```

```
 INPUT ---    rlabel(17)=S;

 INPUT ---    rlabel(18)=S;

 INPUT ---    rlabel(19)=S;

 INPUT ---    rlabel(20)=S;

 INPUT ---    rlabel(21)=S;

 INPUT ---    rlabel(22)=S;

 INPUT ---    rlabel(23)=S;

 INPUT ---    rlabel(24)=S;

 INPUT ---    rlabel(25)=S;

 INPUT ---    rlabel(26)=S;

 INPUT ---    rlabel(27)=S;

 INPUT ---    rlabel(28)=S;

 INPUT ---    rlabel(29)=S;

 INPUT ---    rlabel(30)=S;

 INPUT ---    rlabel(31)=S;

 INPUT ---    rlabel(32)=S;

 INPUT ---    rlabel(33)=S;

 INPUT ---    rlabel(34)=S;

 INPUT ---    rlabel(35)=S;

 INPUT ---    rlabel(36)=S;

 INPUT ---    rlabel(37)=S;

 INPUT ---    rlabel(38)=S;

 INPUT ---    rlabel(39)=S;
```

```
 Program  MARK  - Survival Rate Estimation with Capture-Recapture Data
  Compaq(Win32) Vers. 5.1 Apr 2007     29-May-2009 10:31:11    Page  011
  Monthly Survival Final
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 INPUT ---    rlabel(40)=S;

 INPUT ---    rlabel(41)=S;

 INPUT ---    rlabel(42)=S;

 INPUT ---    rlabel(43)=S;

 INPUT ---    rlabel(44)=S;

 INPUT ---    rlabel(45)=S;

 INPUT ---    rlabel(46)=S;

 INPUT ---    rlabel(47)=S;

 INPUT ---    rlabel(48)=S;

Link Function Used is SIN

Variance Estimation Procedure Used is 2ndPart
-2logL(saturated) = 95.744181
Effective Sample Size = 746

Number of function evaluations was 22 for 8 parameters.
Time for numerical optimization was 0.02 seconds.
-2logL {S(nonhunt/hunt*species*sex)} = 152.02577
Penalty {S(nonhunt/hunt*species*sex)} = 0.0000000
Gradient {S(nonhunt/hunt*species*sex)}:
-0.1168812E-05 0.2516225E-05  0.000000     0.1499474E-05  0.000000
 0.1308489E-05 0.1105561E-05 0.8542095E-06
S Vector {S(nonhunt/hunt*species*sex)}:
  207.0000      166.0000      82.00000      71.00001      59.00000
  51.00000      22.00000      14.50000
Time to compute number of parameters was 0.02 seconds.
  Threshold =  0.1800000E-06     Condition index =  0.7004832E-01
Conditioned S Vector {S(nonhunt/hunt*species*sex)}:
  1.000000     0.8019324     0.3961353     0.3429952     0.2850242
 0.2463768     0.1062802     0.7004832E-01
Number of Estimated Parameters {S(nonhunt/hunt*species*sex)} = 8
DEVIANCE {S(nonhunt/hunt*species*sex)} = 56.281590
DEVIANCE Degrees of Freedom {S(nonhunt/hunt*species*sex)} = 165
c-hat {S(nonhunt/hunt*species*sex)} = 0.3411005
AIC {S(nonhunt/hunt*species*sex)} = 168.02577
AICc {S(nonhunt/hunt*species*sex)} = 168.22116
BIC {S(nonhunt/hunt*species*sex)} = 204.94358
Pearson Chisquare {S(nonhunt/hunt*species*sex)} = Not a Number

               SIN Link Function Parameters of {S(nonhunt/hunt*species*sex)}
                                                           95% Confidence Interval
Parameter                    Beta         Standard Error      Lower          Upper
-------------------------  --------------  --------------  --------------  ----------
   1:                      1.4316745       0.0695048       1.2954451       1.5679040
```

2:	1.2590756	0.0776151	1.1069501	1.4112011
3:	1.5707963	0.1301889	1.3156260	1.8259666
4:	0.8954457	0.1104315	0.6789999	1.1118915
5:	1.8087134	0.1186782	1.5761042	2.0413226
6:	1.1721019	0.1400280	0.8976470	1.4465568
7:	1.5707963	0.2626129	1.0560751	2.0855175
8:	2.3272527	0.2132007	1.9093793	2.7451261

Real Function Parameters of {S(nonhunt/hunt*species*sex)}

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
1:S	0.9951691	0.0048192	0.9665320	0.9993199
2:S	0.9951691	0.0048192	0.9665320	0.9993199
3:S	0.9951691	0.0048192	0.9665320	0.9993199
4:S	0.9951691	0.0048192	0.9665320	0.9993199
5:S	0.9951691	0.0048192	0.9665320	0.9993199
6:S	0.9951691	0.0048192	0.9665320	0.9993199
7:S	0.9951691	0.0048192	0.9665320	0.9993199
8:S	0.9759036	0.0119021	0.9375718	0.9909269
9:S	0.9759036	0.0119021	0.9375718	0.9909269
10:S	0.9759036	0.0119021	0.9375718	0.9909269
11:S	0.9759036	0.0119021	0.9375718	0.9909269
12:S	0.9759036	0.0119021	0.9375718	0.9909269
13:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
14:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
15:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
16:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
17:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
18:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
19:S	1.0000000	0.1371763E-008	1.0000000	1.0000000
20:S	0.8902439	0.0345193	0.8023104	0.9418966
21:S	0.8902439	0.0345193	0.8023104	0.9418966
22:S	0.8902439	0.0345193	0.8023104	0.9418966
23:S	0.8902439	0.0345193	0.8023104	0.9418966
24:S	0.8902439	0.0345193	0.8023104	0.9418966
25:S	0.9859155	0.0139850	0.9067468	0.9980195
26:S	0.9859155	0.0139850	0.9067468	0.9980195
27:S	0.9859155	0.0139850	0.9067468	0.9980195
28:S	0.9859155	0.0139850	0.9067468	0.9980195
29:S	0.9859155	0.0139850	0.9067468	0.9980195
30:S	0.9859155	0.0139850	0.9067468	0.9980195
31:S	0.9859155	0.0139850	0.9067468	0.9980195
32:S	0.9607843	0.0271805	0.8562815	0.9901716

- -

33:S	0.9607843	0.0271805	0.8562815	0.9901716
34:S	0.9607843	0.0271805	0.8562815	0.9901716
35:S	0.9607843	0.0271805	0.8562815	0.9901716
36:S	0.9607843	0.0271805	0.8562815	0.9901716
37:S	1.0000000	0.0000000	1.0000000	1.0000000
38:S	1.0000000	0.0000000	1.0000000	1.0000000
39:S	1.0000000	0.0000000	1.0000000	1.0000000
40:S	1.0000000	0.0000000	1.0000000	1.0000000
41:S	1.0000000	0.0000000	1.0000000	1.0000000
42:S	1.0000000	0.0000000	1.0000000	1.0000000
43:S	1.0000000	0.0000000	1.0000000	1.0000000
44:S	0.8636364	0.0731650	0.6520711	0.9553617
45:S	0.8636364	0.0731650	0.6520711	0.9553617
46:S	0.8636364	0.0731650	0.6520711	0.9553617
47:S	0.8636364	0.0731650	0.6520711	0.9553617
48:S	0.8636364	0.0731650	0.6520711	0.9553617

Estimates of Derived Parameters

Survival Estimates of {S(nonhunt/hunt*species*sex)}

Group	Pr. Surviving Duration of Study	Standard Error	95% Confidence Interval Lower	Upper
1	0.8556827	0.0596998	0.6968504	0.9386257
2	0.8556827	0.0596998	0.6968504	0.9386257
3	0.5591715	0.1084096	0.3488261	0.7502233
4	0.5591715	0.1084096	0.3488261	0.7502233
5	0.7413228	0.1281160	0.4361971	0.9139086
6	0.7413228	0.1281160	0.4361971	0.9139086
7	0.4804571	0.2035149	0.1575980	0.8205071
8	0.8556827	0.0596998	0.6968504	0.9386257

- -

9	0.8556827	0.0596998	0.6968504	0.9386257
10	0.5591715	0.1084096	0.3488261	0.7502233
11	0.5591715	0.1084096	0.3488261	0.7502233
12	0.7413228	0.1281160	0.4361971	0.9139086
13	0.7413228	0.1281160	0.4361971	0.9139086
14	0.4804571	0.2035149	0.1575980	0.8205071
15	0.4804571	0.2035149	0.1575980	0.8205071

Time in seconds for last procedure was 0.09

INPUT --- proc stop;

Time in minutes for this job was 0.00

E X E C U T I O N   S U C C E S S F U L

Appendix G. Input Data and Results of Harvest Rate Analysis from Program MARK.

```
 Program  MARK  - Survival Rate Estimation with Capture-Recapture Data
  Compaq(Win32) Vers. 4.4 April 2007   27-Feb-2008 19:12:37    Page  001
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 INPUT --- proc title Harvest Rate;

    Time in seconds for last procedure was 0.00

 INPUT --- proc chmatrix occasions=5 groups=15 etype=Known NoHist
 INPUT --- hist=300;

 INPUT ---    glabel(1)=Group 1;

 INPUT ---    glabel(2)=Group 2;

 INPUT ---    glabel(3)=Group 3;

 INPUT ---    glabel(4)=Group 4;

 INPUT ---    glabel(5)=Group 5;

 INPUT ---    glabel(6)=Group 6;

 INPUT ---    glabel(7)=Group 7;

 INPUT ---    glabel(8)=Group 8;

 INPUT ---    glabel(9)=Group 9;

 INPUT ---    glabel(10)=Group 10;

 INPUT ---    glabel(11)=Group 11;

 INPUT ---    glabel(12)=Group 12;

 INPUT ---    glabel(13)=Group 13;

 INPUT ---    glabel(14)=Group 14;

 INPUT ---    glabel(15)=Group 15;

 INPUT ---    time interval  1 1 1 1 1;

 INPUT ---    /*Known fate monthly survival model for Mark. Monthly
 INPUT ---    analysis: Month 1 = September 1st. Juv = 1.5 year old
 INPUT ---    deer.Group 1 = SIKA AD FEMALE 06, Group 2 = SIKA JUV FEMALE
 INPUT ---    06, GROUP 3 = SIKA AD MALE 06, GROUP 4 = SIKA JUV MALE 06,
```

```
 INPUT ---    GROUP 5 = WTD AD FEMALE 06, GROUP 6 = WTD JUV FEMALE 06,
 INPUT ---    GROUP 7 = WTD JUV MALE 06, GROUP 8 = SIKA AD FEMALE 07,
 INPUT ---    GROUP 9 = SIKA JUV FEMALE 07, GROUP 10 = SIKA AD MALE 07,
 INPUT ---    GROUP 11 = SIKA JUV MALE 07, GROUP 12 = WTD AD FEMALE 07,
 INPUT ---    GROUP 13 = WTD JUV FEMALE 07, GROUP 14 = WTD AD MALE 07,
 INPUT ---    GROUP 15 = WTD JUV MALE 07*/
 INPUT ---    Known   Fate Group=1;
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 0;
 INPUT ---       9 1;

 INPUT ---    Known   Fate Group=2;
 INPUT ---       5 0;
 INPUT ---       5 1;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;

 INPUT ---    Known   Fate Group=3;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 1;
 INPUT ---       3 0;
 INPUT ---       3 0;

 INPUT ---    Known   Fate Group=4;
 INPUT ---       5 0;
 INPUT ---       5 0;
 INPUT ---       5 1;
 INPUT ---       4 1;
 INPUT ---       3 0;

 INPUT ---    Known   Fate Group=5;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 1;

 INPUT ---    Known   Fate Group=6;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
```

```
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=7;
 INPUT ---       2 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=8;
 INPUT ---       19 0;
 INPUT ---       19 0;
 INPUT ---       19 0;
 INPUT ---       19 1;
 INPUT ---       18 1;

 INPUT ---    Known   Fate Group=9;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=10;
 INPUT ---       9 0;
 INPUT ---       9 1;
 INPUT ---       8 2;
 INPUT ---       6 1;
 INPUT ---       5 2;

 INPUT ---    Known   Fate Group=11;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=12;
 INPUT ---       5 1;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
 INPUT ---       4 0;
```

```
 INPUT ---    Known   Fate Group=13;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;
 INPUT ---       1 0;

 INPUT ---    Known   Fate Group=14;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 1;
 INPUT ---       1 1;
 INPUT ---       0 0;

 INPUT ---    Known   Fate Group=15;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       2 0;
 INPUT ---       1 0;

     Number of unique encounter histories read was 10.

     Number of individual covariates read was 0.
     Time interval lengths are all equal to 1.

     Data type is Known Fates.

    Time in seconds for last procedure was 0.34
```

```
 INPUT --- proc estimate link=Sin varest=2ndPart ;

 INPUT --- model={S(species*sex)};

 INPUT ---    group=1 S rows=1 cols=5 Square;
 INPUT ---               1   1   1   1   1;

 INPUT ---    group=2 S rows=1 cols=5 Square;
 INPUT ---               1   1   1   1   1;

 INPUT ---    group=3 S rows=1 cols=5 Square;
 INPUT ---               2   2   2   2   2;

 INPUT ---    group=4 S rows=1 cols=5 Square;
 INPUT ---               2   2   2   2   2;

 INPUT ---    group=5 S rows=1 cols=5 Square;
 INPUT ---               3   3   3   3   3;

 INPUT ---    group=6 S rows=1 cols=5 Square;
 INPUT ---               3   3   3   3   3;

 INPUT ---    group=7 S rows=1 cols=5 Square;
 INPUT ---               4   4   4   4   4;

 INPUT ---    group=8 S rows=1 cols=5 Square;
 INPUT ---               1   1   1   1   1;

 INPUT ---    group=9 S rows=1 cols=5 Square;
 INPUT ---               1   1   1   1   1;

 INPUT ---    group=10 S rows=1 cols=5 Square;
 INPUT ---               2   2   2   2   2;

 INPUT ---    group=11 S rows=1 cols=5 Square;
 INPUT ---               2   2   2   2   2;

 INPUT ---    group=12 S rows=1 cols=5 Square;
 INPUT ---               3   3   3   3   3;

 INPUT ---    group=13 S rows=1 cols=5 Square;
 INPUT ---               3   3   3   3   3;
```

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 INPUT ---    group=14 S rows=1 cols=5 Square;
 INPUT ---              4   4   4   4   4;

 INPUT ---    group=15 S rows=1 cols=5 Square;
 INPUT ---              4   4   4   4   4;

 INPUT ---    design matrix constraints=4 covariates=4 identity;

 INPUT ---    blabel(1)=S;

 INPUT ---    blabel(2)=S;

 INPUT ---    blabel(3)=S;

 INPUT ---    blabel(4)=S;

 INPUT ---    rlabel(1)=S;

 INPUT ---    rlabel(2)=S;

 INPUT ---    rlabel(3)=S;

 INPUT ---    rlabel(4)=S;

Link Function Used is SIN

Variance Estimation Procedure Used is 2ndPart
-2logL(saturated) = 80.532301
Effective Sample Size = 321

Number of function evaluations was 13 for 4 parameters.
Time for numerical optimization was 0.02 seconds.
-2logL {S(species*sex)} = 124.73244
Penalty {S(species*sex)} = 0.0000000
Gradient {S(species*sex)}:
 0.3145281E-05  0.000000    -0.6542444E-06 0.7256947E-06
S Vector {S(species*sex)}:
  166.0000      82.00000      51.00000      22.00000
Time to compute number of parameters was 0.01 seconds.
  Threshold =  0.1000000E-06     Condition index =  0.1325301
Conditioned S Vector {S(species*sex)}:
  1.000000     0.4939759     0.3072289     0.1325301
Number of Estimated Parameters {S(species*sex)} = 4
DEVIANCE {S(species*sex)} = 44.200138
DEVIANCE Degrees of Freedom {S(species*sex)} = 70
c-hat {S(species*sex)} = 0.6314305
AIC {S(species*sex)} = 132.73244
AICc {S(species*sex)} = 132.85902
Pearson Chisquare {S(species*sex)} = Not a Number
```

SIN Link Function Parameters of {S(species*sex)}

Parameter	Beta	Standard Error	95% Confidence Interval Lower	Upper
1:S	1.2590756	0.0776151	1.1069501	1.4112011
2:S	0.8954457	0.1104315	0.6789999	1.1118915
3:S	1.1721019	0.1400280	0.8976470	1.4465568
4:S	0.9582416	0.2132007	0.5403682	1.3761150

Real Function Parameters of {S(species*sex)}

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
1:S	0.9759036	0.0119021	0.9375718	0.9909269
2:S	0.8902439	0.0345193	0.8023105	0.9418966
3:S	0.9607843	0.0271805	0.8562815	0.9901716
4:S	0.9090909	0.0612909	0.7003595	0.9771605

Estimates of Derived Parameters

Survival Estimates of {S(species*sex)}

Group	Pr. Surviving Duration of Study	Standard Error	95% Confidence Interval Lower	Upper
1	0.8851862	0.0539787	0.7313511	0.9562063
2	0.8851862	0.0539787	0.7313511	0.9562063
3	0.5591715	0.1084096	0.3488261	0.7502234
4	0.5591715	0.1084096	0.3488261	0.7502234

- -

5	0.8187089	0.1158060	0.4945917	0.9542128
6	0.8187089	0.1158060	0.4945917	0.9542128
7	0.6209213	0.2093124	0.2227885	0.9034719
8	0.8851862	0.0539787	0.7313511	0.9562063
9	0.8851862	0.0539787	0.7313511	0.9562063
10	0.5591715	0.1084096	0.3488261	0.7502234
11	0.5591715	0.1084096	0.3488261	0.7502234
12	0.8187089	0.1158060	0.4945917	0.9542128
13	0.8187089	0.1158060	0.4945917	0.9542128
14	0.6209213	0.2093124	0.2227885	0.9034719
15	0.6209213	0.2093124	0.2227885	0.9034719

Time in seconds for last procedure was 0.08

INPUT --- proc stop;

Time in minutes for this job was 0.01

E X E C U T I O N   S U C C E S S F U L

Appendix H. Output from Program SURVIV to Estimate *N* Using Catch-Effort Model for Antlered Sika Deer.

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
 Jun 30  2009   15:37:18         Version 2.0(UNIX)   Oct., 1999      Page  001

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  ----------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.


  INPUT --- PROC TITLE ASIS Sika Male Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=14;

  INPUT ---    COHORT=22;
  INPUT ---       3:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       1:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       4:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
```

```
INPUT ---       0:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       4:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       0:EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)
INPUT ---       * S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(11)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       0:EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(12)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(13)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       5:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*(1-EXP(-S(14)*S(1)))/(1-EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
```

```
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));

  INPUT ---    LABELS;
  INPUT ---       S(1)=k;
  INPUT ---       S(2)=NOV24;
  INPUT ---       S(3)=NOV26;
  INPUT ---       S(4)=NOV27;
  INPUT ---       S(5)=NOV28;
  INPUT ---       S(6)=NOV29;
  INPUT ---       S(7)=NOV30;
  INPUT ---       S(8)=DEC1;
  INPUT ---       S(9)=DEC3;
  INPUT ---       S(10)=DEC4;
  INPUT ---       S(11)=DEC5;
  INPUT ---       S(12)=DEC6;
  INPUT ---       S(13)=DEC7;
  INPUT ---       S(14)=DEC8;
0PROGRAM TERMINATED FOR FORTRAN COMPILATION OF SUBROUTINE EST
```

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
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 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  ----------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.


  INPUT --- PROC TITLE ASIS Sika Male Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=14;

  INPUT ---    COHORT=22;
  INPUT ---       3:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       1:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       4:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
```

```
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       4:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       0:EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)
INPUT ---       * S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(11)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       0:EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(12)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(13)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       5:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*(1-EXP(-S(14)*S(1)))/(1-EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
```

```
INPUT ---    LABELS;
INPUT ---       S(1)=k;
INPUT ---       S(2)=NOV24;
INPUT ---       S(3)=NOV26;
INPUT ---       S(4)=NOV27;
INPUT ---       S(5)=NOV28;
INPUT ---       S(6)=NOV29;
INPUT ---       S(7)=NOV30;
INPUT ---       S(8)=DEC1;
INPUT ---       S(9)=DEC3;
INPUT ---       S(10)=DEC4;
INPUT ---       S(11)=DEC5;
INPUT ---       S(12)=DEC6;
INPUT ---       S(13)=DEC7;
INPUT ---       S(14)=DEC8;

   CPU time in seconds for last procedure was    0.00

INPUT --- PROC ESTIMATE NAME=GENERAL NOVAR MAXFN=3000;

INPUT ---    initial;
INPUT ---       all=0.02;

INPUT ---    CONSTRAINTS;
INPUT ---       S(2)=1.37;
INPUT ---       S(3)=.59;
INPUT ---       S(4)=.36;
INPUT ---       S(5)=.74;
INPUT ---       S(6)=.8;
INPUT ---       S(7)=.45;
INPUT ---       S(8)=.61;
INPUT ---       S(9)=.23;
INPUT ---       S(10)=.45;
INPUT ---       S(11)=.54;
INPUT ---       S(12)=.36;
INPUT ---       S(13)=.48;
INPUT ---       S(14)=.43;

    Number of parameters in model  =  14

    Number of parameters set equal =   0

    Number of parameters fixed     =  13

    Number of parameters estimated =   1

                              Lower    Upper
 I   Parameter   S(I)     Bound    Bound  Label
---  ---------  ------   -----    -----  --------------------
 1       1      0.020    0.000    1.000  k
 2      -2      1.370    1.370    1.370  NOV24
 3      -3      0.590    0.590    0.590  NOV26
 4      -4      0.360    0.360    0.360  NOV27
 5      -5      0.740    0.740    0.740  NOV28
 6      -6      0.800    0.800    0.800  NOV29
 7      -7      0.450    0.450    0.450  NOV30
 8      -8      0.610    0.610    0.610  DEC1
 9      -9      0.230    0.230    0.230  DEC3
10     -10      0.450    0.450    0.450  DEC4
11     -11      0.540    0.540    0.540  DEC5
12     -12      0.360    0.360    0.360  DEC6
13     -13      0.480    0.480    0.480  DEC7
14     -14      0.430    0.430    0.430  DEC8
```

Final function value 56.252723 (Error Return = 0)

Number of significant digits 6

Number of function evaluations 29

I		Parameter	S(I)	Standard Error	95% Confidence Interval Lower	Upper
1	1	k	0.573521E-09	0.100218	-.196428	0.196428
2	-2	NOV24	1.37000	0.00000	1.37000	1.37000
3	-3	NOV26	0.590000	0.00000	0.590000	0.590000
4	-4	NOV27	0.360000	0.00000	0.360000	0.360000
5	-5	NOV28	0.740000	0.00000	0.740000	0.740000
6	-6	NOV29	0.800000	0.00000	0.800000	0.800000
7	-7	NOV30	0.450000	0.00000	0.450000	0.450000
8	-8	DEC1	0.610000	0.00000	0.610000	0.610000
9	-9	DEC3	0.230000	0.00000	0.230000	0.230000
10	-10	DEC4	0.450000	0.00000	0.450000	0.450000
11	-11	DEC5	0.540000	0.00000	0.540000	0.540000
12	-12	DEC6	0.360000	0.00000	0.360000	0.360000
13	-13	DEC7	0.480000	0.00000	0.480000	0.480000
14	-14	DEC8	0.430000	0.00000	0.430000	0.430000

```
    Cohort  Cell   Observed  Expected  Chi-square  Note
    ------  ----   --------  --------  ----------  -------------
       1      1       3.000     4.067      0.280   0 < P < 1
       1      2       1.000     1.752      0.323   0 < P < 1
       1      3       0.000     1.069      1.069   0 < P < 1
       1      4       4.000     2.197      1.480   0 < P < 1
       1      5       0.000     2.375      2.375   0 < P < 1
       1      6       0.000     1.336      1.336   0 < P < 1
       1      7       4.000     1.811      2.646   0 < P < 1
       1      8       2.000     0.683      2.541   0 < P < 1
       1      9       1.000     1.336      0.085   0 < P < 1
       1     10       0.000     1.603      1.603   0 < P < 1
       1     11       0.000     1.069      1.069   0 < P < 1
       1     12       2.000     1.425      0.232   0 < P < 1
       1     13       5.000     1.277     10.859   0 < P < 1
       1 Cohort df=  6                     8.414   P = 0.2093
    ------------------------------------------------------------
 @@    1    0    0  11   26.9115       5   8.41389     -22.1032      46.2064
    G Total (Degrees of freedom =  11)      26.912
    Pr(Larger Chi-square) = 0.0047
    With pooling, Degrees of freedom =   5  Pearson Chi-square =      8.414
    Pr(Larger Chi-square) = 0.1349

    Log-likelihood = -22.103195        Akaike Information Criterion =  46.206390

      CPU time in seconds for last procedure was    0.00

   INPUT --- PROC STOP;

      CPU time in minutes for this job was    0.00

           E X E C U T I O N   S U C C E S S F U L
```

Appendix I. Output from Program SURVIV to Estimate *N* Using Catch-Effort Model for Antlerless Sika Deer

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
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 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  ---------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.


  INPUT --- PROC TITLE ASIS Sika Female Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=14;

  INPUT ---    COHORT=23;
  INPUT ---       8:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       2:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
```

```
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       4:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)
INPUT ---       * S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(11)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(12)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(13)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*(1-EXP(-S(14)*S(1)))/(1-EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
```

```
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));

  INPUT ---    LABELS;
  INPUT ---       S(1)=k;
  INPUT ---       S(2)=NOV24;
  INPUT ---       S(3)=NOV26;
  INPUT ---       S(4)=NOV27;
  INPUT ---       S(5)=NOV28;
  INPUT ---       S(6)=NOV29;
  INPUT ---       S(7)=NOV30;
  INPUT ---       S(8)=DEC1;
  INPUT ---       S(9)=DEC3;
  INPUT ---       S(10)=DEC4;
  INPUT ---       S(11)=DEC5;
  INPUT ---       S(12)=DEC6;
  INPUT ---       S(13)=DEC7;
  INPUT ---       S(14)=DEC8;
0PROGRAM TERMINATED FOR FORTRAN COMPILATION OF SUBROUTINE EST
```

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
 Jun 30  2009   15:34:03         Version 2.0(UNIX)   Oct., 1999      Page  001

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  -------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.

  INPUT --- PROC TITLE ASIS Sika Female Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=14;

  INPUT ---    COHORT=23;
  INPUT ---       8:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       0:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       2:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
  INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
  INPUT ---       2:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
```

```
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       4:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)
INPUT ---       * S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(11)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(12)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       1:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(13)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
INPUT ---       2:EXP(-S(12)*S(1))*EXP(-S(11)*S(1))*EXP(-S(10)*S(1))*EXP(-S(
INPUT ---       9)*S(1))*
INPUT ---       EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*
INPUT ---       S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*(1-EXP(-S(14)*S(1)))/(1-EXP(-S(2)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1))*EXP(-S(11)*S(1))*EXP(-S(12)*S(1))*
INPUT ---       EXP(-S(13)*S(1))*EXP(-S(14)*S(1)));
```

```
INPUT ---    LABELS;
INPUT ---       S(1)=k;
INPUT ---       S(2)=NOV24;
INPUT ---       S(3)=NOV26;
INPUT ---       S(4)=NOV27;
INPUT ---       S(5)=NOV28;
INPUT ---       S(6)=NOV29;
INPUT ---       S(7)=NOV30;
INPUT ---       S(8)=DEC1;
INPUT ---       S(9)=DEC3;
INPUT ---       S(10)=DEC4;
INPUT ---       S(11)=DEC5;
INPUT ---       S(12)=DEC6;
INPUT ---       S(13)=DEC7;
INPUT ---       S(14)=DEC8;

   CPU time in seconds for last procedure was    0.00

INPUT --- PROC ESTIMATE NAME=GENERAL NOVAR MAXFN=3000;

INPUT ---    initial;
INPUT ---       all=0.02;

INPUT ---    CONSTRAINTS;
INPUT ---       S(2)=1.37;
INPUT ---       S(3)=.59;
INPUT ---       S(4)=.36;
INPUT ---       S(5)=.74;
INPUT ---       S(6)=.8;
INPUT ---       S(7)=.45;
INPUT ---       S(8)=.61;
INPUT ---       S(9)=.23;
INPUT ---       S(10)=.45;
INPUT ---       S(11)=.54;
INPUT ---       S(12)=.36;
INPUT ---       S(13)=.48;
INPUT ---       S(14)=.43;

    Number of parameters in model  =  14

    Number of parameters set equal =   0

    Number of parameters fixed     =  13

    Number of parameters estimated =   1

                          Lower    Upper
 I   Parameter   S(I)     Bound    Bound  Label
---  ---------  ------    -----    -----  --------------------
 1       1      0.020    0.000    1.000  k
 2      -2      1.370    1.370    1.370  NOV24
 3      -3      0.590    0.590    0.590  NOV26
 4      -4      0.360    0.360    0.360  NOV27
 5      -5      0.740    0.740    0.740  NOV28
 6      -6      0.800    0.800    0.800  NOV29
 7      -7      0.450    0.450    0.450  NOV30
 8      -8      0.610    0.610    0.610  DEC1
 9      -9      0.230    0.230    0.230  DEC3
10     -10      0.450    0.450    0.450  DEC4
11     -11      0.540    0.540    0.540  DEC5
12     -12      0.360    0.360    0.360  DEC6
13     -13      0.480    0.480    0.480  DEC7
14     -14      0.430    0.430    0.430  DEC8
```

Final function value 54.807519 (Error Return = 0)

Number of significant digits 8

Number of function evaluations 36

I		Parameter	S(I)	Standard Error	95% Confidence Interval Lower	Upper
1	1	k	0.168820E-02	0.980307E-01	-.190452	0.193828
2	-2	NOV24	1.37000	0.00000	1.37000	1.37000
3	-3	NOV26	0.590000	0.00000	0.590000	0.590000
4	-4	NOV27	0.360000	0.00000	0.360000	0.360000
5	-5	NOV28	0.740000	0.00000	0.740000	0.740000
6	-6	NOV29	0.800000	0.00000	0.800000	0.800000
7	-7	NOV30	0.450000	0.00000	0.450000	0.450000
8	-8	DEC1	0.610000	0.00000	0.610000	0.610000
9	-9	DEC3	0.230000	0.00000	0.230000	0.230000
10	-10	DEC4	0.450000	0.00000	0.450000	0.450000
11	-11	DEC5	0.540000	0.00000	0.540000	0.540000
12	-12	DEC6	0.360000	0.00000	0.360000	0.360000
13	-13	DEC7	0.480000	0.00000	0.480000	0.480000
14	-14	DEC8	0.430000	0.00000	0.430000	0.430000

```
   Cohort  Cell   Observed  Expected  Chi-square  Note
   ------  ----   --------  --------  ----------  -------------
      1      1       8.000     4.274      3.248   0 < P < 1
      1      2       0.000     1.838      1.838   0 < P < 1
      1      3       0.000     1.120      1.120   0 < P < 1
      1      4       0.000     2.301      2.301   0 < P < 1
      1      5       2.000     2.484      0.094   0 < P < 1
      1      6       2.000     1.396      0.261   0 < P < 1
      1      7       1.000     1.890      0.419   0 < P < 1
      1      8       1.000     0.712      0.116   0 < P < 1
      1      9       4.000     1.393      4.880   0 < P < 1
      1     10       1.000     1.670      0.269   0 < P < 1
      1     11       1.000     1.112      0.011   0 < P < 1
      1     12       1.000     1.482      0.157   0 < P < 1
      1     13       2.000     1.327      0.342   0 < P < 1
      1 Cohort df=  6                     9.939   P = 0.1272
   ------------------------------------------------------------
@@    1    0    0  11   18.0615       5   9.93902     -19.0629      40.1259
   G Total (Degrees of freedom =  11)      18.061
   Pr(Larger Chi-square) = 0.0802
   With pooling, Degrees of freedom =   5  Pearson Chi-square =      9.939
   Pr(Larger Chi-square) = 0.0770

   Log-likelihood = -19.062941        Akaike Information Criterion =  40.125883

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC STOP;

     CPU time in minutes for this job was    0.00

          E X E C U T I O N   S U C C E S S F U L
```

Appendix J. Output from Program SURVIV to Estimate *N* Using Catch-Effort Model for Sika Deer.

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
 Jul  1  2009   12:12:10         Version 2.0(UNIX)   Oct., 1999      Page  001

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  ----------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.

  INPUT --- PROC TITLE ASIS Sika Female Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=10;

  INPUT ---    COHORT=67;
  INPUT ---       18:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       4:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
```

```
  INPUT ---       18:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       17:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       10:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
  INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));

  INPUT ---    LABELS;
  INPUT ---       S(1)=k;
  INPUT ---       S(2)=OCT12;
  INPUT ---       S(3)=OCT19;
  INPUT ---       S(4)=OCT26;
  INPUT ---       S(5)=NOV2;
  INPUT ---       S(6)=NOV9;
  INPUT ---       S(7)=NOV16;
  INPUT ---       S(8)=NOV23;
  INPUT ---       S(9)=NOV30;
  INPUT ---       S(10)=DEC7;
0PROGRAM TERMINATED FOR FORTRAN COMPILATION OF SUBROUTINE EST
```

```
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  -------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.

  INPUT --- PROC TITLE ASIS Sika Female Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=10;

  INPUT ---    COHORT=67;
  INPUT ---       18:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       4:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       18:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
```

```
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1)));
INPUT ---       17:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1)));
INPUT ---       10:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1)));

INPUT ---    LABELS;
INPUT ---       S(1)=k;
INPUT ---       S(2)=OCT12;
INPUT ---       S(3)=OCT19;
INPUT ---       S(4)=OCT26;
INPUT ---       S(5)=NOV2;
INPUT ---       S(6)=NOV9;
INPUT ---       S(7)=NOV16;
INPUT ---       S(8)=NOV23;
INPUT ---       S(9)=NOV30;
INPUT ---       S(10)=DEC7;

   CPU time in seconds for last procedure was    0.00

INPUT --- PROC ESTIMATE NAME=GENERAL NOVAR MAXFN=3000;

INPUT ---    initial;
INPUT ---       all=0.02;

INPUT ---    CONSTRAINTS;
INPUT ---       S(2)=5.25;
INPUT ---       S(3)=1.82;
INPUT ---       S(4)=.25;
INPUT ---       S(5)=.50;
INPUT ---       S(6)=.43;
INPUT ---       S(7)=.64;
INPUT ---       S(8)=4.14;
INPUT ---       S(9)=7.92;
INPUT ---       S(10)=2.73;

    Number of parameters in model  =  10

    Number of parameters set equal =   0

    Number of parameters fixed     =   9

    Number of parameters estimated =   1
```

```
                        Lower    Upper
 I   Parameter   S(I)    Bound    Bound  Label
---  ---------  ------   -----    -----  --------------------
 1       1      0.020    0.000    1.000  k
 2      -2      5.250    5.250    5.250  OCT12
 3      -3      1.820    1.820    1.820  OCT19
 4      -4      0.250    0.250    0.250  OCT26
 5      -5      0.500    0.500    0.500  NOV2
 6      -6      0.430    0.430    0.430  NOV9
 7      -7      0.640    0.640    0.640  NOV16
 8      -8      4.140    4.140    4.140  NOV23
 9      -9      7.920    7.920    7.920  NOV30
10     -10      2.730    2.730    2.730  DEC7

   Final function value  108.96683     (Error Return =   0)

   Number of significant digits      10

   Number of function evaluations    39

                                                       95% Confidence Interval
 I       Parameter            S(I)     Standard Error    Lower         Upper
---  -------------------- ------------ ----------- ------------ ------------
 1   1 k                   0.408817E-02 0.183918E-01 -.319597E-01 0.401360E-01
 2  -2 OCT12                 5.25000      0.00000      5.25000      5.25000
 3  -3 OCT19                 1.82000      0.00000      1.82000      1.82000
 4  -4 OCT26               0.250000      0.00000     0.250000     0.250000
 5  -5 NOV2                0.500000      0.00000     0.500000     0.500000
 6  -6 NOV9                0.430000      0.00000     0.430000     0.430000
 7  -7 NOV16               0.640000      0.00000     0.640000     0.640000
 8  -8 NOV23                 4.14000      0.00000      4.14000      4.14000
 9  -9 NOV30                 7.92000      0.00000      7.92000      7.92000
10 -10 DEC7                  2.73000      0.00000      2.73000      2.73000

 Cohort  Cell   Observed  Expected  Chi-square  Note
 ------  ----   --------  --------  ----------  -------------
    1      1      18.000    15.419      0.432   0 < P < 1
    1      2       4.000     5.268      0.305   0 < P < 1
    1      3       0.000     0.721      0.721   0 < P < 1
    1      4       0.000     1.439      1.439   0 < P < 1
    1      5       0.000     1.235      1.235   0 < P < 1
    1      6       0.000     1.834      1.834   0 < P < 1
    1      7      18.000    11.751      3.323   0 < P < 1
    1      8      17.000    21.934      1.110   0 < P < 1
    1      9      10.000     7.398      0.916   0 < P < 1
    1 Cohort df=  6                    11.315   P = 0.0791
 ------------------------------------------------------------
@@    1    0    0   7   16.0829       5   11.3149     -15.8083      33.6167
 G Total (Degrees of freedom =   7)      16.083
 Pr(Larger Chi-square) = 0.0244
 With pooling, Degrees of freedom =   5  Pearson Chi-square =     11.315
 Pr(Larger Chi-square) = 0.0455

 Log-likelihood = -15.808325        Akaike Information Criterion =  33.616651

   CPU time in seconds for last procedure was    0.00

INPUT --- PROC STOP;

   CPU time in minutes for this job was    0.00

        E X E C U T I O N   S U C C E S S F U L
```

Appendix K. Output from Program SURVIV to Estimate *N* Using Catch-Effort Model for White-tailed Deer.

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
 Jul  1  2009   12:18:41         Version 2.0(UNIX)   Oct., 1999      Page  001

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  ----------------------------------------------------------------
  Oct., 99   INLINE statement added to allow additional code in estimation
               routine.
  March, 90  NORMALIZE option for PROC MODEL to normalize cell probabilities.
  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.

  INPUT --- PROC TITLE ASIS Sika Female Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=10;

  INPUT ---    COHORT=27;
  INPUT ---       6:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       6:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       1:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       1:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
```

```
  INPUT ---       9:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       2:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       2:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
  INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));

  INPUT ---    LABELS;
  INPUT ---       S(1)=k;
  INPUT ---       S(2)=OCT12;
  INPUT ---       S(3)=OCT19;
  INPUT ---       S(4)=OCT26;
  INPUT ---       S(5)=NOV2;
  INPUT ---       S(6)=NOV9;
  INPUT ---       S(7)=NOV16;
  INPUT ---       S(8)=NOV23;
  INPUT ---       S(9)=NOV30;
  INPUT ---       S(10)=DEC7;
0PROGRAM TERMINATED FOR FORTRAN COMPILATION OF SUBROUTINE EST
```

```
SURVIV - Survival Rate Estimation with User Specified Cell Probabilities
 Jul  1  2009   12:18:42         Version 2.0(UNIX)   Oct., 1999      Page  001

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

      Dimension limitations for this run:
        Maximum number of parameters              999
        Maximum number of cohorts                 128
        Maximum number of classes within a cohort 128
        Maximum number of models for PROC TEST     30
      If your problem needs larger dimensions, reset the values
      in the modelc include file and recompile the program.

  Date       Modifications
  ---------  -------------------------------------------------------------
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  March, 90  ADDCELL option for PROC MODEL to add cell with 1 - sum of cells.
  March, 90  NOBINCOF option for PROC ESTIMATE to not add bin. coef. to like.

  INPUT --- PROC TITLE ASIS Sika Female Season 2007 - 24NOV-8DEC;

     CPU time in seconds for last procedure was    0.00

  INPUT --- PROC MODEL NPAR=10;

  INPUT ---    COHORT=27;
  INPUT ---       6:(1-EXP(-S(2)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       6:EXP(-S(2)*S(1))*(1-EXP(-S(3)*S(1)))/(1-EXP(-S(2)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*(1-EXP(-S(4)*S(1)))/
  INPUT ---       (1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       0:EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(5)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       1:EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(6)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       1:EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
  INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(7)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
  INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
  INPUT ---       EXP(-S(10)*S(1)));
  INPUT ---       9:EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
  INPUT ---       (1-EXP(-S(8)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
  INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
```

```
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1)));
INPUT ---       2:EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(9)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1)));
INPUT ---       2:EXP(-S(9)*S(1))*EXP(-S(8)*S(1))*EXP(-S(7)*S(1))*
INPUT ---       EXP(-S(6)*S(1))*EXP(-S(5)*S(1))*EXP(-S(4)*S(1))*
INPUT ---       EXP(-S(3)*S(1))*EXP(-S(2)*S(1))*
INPUT ---       (1-EXP(-S(10)*S(1)))/(1-EXP(-S(2)*S(1))*EXP(-S(3)*S(1))*
INPUT ---       EXP(-S(4)*S(1))*EXP(-S(5)*S(1))*EXP(-S(6)*S(1))*
INPUT ---       EXP(-S(7)*S(1))*EXP(-S(8)*S(1))*EXP(-S(9)*S(1))*
INPUT ---       EXP(-S(10)*S(1)));

INPUT ---    LABELS;
INPUT ---       S(1)=k;
INPUT ---       S(2)=OCT12;
INPUT ---       S(3)=OCT19;
INPUT ---       S(4)=OCT26;
INPUT ---       S(5)=NOV2;
INPUT ---       S(6)=NOV9;
INPUT ---       S(7)=NOV16;
INPUT ---       S(8)=NOV23;
INPUT ---       S(9)=NOV30;
INPUT ---       S(10)=DEC7;

   CPU time in seconds for last procedure was    0.00

INPUT --- PROC ESTIMATE NAME=GENERAL NOVAR MAXFN=3000;

INPUT ---    initial;
INPUT ---       all=0.02;

INPUT ---    CONSTRAINTS;
INPUT ---       S(2)=5.25;
INPUT ---       S(3)=1.82;
INPUT ---       S(4)=.25;
INPUT ---       S(5)=.50;
INPUT ---       S(6)=.43;
INPUT ---       S(7)=.64;
INPUT ---       S(8)=4.14;
INPUT ---       S(9)=7.92;
INPUT ---       S(10)=2.73;

    Number of parameters in model  =  10

    Number of parameters set equal =   0

    Number of parameters fixed     =   9

    Number of parameters estimated =   1
```

```
                          Lower     Upper
  I   Parameter   S(I)    Bound     Bound  Label
 ---  ---------  ------   -----     -----  --------------------
  1       1      0.020    0.000     1.000  k
  2      -2      5.250    5.250     5.250  OCT12
  3      -3      1.820    1.820     1.820  OCT19
  4      -4      0.250    0.250     0.250  OCT26
  5      -5      0.500    0.500     0.500  NOV2
  6      -6      0.430    0.430     0.430  NOV9
  7      -7      0.640    0.640     0.640  NOV16
  8      -8      4.140    4.140     4.140  NOV23
  9      -9      7.920    7.920     7.920  NOV30
 10     -10      2.730    2.730     2.730  DEC7

    Final function value  52.032053     (Error Return =   0)

    Number of significant digits      10

    Number of function evaluations    32

                                                              95% Confidence Interval
  I       Parameter            S(I)     Standard Error    Lower         Upper
 ---  -------------------- ------------ ------------ ------------ ------------
  1   1 k                  0.620384E-01 0.305062E-01 0.224619E-02 0.121831
  2  -2 OCT12               5.25000      0.00000      5.25000      5.25000
  3  -3 OCT19               1.82000      0.00000      1.82000      1.82000
  4  -4 OCT26              0.250000      0.00000     0.250000     0.250000
  5  -5 NOV2               0.500000      0.00000     0.500000     0.500000
  6  -6 NOV9               0.430000      0.00000     0.430000     0.430000
  7  -7 NOV16              0.640000      0.00000     0.640000     0.640000
  8  -8 NOV23               4.14000      0.00000      4.14000      4.14000
  9  -9 NOV30               7.92000      0.00000      7.92000      7.92000
 10 -10 DEC7                2.73000      0.00000      2.73000      2.73000

  Cohort  Cell   Observed  Expected  Chi-square  Note
  ------  ----   --------  --------  ----------  -------------
     1      1       6.000     9.749      1.442   0 < P < 1
     1      2       6.000     2.704      4.019   0 < P < 1
     1      3       0.000     0.348      0.348   0 < P < 1
     1      4       0.000     0.680      0.680   0 < P < 1
     1      5       1.000     0.568      0.328   0 < P < 1
     1      6       1.000     0.818      0.040   0 < P < 1
     1      7       9.000     4.576      4.276   0 < P < 1
     1      8       2.000     6.066      2.726   0 < P < 1
     1      9       2.000     1.490      0.175   0 < P < 1
     1 Cohort df=  4                    11.482   P = 0.0216
  ------------------------------------------------------------
@@    1    0    0   7   14.1864       3   11.4820     -14.8211      31.6423
  G Total (Degrees of freedom =   7)      14.186
  Pr(Larger Chi-square) = 0.0480
  With pooling, Degrees of freedom =   3  Pearson Chi-square =     11.482
  Pr(Larger Chi-square) = 0.0094

  Log-likelihood = -14.821138        Akaike Information Criterion =  31.642277

    CPU time in seconds for last procedure was    0.00

 INPUT --- PROC STOP;

    CPU time in minutes for this job was    0.00

        E X E C U T I O N   S U C C E S S F U L
```

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior

Northeast Region
Natural Resources and Science
200 Chestnut Street
Philadelphia, Pennsylvania 19106-2878

http://www.nps.gov/nero/science/