BIOLOGICAL AND CONSERVATION STUDIES OF THE CORAL PINK SAND DUNES TIGER BEETLE, *CICINDELA ALBISSIMA* IN 2012

FINAL REPORT

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(Female ovipositing, photo by Chris Wirth)

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ABSTRACT

This report gives results of the continuing studies of the biology and conservation of the Coral Pink Sand Dunes Tiger Beetle funded by the Utah Office of the Bureau of Land Management and by the Utah Ecological Services of the U.S. Fish and Wildlife Office. The work in 2012 included various new and ongoing studies such as adult monitoring of distribution and abundance in the core area, surveys for adults throughout the dune field, larval translocations, and continuation of previous studies within the core area and throughout dune field. A separate companion report presents studies characterizing the habitat of *C. albissima* at CPSD.

The **total adult population size estimate for *C. albissima* in 2012 was 1786 with a 95% confidence range of 1559 to 2013.** This count compares with 1116 in 2011, 1264 in 2010, 1131 in 2009, 1072 in 2008, 700 in 2007 and 1112 in 2006. This indicates a progressive and significant increase in numbers since the 700 in 2007; the highest increase is this years count of 1786. Numbers of adults in swales within and outside of Conservation Area A have varied significantly from 1998 to 2012. Overall, the percent of adults within the Conservation Area A (protection area) has ranged from 73 to 88% of the total adult numbers in all swales. The percent was lower (73-77%) in years 1998 to 2003 and significantly higher (80-88%) in years since that time (2004-2011). The 87% in 2012 was the same percent as in 2011. We believe these higher percentages in the more recent years support our hypothesis that this is a result of the establishment of the conservation area with increased protection inside the protection area and increased habitat impacts in the travel corridor.

There have been some notable changes in adult numbers in various swales over the years. In Conservation Area A, swales 2-3, JK, and HWH have varied considerably over the years, but consistently supported the highest number of adults of any swales. In 2012, HWH had 566 (the highest count ever in this swale), JK had 465, 2-3 had 266 and Public had 250 adults. Swale 1 supported high numbers, averaging over 75 adults until the last two years when numbers declined to 23 in 2011 and 11 in 2012. Swale 4 had over 60 adults in 1998, 2001, and 2002, but was lower to very low in most other years; in 2012 the count in this swale was 13. Swales WX and WY, have supported high numbers of adults in some years, often over 35-40 but both had only 4 adults in 2012. The decline in these two swales and in WWW in recent years is believed a result of dune movement which has deposited loose sand over some of the gravel and other suitable swale larval habitat. Only 1 adult was found in Conservation Area B at north end of dune field. Larval numbers were also low is this area (only 47 counted, most in swale AAA-2); 63 were present in 2011, 38 in 2010, and 111 in 2009.

Numbers of adults in most of the travel corridor (unprotected) swales have been lower to much lower than Conservation Area A swales in all years, although numbers in most of these have been higher in 2012 as has the total adult population. The highest counts in the travel corridor in 2012 were swale E1 with 68 adults and the series of swales North of Swale 4 (swales 5 through 10) with 42 total adults (the highest count since 74 in 2002). Swale E6-7 had 30, the highest count there since 53 in 2002 and E2-3 had 32 compared to 11 the previous two years. Swale QR has had consistently high

counts every year, ranging from 24 in 1998 to 156 in 2002 and 150 in 2011 but declined to 9 in 2012.

Plans to conduct extensive larval surveys within Conservation Area A and throughout the rest of the dune field were impacted by progressively drier conditions in May so only limited surveys were done. Earlier counts did yield counts of 553 in JK to only 69 in 2-3 and 66 in HWH. The 485 in E2 were mostly C. tranquebarica larvae. Because of survey problems, we also include here results of larval surveys from 2009-2010 when conditions were ideal. These results are the same as in the 2011 report. Those results indicated significantly higher density of burrows in patches of more compact soil referred to as clay lenses (13.9 burrows per 10 sq. m) than in non lens areas (3.1).

The total rainfall for 2012 was only 0.56 for April-June (the second lowest ever) with no rainfall reported in May and June and 5.3 9 (about the norm) for April-October. The trend of declining rainfall from 1992 to 2012 probably explains at least in part the general trend of declining adult numbers during this period. For the more recent years, there was a progressive increase of April-October rainfall (2.82 in 2009, 5.29 in 2010, and 7.81 in 2011) which may explain the increase in adult numbers during this period and into 2012.

Movement of the dune ridgelines has varied from year to year and among the different ridgelines. Overall the movement was to the north to northeast with the prevailing wind direction. We have observed dune movement causing the loss of larval habitat in several areas and a likely cause of adult numbers in swales EQR, E6-7, and part of QR due to coverage of the surface with accumulated sand. This effect also seems to be a probable cause of decline in numbers in swales WX and WY in the past two years.

The translocaton results indicated that for the May 2011 translocation, 51 of the 112 translocated larvae were still active in September but by the following May, only 12 were active third instar larvae and no adults were recorded in the area. For the 2012 translocation 44 of 118 larvae from May were active in September 2012 and will be rechecked in April or May 2012 for surviving larvae and/or emerging adults. These results are comparable to several previous translocations which resulted in high mortality after a year and provided no evidence of successful complete development or emerging adults.

INTRODUCTION

The Coral Pink Sand Dunes Tiger Beetle, *Cicindela albissima*, is known only from the Coral Pink Sand Dunes in southern Utah, and within a limited section of that dune field. Studies on this rare insect were begun in 1991 when a population count was made and preliminary studies were conducted. Research was expanded and continued in all of the subsequent years to the present. One of these earlier studies on the taxonomy of the CPSD Tiger Beetle and its relatives in the *Cicindela martima* group using mitochondria DNA determined the CPSD Tiger Beetle was sufficiently distinct from the other subspecies of *Cicindela limbata* that it should be considered a separate species, *C. albissima*. Additional studies have documented a highly variable population size, with adult numbers ranging from a peak of 2944 in 2002 to a low count of 595 in 2003. Studies on this beetle were continued in 2012 with the following research objectives: 1. Continue monitoring the adult population size of the CPSDTB using the removal method. Report numbers in all individual swales with swale maps. Determine dispersal by marking and recapture of adults in select swales; 2. Resurvey the whole dune field to determine if there are adults or potential habitat in areas of the dunefield that may have been previously overlooked or unsuitable in earlier surveys; 3. Continue to evaluate the effects of the establishment of the conservation area by comparing counts of adult counts within and outside of the conservation area; 4. Continue recording rainfall amounts so these might be related to population dynamics of beetles; 5. Continue translocation of larvae from the core habitat to Conservation Area A. Over 100 larvae were translocated in 2011. These larvae will be monitored and an additional 100-200 larvae will be translocated in 2012 to determine likelihood of establishing a population in this area; 6. Continue surveys and mapping of larval distribution and abundance throughout the dunefield to determine prime areas of recruitment and larval habitat; 7. Continue to monitor dune movement by mapping swale ridge lines. A separate companion report for the 2012 work included a detailed characterization of the habitat of *C. albissima* by comparing existing habitat within Conservation area A with non-habitat using two approaches: Field assessment of current geological conditions and historical assessment of aerial photographs to examine habitat changes over time.

METHODS

Field research in 2012 was conducted primarily from May 12 to 30. Data analysis and additional work including laboratory studies and preparation of this final report were continued from June through December.

Adult Distribution and Abundance

<u>Core Habitat Area.</u> Determination of adult population size was conducted in 2012 using the same methods initiated in and continued since 1998. The objective is to make accurate determinations of adult population size since this is critical for monitoring both

the viability of the beetle population and the health of the habitat at CPSD. It is also an important requirement of the Conservation Agreement. These adult surveys also allow for a comparison of numbers among various swales, especially within (Conservation Area A) and outside the protected area over the years and identification of important trends of increase or decrease. The 2012 population estimates were conducted from May 15-26. The removal method in 2012 involved-3 experienced workers systematically walking slowly through the swale area and adjacent slopes and collecting all of the adults that were observed. Typically, some proportion of the adults was missed, flew off, or otherwise not captured. The captured adults from this first pass were counted and placed in individual vials and retained in a cooler with ice for later release. Two and sometimes three or four additional passes and collections were made in the same way, with the usual result of decreasing numbers collected with each pass. After the last pass all of the adults were released throughout the swale areas from which they were collected.

The numbers collected from each pass for each swale were analyzed using Program CAPTURE to produce population estimates and associated variances, and finally a total estimate for the population and the 95% confidence intervals for the total population in the primary habitat at CPSD. If the number of adults in a swale was low (usually less than 10-15) or if several passes failed to produce a suitable reduction in numbers per pass, the total number of adults captured were added together and considered as an index count. In most cases the index count was comparable to the first pass of the removal method. The separate index counts were then added to the total calculated for the removal method values for swales to give the total population size estimate. After each swale was sampled we walked the perimeter of the specific area sampled with a GPS and from this produced a GIS map of all of the swales and the whole survey area. From these maps and the adult numbers we computed densities of adults per swale which would provide an indication of the probable habitat quality of swales for supporting beetles. Numbers of adults from swales within and outside of Conservation Area A were compared with previous years and the results discussed. In addition, we also used the index count method to estimate adult numbers in selected swales in Conservation Area B (area AAA) at the north end of the dune field where small numbers of adults have been found in some years.

<u>Other Areas of the Dune Field.</u> As a part of the 2012 field work we conducted extensive surveys for adults thorough the whole dune field to determine if there might be other pockets of potential habitat. One survey was conducted by three FWS workers who walked the whole length of the dune field from south to north covering areas of potential habitat and recording any adults seen. Additional surveys were conducted by CBK on several days covering most of the dune field north and south of the core habitat area.

Larval Surveys. Distribution and Abundance within Swales

Our plan to conduct extensive larval surveys in all swales in Conservation Area A and in other areas throughout the dune field was limited by the extremely dry conditions during May 2012. Rainfall records at the Park Headquarters indicated that the last rain was on April 13 and no rain was recorded during May while we were there. Several swales were surveyed for larvae under marginal conditions and these results included here but other swales were not surveyed as conditions rapidly became unsuitable. Because of this we present below the larval survey results from 2009 and 2010 when conditions were ideal. The survey method involves using a visual index count method by systematically crossing back and forth throughout the area of these interdunal swales to record the number and stage of all larvae seen. The larval survey approach is similar to searching for adults but requires a closer search image to find the larval burrows on the soil surface. Because larvae tend to plug their burrows as sand surface temperatures increase during the day making them impossible to see, larval surveys were done during early morning, 700 to 1000h. Individual stages of each burrow (first, second, and third instar) within 2-10 m^2 patches were recorded using a handheld GPS unit. While some burrows were missed (those with burrows plugged) during this survey, the distribution and relative abundance among the swales throughout the dune field could be determined with this method, and useful for comparisons among swales and over the years. As a part of the surveys we also recorded the area of more compact soil (clay lenses) and area of surface rock with a handheld GPS and subsequently mapped these features along with larval burrow numbers for each swale.

Rainfall Patterns and Effects

In this report as in previous ones we include monthly rainfall records at Kanab during the period of the adult and larval beetle activity (April through October) for the period 1991 through 2012. We have used the Kanab weather rainfall records since it provides a long term and consistent record and the CPSD rainfall gauge has been periodically inoperative. The rainfall data presented includes separate totals for April through June which is the prime time for adult ovipositon and first instar development. Totals for July through October when larvae are continuing development are also included. These rainfall amounts are compared with previous years so that their effect on population trends might be better understood.

Adult Dispersal

We conducted a limited study of adult dispersal by marking adults in several large swales (JK, 2-3 and Public) and recording recaptures during the removal method in other swales. Adults were marked by placing a dot of a swale specific color on the elytra. Distance from the mark to the recapture swales were measured on aerial photographs in Google Earth.

Translocation of Larvae

An additional translocation was conducted in May 2012 using the same approach as in 2011. The translocations methods used in this attempt to establish a population in Conservation Area A at the north end of the dune field are comparable to those tried previously at CPSD and similar to those used to successfully translocate larvae of *Cicindela dorsalis* from Virginia to New Jersey and establish a population there. In this translocation, second and third instar larvae were dug individually from burrows in several swales (JK, Public and HWH) during early morning or late evening where they were active. This involved placing a grass stem into the burrow and using a knife to remove soil along the burrow until the larva was located. Additional larvae were collected at night by stabbing a knife into the larvae burrow when larvae were at the burrow mouth to prevent their retreat into the burrow. The larvae were placed into separate vials and the hole refilled with soil. The vials with larvae were kept cool (50 F) for 12-36 hours. A total of 124 larvae were collected and then taken to swale AAA-2 at the far north end of the dune field. At the translocation site, the soil within 4 2 m x 20 m plots was water with a watering can. This was done to provide suitable substrate conditions for larvae to dig in. The location was 200 m from the site of the 2011 translocation. The larvae were placed on the ground surface in 5 rows of 20 and one of 24 larvae. After each larva was placed, the vial, open top down, was pressed into the soil slightly to confine the larvae and promote burrow digging. After all larvae were placed they were checked within the next 20-40 minutes to check on burrow digging. Vials were removed when a larva had dug a burrow deep enough that it was below the surface. Burrow digging was initiated within minutes for most larvae, and all except 15 individuals dug burrows within about 30 minutes. Vials were left on the 15 others and rechecked the following day to determine the status of the burrows. Six of these did not dig burrows and appeared to be injured or dead so were discarded. Follow up surveys were made on these larvae in late June and late September by an assistant. These will be again checked in April and May of 2013 to determine larval survival, development and any adult emergence.

Dune Movement

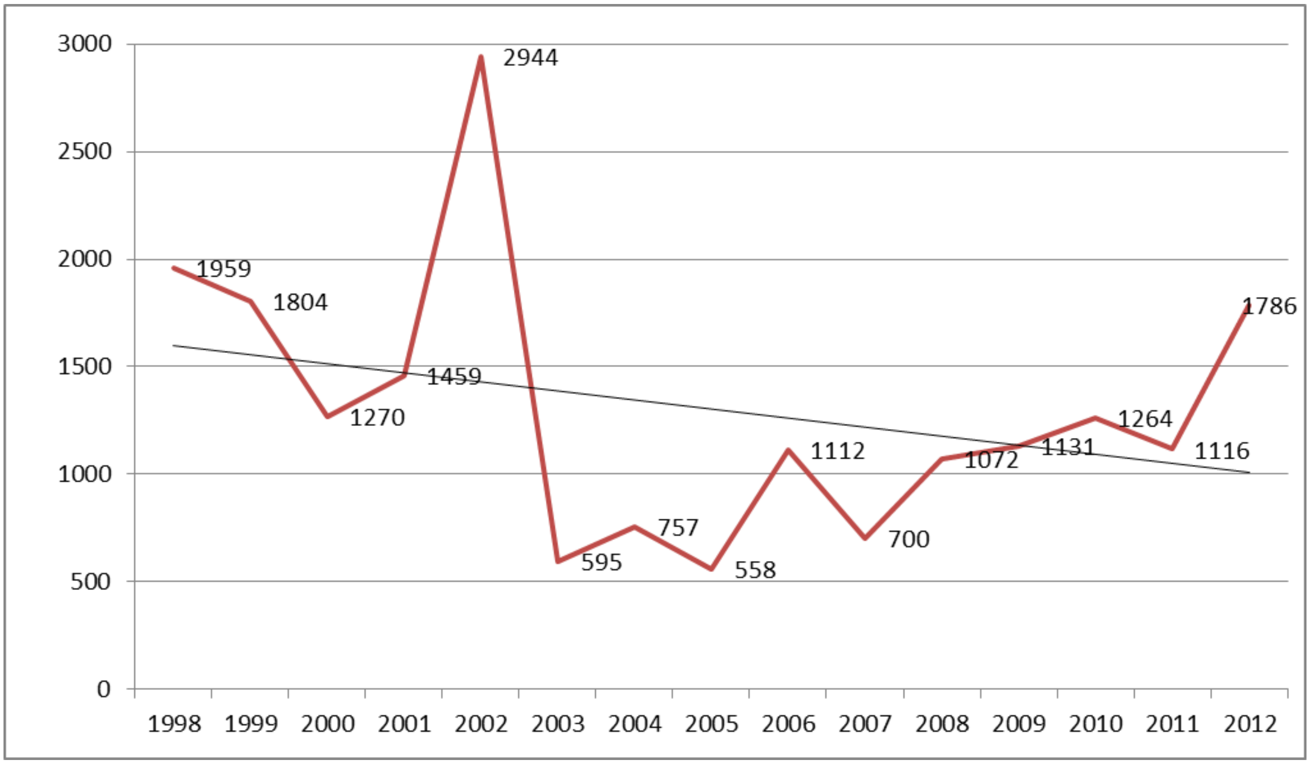
Monitoring of dune movement within Conservation Area A has been conducted in most years from 2000 to the present by GPSing the well defined ridgelines associated with the primary swales in the core beetle area. This was continued in 2012 and maps produced showing changes in ridgeline movement over the years.

RESULTS AND DISCUSSION

Adult Population Estimates

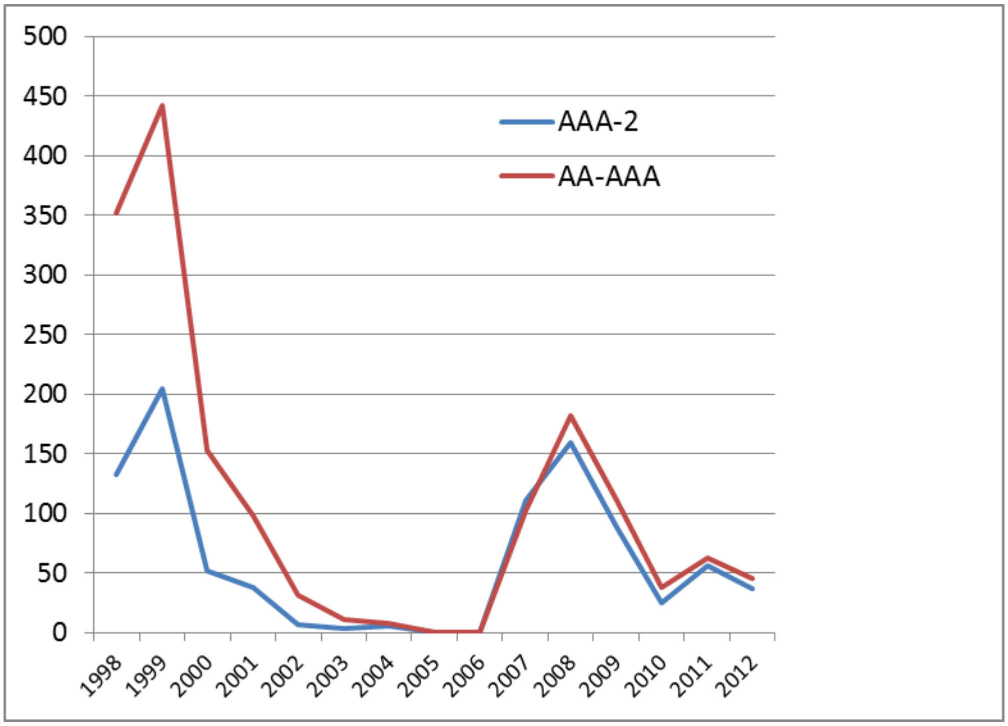
The **total adult population size estimate for *C. albissima* in 2012 was 1786 with a 95% confidence range of 1559 to 2013** (see Appendix for details of estimates). This count compares with other recent counts of 1264 in 2010, 1131 in 2009, 1072 in 2008, 700 in 2007 and 1112 in 2006 (Fig. 1). These results indicate a progressive and significant increase in numbers since the 700 in 2007 with the greatest increase the 1786 in 2012. Despites some annual fluctuations, there has been a progressive increase since the 558 in 2003. As indicated in last year’s report, the 2011 count was likely a significant underestimate because of poor weather conditions during surveys of some key swales. We previously demonstrated that the removal method produces very reliable estimates of population size, and includes associated confidence limits while the previously used mark recapture method significantly overestimated abundance, often 2-3 fold. Consequently, since the estimates made in 1992 to 1998 are overestimates, comparisons of population size before and after 1998 are not valid.

Fig. 1. Total estimate of adult C. albissima population size at CPSD using the removal method from 1998 to 2012. ***Note that the 2011 estimate shown is an underestimate of actual numbers because of unsuitable weather during surveys.***



As in all other years of our studies very few adults (typically zero to 10) have been found in the AAA and AA swales (Conservation area B) at the north end of the dune field. The total count for this area was 1 adult in 2012 (in AAA9), 3 adults in 2011 (all in swale AAA-2) compared to a total of 4 adults in 2010 and 7 in 2009. Larvae have been much more numerous in this northern area, but have varied significantly over the years (Fig. 2). The number of larvae counted in 2012 was 45, compared to 63 in 2011, 38 in 2010 and 1 11 in 2009. In all years most of these larvae were in swale AAA-2, including 37 in 2012. Note that this includes 12 surviving larvae in the translocation transect. The pattern of larval numbers over the years has generally paralleled the total adult counts at CPSD (in Conservation Area A), with highest numbers of larvae found in 1998 and 1999 before a decline to very few or none during 2002-2006 when adult numbers were at their lowest. However, the pattern did not hold in the past several years when adults increased significantly while larval numbers declined. This apparent correlation suggests that when conditions are ideal for population increase, Conservation Area B also experiences higher recruitment of larvae possibly produced by dispersing adults from Conservation Area A or higher recruitment or survival of larvae. Most important about this pattern is that under any conditions, even when there are larger numbers of larvae in the northern area, it has not resulted in a correspondingly higher numbers of adults or the establishment of a viable adult population. Some factor, such as dune characteristics which cause reduced food supply, lower moisture levels or other factors in this northern area result in high larval mortality so that few complete development to the adult stage.

Fig. 2. Total numbers of larvae counted in all of the northern swales of Conservation Area B (areas AAA and AA) and in swale AAA-2, 1996-2012.



Adult numbers in individual swales within Conservation Area A (protected) and in the travel corridor (subject to OHV traffic)

Numbers of adults in swales within and outside of Conservation Area A have varied significantly from 1998 to 2012. In all years the removal method was used (except for a few swales where index counts were used) to determine adult numbers so comparisons among years and swales are valid (Table 1). Overall, the percent of adults within Conservation Area A (protection area) has ranged from 73 to 88% of the total adult numbers in all swales. The percent has been lower (73-77%) in years 1998 to 2003 and significantly higher (80-88%) in years since (2004-2011). The 87% in 2012 was the same percent as in 2011. These are the second higher percents since 1998. We believe these high percents in the more recent years supports our hypothesis that the establishment of the conservation area has provided an increased proportion of the total population within these protected swales (se below).

There have been some notable changes in adult numbers in various swales over the years, although several swales continue to account for a high percent of the total adults. In the protection area (Conservation Area A), swales 2-3, JK, and HWH have varied considerably over the years, but consistently supported the highest number of adults of any swales. In 2012, the highest counts were in these same three swales: HWH with 566 (the highest count ever in this swale), JK with 465, and 2-3 with 266. The other high count in 2012 was Public swale with 250 adults (Fig. 3). Adult numbers in this swale have varied more than any other in the core area over the years, from 275 in to 6 in 2005. Swale 1 supported high numbers, averaging over 75 adults until the last two years when numbers decline to 23 in 2011 and 11 in 2012. Swale 4 also supported relatively high numbers, over 60 adults in 1998, 2001, and 2002, but was lower to very low in most other years. In 2012 the count in this swale was 13 adults.

Two other Conservation Area swales, WX and WY, have supported high numbers of adults in some years, often over 35-40 to but both had only 4 adults in 2012. Swale WWW had 31 in 1998 and 18 in 1999 but less than 5 in all years since. The cause for the reduced numbers in recent years is probably a result of dune movement which has deposited loose sand over some of the gravel and other previously suitable interdunal swale larval habitat.

Numbers of adults in most of the travel corridor (unprotected) swales have been lower to much lower than Conservation Area A swales in all years, although numbers in most of these were higher in 2012 as has the total adult population. In previous reports we found that in years when total population is higher, numbers in peripheral swales tend to be higher probably a result of adults dispersing from the high density swales. The highest count in the travel corridor in 2012 was swale E1 with 68 adults. This swale is adjacent to swale 1 and has ranged from less than 10 to as many as 104 adults over the years. The series of swales North of Swale 4 (5 through 10) had 42 adults which was the highest count since 74 in 2002. Swale E6-7 had 30, the highest count there since 53 in 2002. Also with exceptionally high counts in 2012 was swale E2-3 (adjacent to swale 2-3) with 32 adults compared to 11 the previous two years. Swale QR has had consistently high counts every year, ranging from 24 in 1998 to 156 in 2002 and 150 in 2011. This swale has several patches of more compact clay/silty soil which supports good numbers of larvae, perhaps because it may experience less ORV traffic than adjacent trails through this swale and/or because the more compact soils with larvae are less impacted. The significant decline to 9 in 2012 could be due to continued movement of sand covering some of the compact sand/gravel substrate in the interdunal swale that was larval habitat. Signs were added to protect this swale in 2011.

Several other travel corridor swales that had significant patterns of decline in more recent years were LMN and EQR. EQR once included a small area of gravelly more stabilized soil where adults were concentrated, but over the past 7 years this has been covered over from sand movement and adults have disappeared. The observed declines in many of the unprotected travel corridor swales has been significant compared to swales within the conservation area, and may be caused by increased ORV traffic in this area. Even if the numbers of OHVs have remained the same, it is reasonable to assume that the establishment of the conservation area would mean less area to ride and a coincidental increase in OHV traffic diverted to the travel corridor, possibly resulting in greater negative impact on beetle habitat in this area. Such an effect would probably take several years after the establishment of the conservation area in 1998 to be realized.

Fig. 3. Aerial photo showing ranges of adult numbers per swale in 2012.

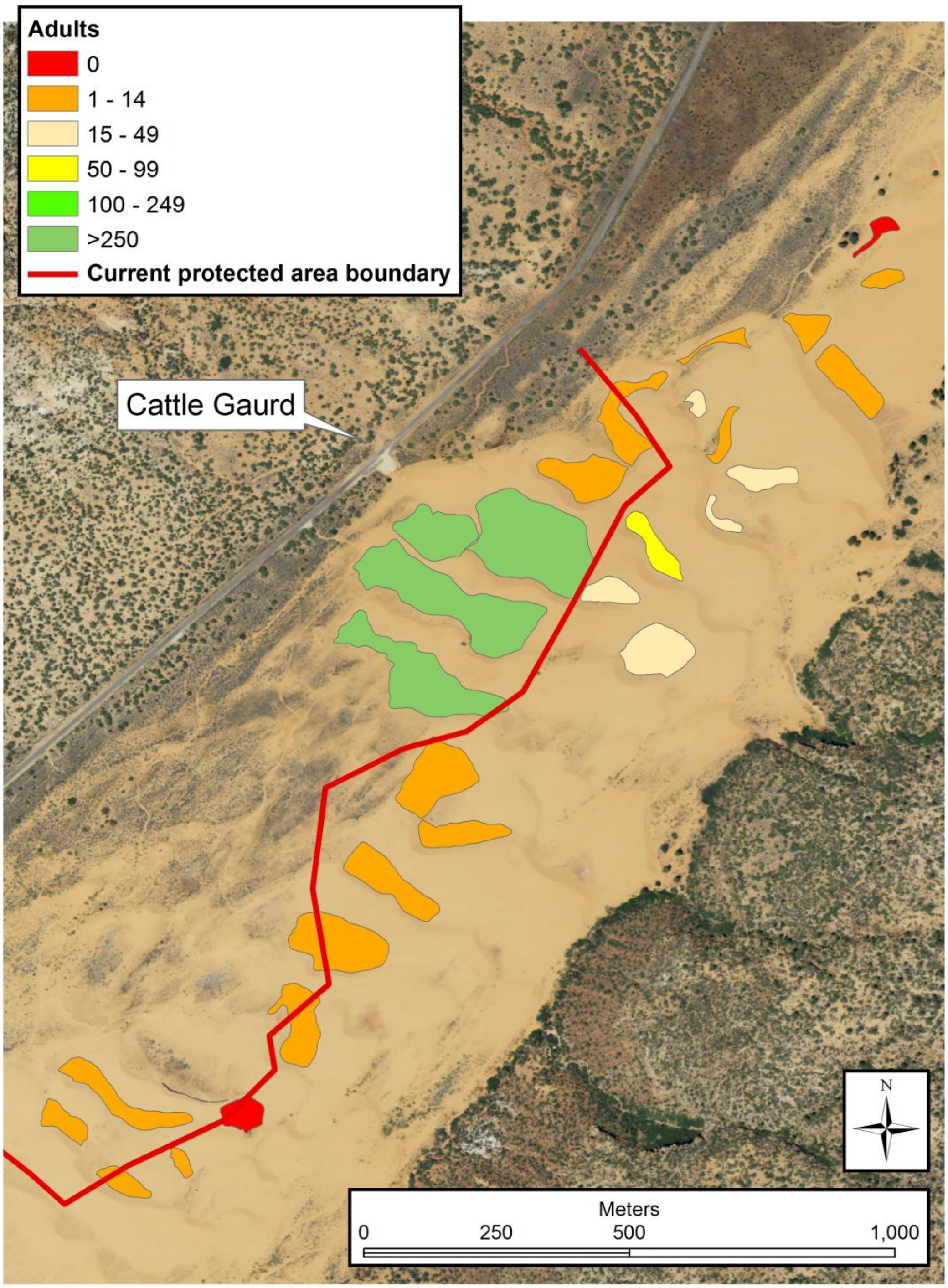


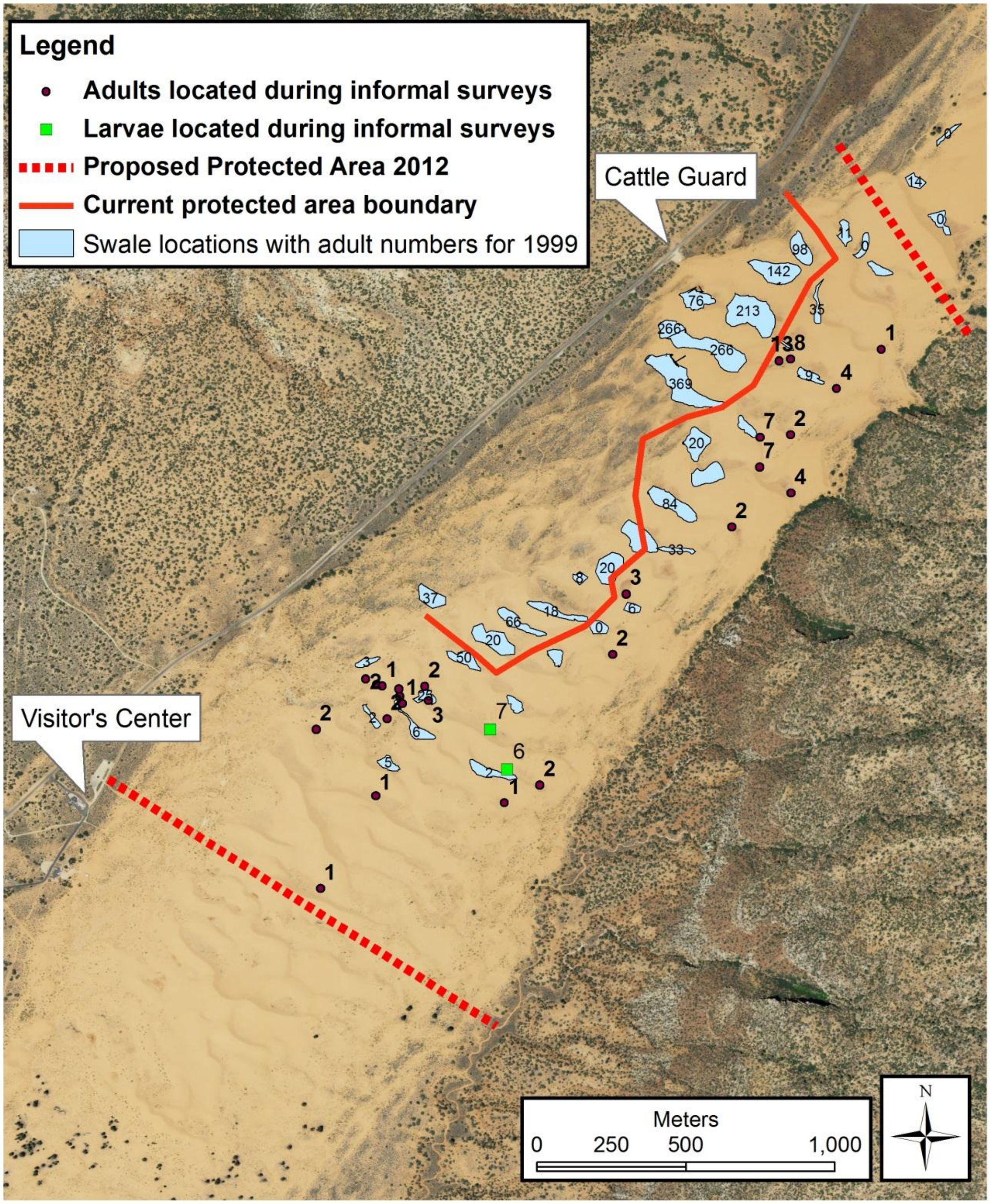
Table 1. Numbers of adults in swales in Conservation Area A (protected swales) and in swales in the travel corridor (unprotected), 1998 to 2012.

Swale	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CONSERVATION AREA SWALES															
4	46	98	23	62	74	20	5	9	28	4	17	40	40	44	13
1	52	142	87	116	205	48	75	72	76	45	118	76	93	23	11
pub		76	97		275	36	65	6	155	60	63	42	99	39	250
2,3	155	213	244	278	349	108	111	144	148	140	171	227	206	158	266
IJK	91	266	189	191	748	114	114	91	265	143	280	241	267	335	465
H WH	59	369	133	180	386	90	179	111	178	114	161	270	220	200	566
W-WW	31	18	3	7	15	2	1	0	0	0	0	0	4	3	0
WX	22	66	82	42	94	30	37	41	40	44	1	39	88	13	4
WY	13	37	45	12	46	5	17	10	25	41	43	4	20	36	4
Total	469	1285	903	888	2192	453	604	484	916	591	854	929	1037	851	1579
% Protected	**73**	**77**	**76**	**78**	**75**	**77**	**84**	**88**	**82**	**84**	**80**	83	82	87	87
UNPROTECTED SWALES															
N of 4	65	30	36	62	74	11	8	3	16	10	13	12	15	2	42
E6-7		6		34	53	2	3		4	3	2	2	0	5	30
E4-6	21	27	50	55	137	2	3	0	1	3	17	5	1	15	15
E2-3												48	11	11	32
E1		35	16		104	6	28	5	61	5	60	66	25	11	68
G	2	7	0	3	6	0	0	0	0	0	0	0	0	0	0
LMN	21	27	24	5	42	12	1	3	5	7	2	5	2	8	7
OP	22	84	3	5	25	21	1	3	9	2	3	1	53	20	2
QR	24	73	82	93	156	68	60	42	83	60	107	38	90	150*	9
EQR		33	27	25	40	7						0	0	0	0
DT											3	0	0	36	22
ST	10	28	34	9	40	0	3	0	1	0	2	3	17	13	7
U	5	0	0	4	0	0	0	0	0	0	0	0	0	0	0
V	2	0	0	0	5	1	0	0	3	2	2	5	4	2	0
X		12		3	11	2	4	4	5	6	2	7	7	0	1
Y		20	9	0	7	2		0	0	2	1	0	2	0	1
Total	172	382	298	298	727	136	115	65	195	108	214	192	227	123	236
% Unprotected	27	23	25	22	25	23	16	12	18	16	20	17	18	13	13

Adult Surveys in other areas of the dune field

Results of the surveys throughout the dunefield confirmed previous surveys conducted in several years since 1992 that very little habitat exists beyond our core survey area (Conservation Area A, the adjacent travel corridor and the area several hundred meters to the north. Survey routes for the various searches throughout the dune field are given in the Appendix and in Fig. 4. All but one of the adults found in the travel corridor east of Conservation Area A and in area D south of Conservation Area A. A total of 44 adults were counted in the travel corridor beyond (further east of) the swales we regularly survey Fig. 4). A total of 16 adults were found singly or in small numbers throughout the D area. We also counted 13 larvae in two separate patches even though larval survey conditions were poor because of drought conditions. Most of these were within or near interdunal swales where much larger numbers of adults were found in several earlier years (1998-2000). As indicated in Fig. 4, one of these swales had 50 adults and another 25 in 1999. Since that time surveys have not been conducted every year, but when they have been done adult numbers were low, less than 10 and not included in annual reports.

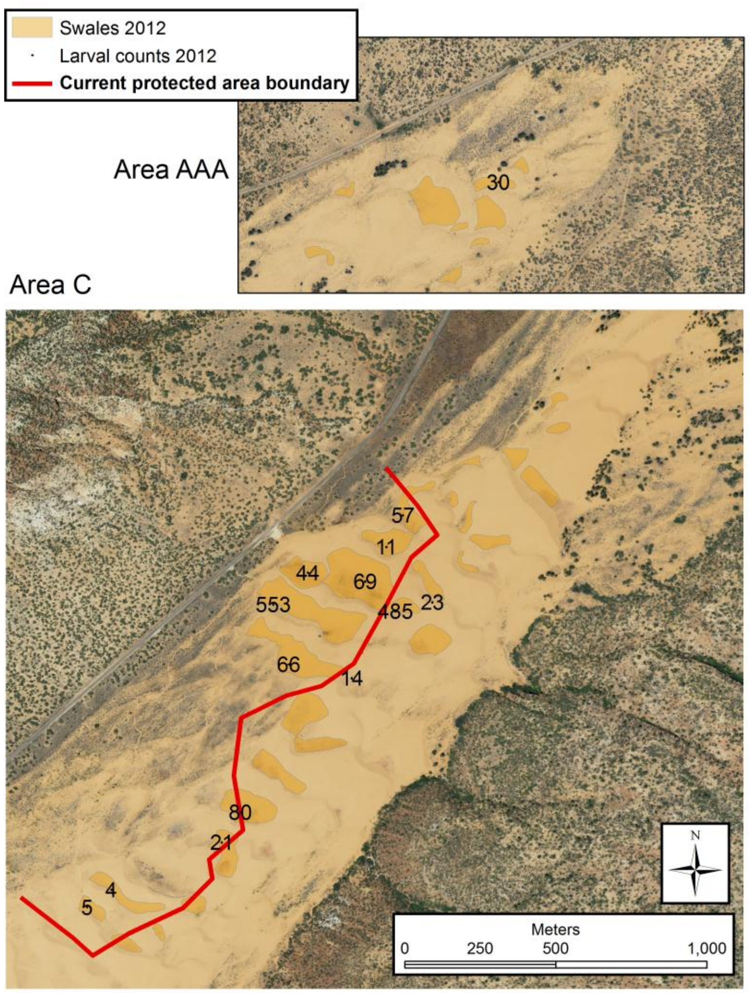
Fig. 4. Aerial photograph of primary habitat area for the CPSD tiger beetle, including interdunal swales with adult numbers and the current and proposed protection area of Conservation Area A.



Larval Distribution and Abundance

As indicated above, the plan to conduct full surveys for larvae in all swales in 2012 could not be done because of the extremely dry conditions result from a lack of rant in all of April and May. Conditions were also suboptimum in 2011. Larval activity becomes progressively reduced with ensuing drought and do not open their burrows, so larval surveys are thus not indicative of their distribution and abundance. The swales done under moderate survey conditions are given in Fig. 5 below and show relative abundance among them. Highest counts were 553 in JK, a swale with very high adult numbers and E-3 where most of the larvae are not *C. albissima* but *C. tranquebarica*. Larval counts for 2012. Interestingly HWH another high adult swale had only 66 larvae suggesting larval recruitment here may be low. Swale 1 especially and to a lesser extent swale 4 had low adults and low larval numbers in 2012 suggesting decline of habitat in these swales possibly due to dune movement. A similar decline of both adult and larvae was seen at WX and WY.

Fig. 5. Total counts of larvae in core area swales that were surveyed in 2012.



Although possibly a bit outdated we include here results of larval surveys from 2009 and 2010 when conditions were ideal for all swales surveyed and additional parameters could be determined. In nearly all swales numbers and densities of larvae were higher, often much higher (5-10 x) than adults. This is a common pattern in insect populations which experience high immature stage mortality and have evolved to have higher fecundities. Comparison of the October and April numbers in these different years are not valid since survey conditions greatly affect the larval activity; however, comparisons among swales surveyed at the same time and the distribution of larvae within swales should be valid.

Interestingly, there was not a close correspondence between adult numbers and larval numbers per swale. Some swales with moderate adult numbers had large numbers of larvae and high larval densities. For example, swales 1 and 4 had high larval numbers and densities compared to adult numbers and swale JK had high numbers of both adults and larvae. Highest larval densities over both surveys were in swales 4, 1, public, and E3 indicating these swales had a relatively high proportion of area suitable for larvae. It is important to note that many of the larvae in swales 1 and E3 were another species, *C. tranquebarica*. These same swales also had relatively high adult densities but lower total adult numbers than the three largest area swales which had the highest numbers of adults (2-3, JK, HWH) but relatively low larval densities. This pattern can be explained by the very large swales (all over 15,000 m^2) all having extensive areas (upper slopes, vegetated flats) which supported no larvae and were apparently unsuitable for oviposition and larval recruitment (see maps). Indeed, as can be seen in the larval maps in the Appendix, most swales had only limited areas with larvae, indicating that oviposition/larval recruitment sites are very limited in the CPSD dune field. Several additional swales had larvae present in 2011 but not in 2009 and 2010. These included swale ST with 49 larvae, V with 38, WWW with 29, 6 with 12, DT with 7, LM with 6, 5 with 4 and 7-8 with 2, and X with 2.

Table 2. Larva and adult numbers and densities in all major swales. Results are for September 2009 and April 2010 and adult numbers for May of 2009 and 2010 (results for 2011 were not used since survey conditions were suboptimum and resulted in lower counts).

Swales	Area m^2	2009 No.of Adults	2010 No. of Adults	2009 No. of Larvae	2010 No. of Larvae	2009 Ad.Density No./100m^2	2009 Lv.Density No./100m^2	2010 Lv.Density No./100m^2
4	5593	40	40	481	482	7.2	8.6	8.6
1*	8341	76	93	722	416	0.58	8.7	5
E3*	1968	48	11	228	270	2.4	11.6	13.7
2,3	18047	227	206	334	53	1.3	1.9	0.3
public	4002	42	99	359	205	1.1	9	5.1
JK	16209	241	267	236	818	1.5	1.5	5.1
HWH	15860	270	220	230	270	1.7	1.5	1.7
QR	7068	36	90	214	76	0.5	3	1.1
OP	7929	1	53	34	6	0.01	0.43	0.1
WX	8322	39	88	131	45	0.47	1.6	0.5
WY	5177	4	20	ns	3	0.08	ns	0.06
E1-4	3488	66	25	348	41	1.9	10	1.2

*These swales have some adults and apparently many larvae of *C. tranquebarica* co-occurring with *C. albissima*

The swale maps showing larval distribution and abundance and clay lenses (included in the Appendix of the 2011 report) provide further explanations for the observed patterns of higher larval densities in more compact, finer grained soils (clay lenses) (Fig. 4). The total number of patches with burrows were significantly higher in the non lens areas (360 to 83), explained because the area was much greater (Table 3). More indicative, however was the significantly higher density of burrows in clay lenses (13.9 burrows per 10 sq. m) than in non lens areas (3.1). The density of patches with larvae was comparably higher in lenses (1.3 patches per swale area) than in non lense areas (0.34). Such patches may be more favorable because they hold more moisture and more compact soil, both of which could provide a more favorable oviposition substrate. The less compact larger grain size sand throughout most of the swale areas could be less favorable for oviposition or result in higher larval mortality because of reduced moisture or more easily disrupted burrow structure.

Results for individual swales indicated swales 4 and 1 at the north end of Conservation Area A have relatively large clay lens areas and high concentration of larval burrows within or adjacent to these clay areas. However, many of the burrows in swale 1 have been identified as *C. tranquebarica*, a species that co-occurs with in this swale. Larvae of this species were rare in swale 1. Similar high concentrations of larvae were also found within and near clay lenses in swales public, 2/3, and JK. Most of the north/northeast areas of these swales were dune slopes which supported few or no larvae. Swale HWH had large numbers of adults but relatively fewer larvae, and many of these were within clay areas. Except for QR and V, larval numbers were lower in most swales south HWH and had few or no clay lenses. Some of these swales had rock and gravel over much of the surface and moderate larval numbers within these areas (Appendix). Although less favorable than clay lenses, rock/gravel surface substrate seemed to be favorable for ovipositon and larvae possibly because it stabilized the soil more than the other loose sand areas within much of the swale area.

Table 3. Summary results of larval distribution within clay lenses and open areas for all major swales (also see maps in Appendix of 2011 report).

Swale Area	Total Area	No. of Burrow Patches	Mean No. Burrows/Patch	% Patches	Total No. of Burrows	Burrows/area	Burrow Density	Burrow Patches/area	Patch Density
Clay Lenses	6245	83	10.5	19	874	874/6245m2	13.9	83/6245	1.3
Non Clay	105,426	360	9.1	21	3269	3269/105,426	3.1	360/105,426	0.34

Fig. 6. Photograph showing a representative clay lens (the darker area) of more compact and more moist soil which support proportionally larger numbers of larvae.

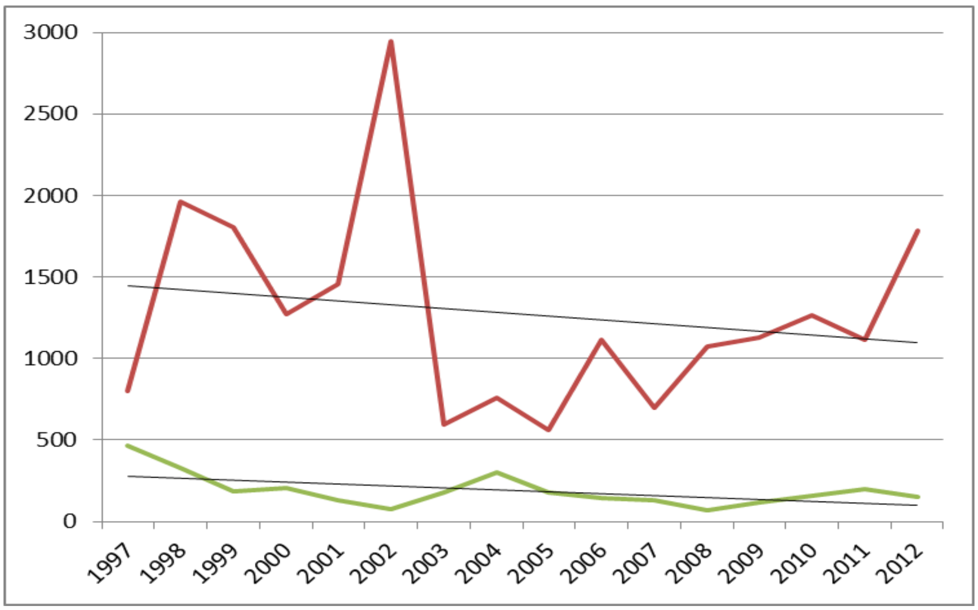
Rainfall Patterns and Effects on C. albissima populations, through 2012)

One of the key goals of our studies with the CPSD Tiger Beetle is to obtain information that will contribute to the protection and recovery of this rare species. Understanding what factors regulate population size and changing dynamics is probably the most critical aspect of this goal. As a result of our long term studies with this beetle and additional experience with tiger beetles, we have become convinced that rainfall is likely to be the primary factor controlling population size in this species as it may be in other species in desert or semidesert areas. Included in these recent studies at CPSD are field experiments that have documented how supplemental watering of patches within interdunal swales attract adults with a coincidental increase in oviposition, larval recruitment,and larval activity (Knisley and Gowan 2006). Additional and more thorough studies of this effect have been initiated and are discussed below. Evidence from studies with other tiger beetles (Knisley 1987, Knisley and Juliano 1988, Hadley et al. 1990) has also demonstrated how increased rainfall and soil moisture increase prey abundance which contributes to increased larval survival and adult fecundity. However, because of the complex life cycle of *C. albissima* and variable effects of rainfall on various parameters which affect adult numbers, direct correlations with rainfall amounts and adult numbers are complex and not clear cut An example of the complexity is the asynchronous development, a two or sometimes three year life cycle and the various direct and indirect effects of rainfall/soil moisture on the many life history parameters. An additional problem may be our use of rainfall data from the Kanab station which may not always directly correlate with what is actually occurring at the dunes. Kanab is the closest station available, has a complete record of rainfall, and can provide general trends in annual rainfall over the years that relate to that at CPSD.

Regardless of these difficulties, we have some evidence that rainfall amount is associated with adult beetle abundance (Table 4, Fig. 7). For example, the high adult numbers in 1996 and 2002 followed several prior years of high rainfall. Also, we have noted reduced adult numbers in 2003-2005 following low rainfall amounts in 2001 to 2003. Another complication for developing correlations is that the actual pattern of rainfall within a year may be more important than the total rainfall. For example, the low adult numbers in 2004 and 2005 might be explained by the low rainfall in the April-June period in 2002 and 2003 compared to most previous years. There was significant rain in April 2003 but this was early in the month when it may have had little positive effect on adult oviposition. Also, total rainfall (April-October) for 2002 and 2003 were the lowest of any two year period since the early 1990's and with low April-June amounts probably combined to explain the low numbers in 2003 and 2004. In contrast, the May and total rainfall from 1997 to 2000 included four of the highest rainfall years since 1992 and may have explained the build-up of larvae in the northern dune area. These northern larvae peaked to highest numbers in 1998 and 1999.

Overall, the trend of April through October and April through June rainfall since 1992 has been downward, and may explain why the beetle population has not increased significant. It is surprising then that the population has increased progressively since 2003 and especially in the past 4 years. Clearly, the way that rainfall affects the beetle, its prey and other components of the CPSD ecosystem are complicated and not fully understood. It is likely that rainfall in May has the most impact since this is the most important month for recruitment since adults are at peak activity and ovipositing. Additional recruitment would also occur in April and June. The downward trend for rainfall during this April-June period, especially in the past 4-5 years could explain lack of a significant population surge. Rainfall in 2010 was again low (.72 inches) for the April-June period and one of the lowest ever totals (.05 inches) in May (Table 4), but April-October total was higher than other recent years. In regard to the most recent pattern, we see a progress increase of April-October of 2.82 in 2009, 4.49, 5.29 in 2010, and 7.81 in 2011, There was also a significant increase in 2011 for both total and April-June and these patterns seem to support our prediction of an increased population size in 2011 and 2012. The total for 2012 was only 0.56 for April-June (the second lowest ever) with no rainfall reported in May and June and 5.3 9 (about the norm) for April-October.

Fig. 7. A. Adult numbers (red line) and total rainfall (green line), April through October at Kanab, 1997-2012. Adults and larvae are active late March through October while April through June, especially May, is main period of oviposition and larval recruitment. A.



B. *Enlarged view of April through October rainfall, 1992-2012*

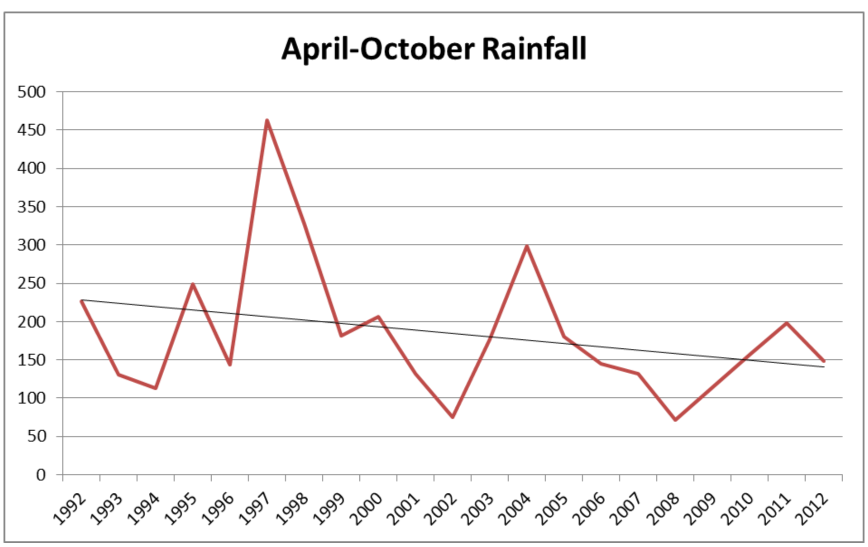


Table 4. Monthly rainfall at Kanab for periods when adults and larvae are active (April through October), 1992-2012.

Months	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Apr	0.17	0.06	2	2.2	0.43	0.89	1.9	2.12	0.41	1.44	0.29	1	1.22	1.36	0.82	1.03	0.07	0.21	0.33	0.67	0.56
May	1.9	0.22	0.28	2.8	0.45	0.4	0.5	0.25	0.08	0.51	0.12	0.59	0	0.49	0.05	0.04	0.13	0.57	0.05	0.65	0
Jun	0.18	0.56	0.11	0.9	0.3	1.34	0.45	0.84	0.53	0.12	0	0	0.16	1.21	0.18	0.03	0.02	0.3	0.35	0.2	0
Ap-Jn Total	**2.3**	**0.84**	**2.4**	**5.9**	**1.2**	**2.6**	**2.9**	**3.21**	**1.02**	**2.07**	**0.41**	**1.59**	**1.38**	**3.06**	**1.05**	**1.1**	**0.22**	**1.08**	**0.73**	**1.52**	0.56
mm	**58**	**21**	**61**	**150**	**31**	**66**	**74**	**81**	**26**	**53**	**10**	**40**	**35**	**78**	**27**	**28**	**6**	**27**	**18**	**39**	**14**
Jul	0.93	0.01	0.02	1.4	1.4	0.6	1.8	4.23	0.62	1.19	0.32	2.32	0.21	0.18	1.14	0.53	0.23	0.97	1.31	1.8	1
Aug	2.7	1.7	0.31	0.87	0.27	4.1	0.6	1.5	2.15	1.46	0.23	1.59	2.88	1.35	0.62	2.09	1.58	0.42	0.48	0.94	2.6
Sep	0.94	0	0.54	1.7	0.91	9.1	5.5	1.4	0.27	0.64	2.56	0.7	1.67	0.01	0.78	1.47	0.14	1.11	0.22	1.79	1.2
Oct	2.1	2.6	1.2	0	1.9	1.8	2.2	0.02	4.04	0.27	1.98	0.76	5.64	2.5	2.12	0.01	0.65	0.91	2.55	1.76	0.5
Jl-Oc Total	**6.67**	**4.31**	**2.07**	**3.97**	**4.48**	**15.6**	**10.1**	**7.15**	**7.08**	**3.56**	**5.09**	**5.37**	**10.4**	**4.04**	**4.66**	**4.1**	**2.6**	**3.41**	**4.56**	**6.29**	**5.3**
Grd Total	**8.92**	**5.15**	**4.46**	**9.82**	**5.66**	**18.2**	**12.9**	**7.15**	**8.1**	**5.28**	**5.5**	**6.96**	**11.8**	**7.1**	**5.71**	**5.2**	**2.82**	**4.49**	**5.29**	**7.81**	5.86
Total (mm)	**227**	**131**	**113**	**249**	**144**	**463**	**328**	**182**	**206**	**132**	**75**	**177**	**299**	**180**	**145**	**132**	**72**	**114**	**157**	**198**	148

Adult Dispersal

A total of 917 adults were marked during removal studies, 305 in swale HWH, 410 in JK, and 202 from swale 2-3). Of this total 44 were recaptured in different swales, as follows:

Mark Swale	Recapture Swale	Minimal Distance Moved
2-3	1 in E1	175 m
2-3	2 in HWH	275 m
2-3	6 in Public	75 m
JK	6 in HWH	75 m
JK	10 in Public	100 m
JK	1 in 8	450 m
JK	2 in DT	125 m
HWH	1 in Public	150 m
HWH	3 in DT	125 m

As the numbers above indicate, there were few adults (4.7%) dispersing beyond the swales where they were marked. The distance dispersed was also minimal with all but three dispersing less than 200 meters. It should be noted, however that the surveys for recaptures were all within 6 days of marking, so there was little time for dispersal.

Translocation

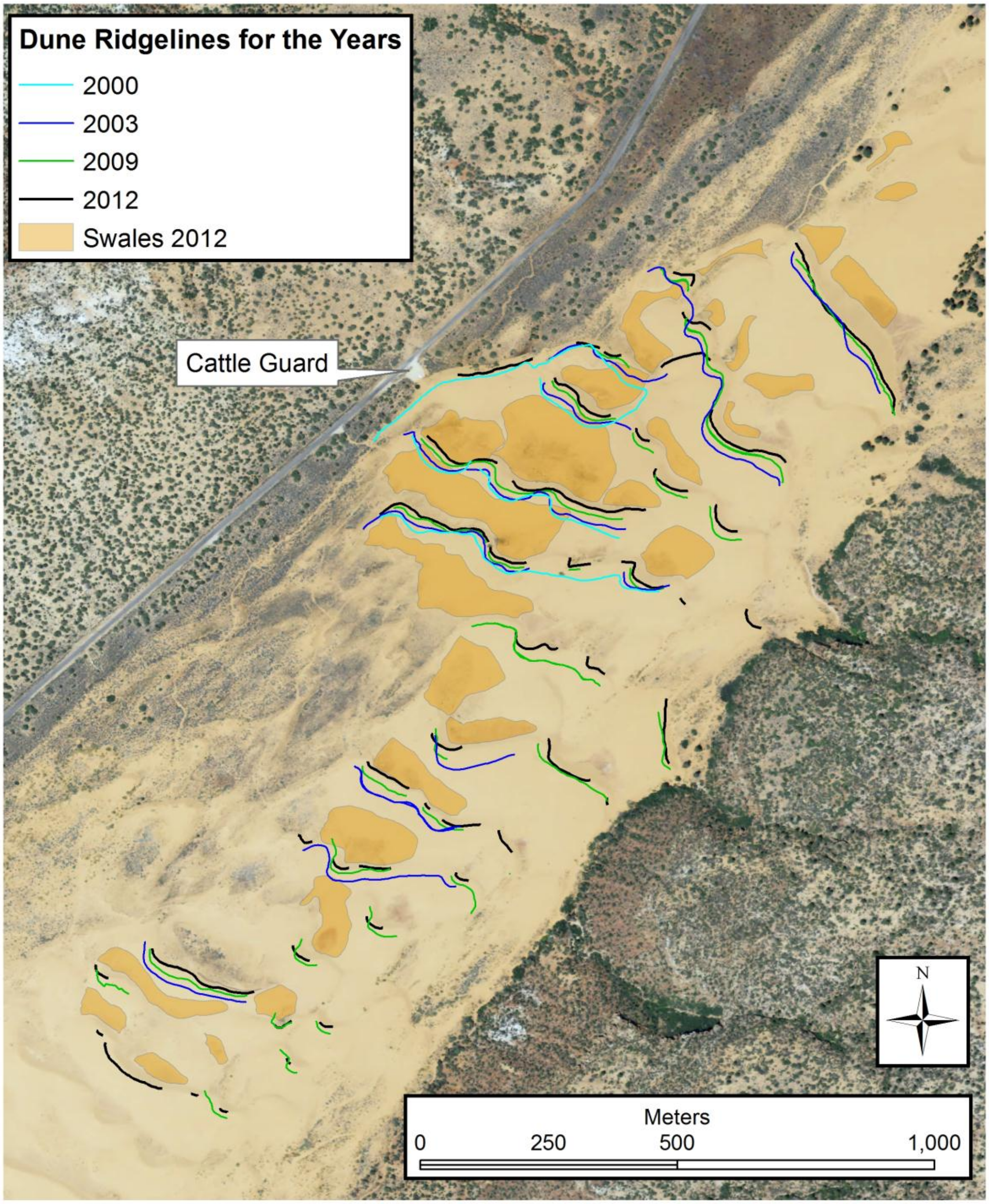
The results of the burrow checks of active surviving larvae and emerging adults for both the 2011 and 2012 translocations are given below. For the May 2011 translocation, 51 of the 112 translocated larvae were still active in September but by the following May when some would have continued at third instars and others emerged as adults, only 12 were active third instar larvae and no adults were recorded in the area. For the 2012 translocation 44 of 118 larvae from May were active in September 2012. These will be rechecked in April or May 2012 for surviving larvae and/or emerging adults. To date these results are comparable to several previous translocations which resulted in high mortality after a year and no evidence of successful complete development or emerging adults. Next years results should provide more conclusive evidence if translocations can be used to establish a population in Conservation Area B.

	2011					2012			
	Trans Date					Trans Date			
	28-May	29-May	2-Jun	15-Jul	17-Sep	26-May	1-Jun	30-Jun	28-Sep
Numbers of Open									
Active Burrows*	112	90	96	32	51	12			
Third Instars	68	58	65	23	39	12			
Second Instars	36	32	31	9	12	0			
Adults	ns	0	0	0	0	0	0	0	0
Number of Open									
Active Burrows*						118	87	64	44
Third Instars						88	68	49	39
Second Instars						30	19	15	5
Adults						0	0	0	0

Dune Movement, 2002 through 2012

As shown in Figure 8, there has been significant north to northeastern movement (the prevailing wind direction) during our period of monitoring this. Movement has varied from year to year and among the different ridgelines. As can be seen movement was to generally greater in the more southern swales but also significant in all mapped swales. We calculated the movement at up to or more than 150’ along most ridge lines and over 200’ in some. Our observations and counts over the years suggest that the significant dune movement in swale 1, WWW and QR has caused the loss of habitat, especially for larvae and contributed to decline in beetle numbers. In swales EQR and E6-7 dune movement has resulted in coverage of the surface with accumulated sand and even greater loss of habitat. Progressive sand coverage may also be the cause of significant decline in numbers in WX and WY in the past two years. Swale V had a patch with large numbers of larvae in a patch of compact sand during the mid-!990s which disappeared within a few years due to sand coverage. The recent 2011 and 2012 surveyed indicated larvae are again present in this patch for the first time since, apparently because or new exposure of the favorable substrate.

Fig. 8. Map of swale area showing GPSed ridgelines mapped in 2000 through 2012 to indicate dune movement.



Rationale for expansion of Conservation Area A

Results of two separate Population Viability Analyses indicated that the single population of *Cicindela albissima* at Coral Pink Sand Dunes is at risk of extinction. This population is highly localized as evidenced by recent adult surveys demonstrating that over 80% of the adult (and larval) population is restricted to Conservation Area A and most of these exist within 3 swale rows (Public-2-3, JK, and HWH). The remainder of the population occurs within regularly-surveyed swales within the protected area, unprotected swales in the existing travel corridor to the east and in several adjacent swale rows outside of the Conservation Area. Factors threatening this population include natural changes to dune morphology and migration patterns that, consequently, cause a reduction in vegetation and prey (i.e., the reduction of habitat within Conservation Area A; swales 1, 4, EQR) and anthropogenic damage to swale vegetation and natural sediment conditions outside of the conservation area.

Studies to better characterize ideal habitat for *C. albissima* and determine if any additional habitat may exist within the dune field were initiated in May 2012 are detailed in the companion report.. One part of these studies involved extensive surveys for adults throughout the whole dune field. As documented above these surveys found adults scattered along the eastern portion of the travel corridor (east of regularly-surveyed swales) and south of Conservation Area A (Fig. 3). These were the same areas where adults were occasionally found in previous years. For example, several swales just to the south of Conservation Area A (the "D swales") produced a few to as many as 50 adults and small numbers of larvae in 1999, the last time comprehensive surveys were made in this area. The only other area supporting the species was at the far north end of the dune field (Conservation Area B) where one adult was found in swale AAA9 and 45 larvae in AAA2. As indicated in previous annual reports, larvae have sometimes been relatively abundant in Conservation Area B (over 100 larvae in several years) before declining, but never more than 5-10 adults have been found. This fluctuation and the failure of translocations to produce a persistent viable population of adults and larvae have convinced us that that Conservation Area B does not provide adequate management options for *C. albissima.* We are convinced the interdunal swales in this region of the dune field lack adequate prey or other necessary conditions for sustaining a population.

The best management option for reducing the extinction risk to the population is to encourage additional habitat development in regions geomorphologically similar to those containing known habitat. The most likely potential habitat is 1) the travel corridor to the east of Conservation Area A, 2) the zone to the south of Conservation Area A including the D swales, and 3) the zone a short distance to the north of Conservation Area A (Figure 3). These areas have supported small numbers of adults in most years we surveyed and often larvae when surveys were conducted. Overall dune type and swale conditions (type and density of vegetation) within these areas are comparable to those in Conservation Area A that consistently support adults and larvae. If OHV activity is eliminated from these areas, we would expect swales to return to a more natural, vegetated condition and provide suitable habitat for *C. albissima* – possibly within a period of 5 years. One option would expand Conservation Area A from 6.4% to 23.7% of the CPSD dune field (Table 1), but would eliminate Conservation Area B altogether (currently 11.5% of the total dune area). These management changes would result in an overall increase of conservation area from 6.4% to 12.2% (23.7%-11.5%) with respect to the entire dune field. Importantly, we recommend an adaptive management strategy that assesses both geologic and biotic/abiotic changes within the new conservation area annually with the goal of modifying the conservation area as needed over time.

Table 1. Coral Pink Sand Dunes: dune area summary (values based on GIS polygon areas.).

Location	Area (m^2)	Percent of Total Dune Field
Current Protected Area B	1,215,135	11.5%
Current Protected Area A	675,966	6.4%
Proposed New Protected Area	2,506,913	23.7%
Total Dune Field	10,599,862	100.0%

Acknowledgments

We greatly appreciate the logistical support, accommodations and cooperation provided by Mike Franklin, Dean Anderson and other personnel at Coral Pink Sand Dunes State Park which was very important to the success of our studies. Thanks to "Bud" Gowan for assistance with all field studies and Paul Abate and Mark Capone for assistance with adult surveys. Special thanks to Ron Bolander for continued interest and financial support of our studies over the years. We also thank Mark Capone of the Utah FWS for his interest in this project and providing securing funding and for his assistance in field work in May 2012.

Relevant Literature:

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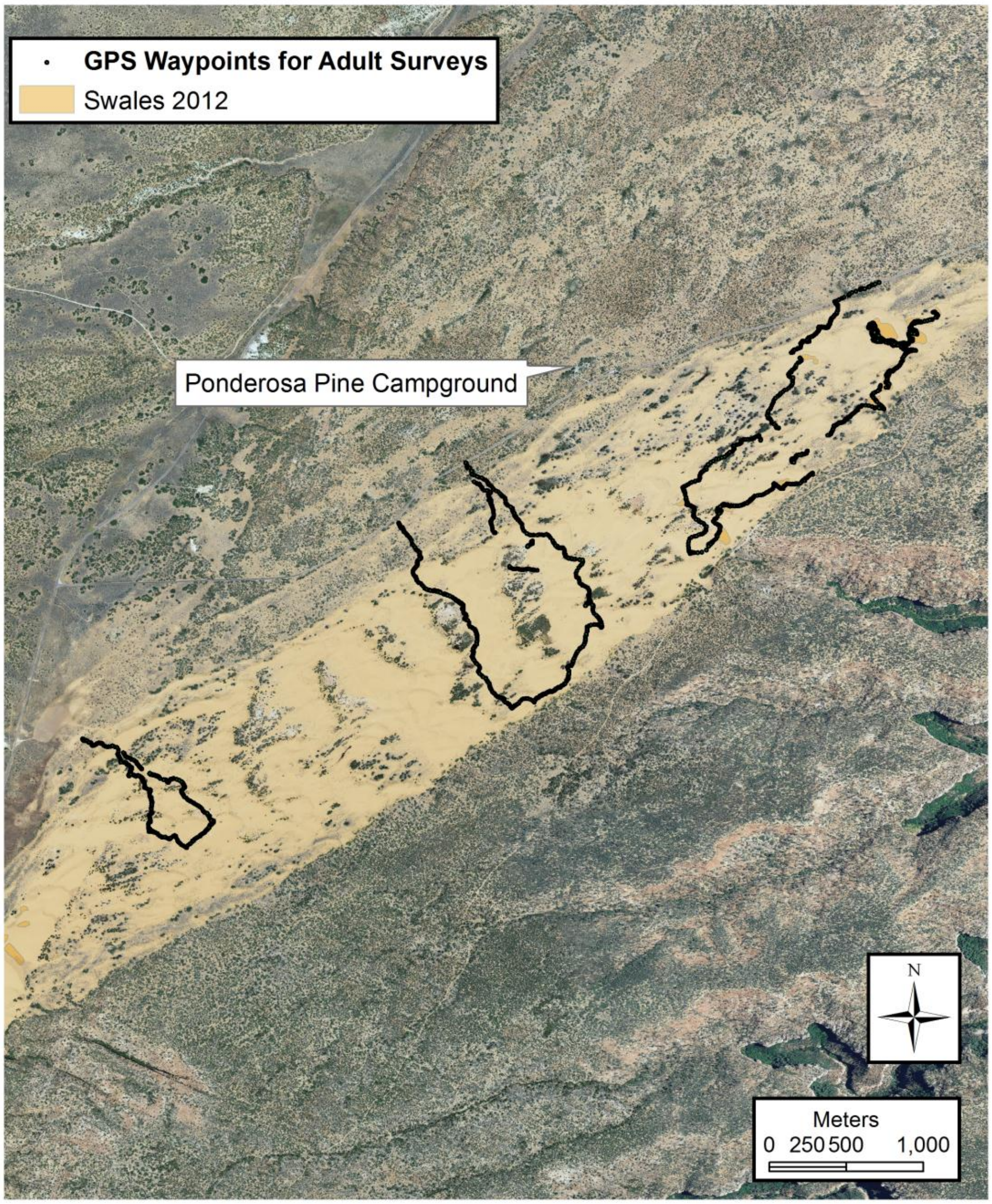
APPENDIX

I. 2012 Adult Population Estimates

Summary of adult population estimates, 2011				
Computed based on removal model by CAPTURE				
Swale	N-hat	SE	Var	
JK	465	10.41	108.368	
HWH	566	93.4121	8725.820	
E4	15	1.3053	1.704	
E1-4	68	6.1711	38.082	
E2-3	32	1.3187	1.739	
Public	250	60.6706	3680.922	
8	24	4.0503	16.405	
DT	22	1.7758	3.153	
2_3	266	28.2619	798.735	
E 6&7	30	1.0987	1.207	
			0.000	
			0.000	
			0.000	
			0.000	
Total:	1738		13376.136	
Locations that estimate failed or only index counts taken:				
LM	4	NA	NA	Index Count
N	3	NA	NA	Index Count
6&7	3	NA	NA	Index Count
1	11	NA	NA	Index Count
4	13	NA	NA	Index Count
5	6	NA	NA	Index Count
9	8	NA	NA	Index Count
E10	2	NA	NA	Index Count
FE9	2	NA	NA	Index Count
10	0	NA	NA	Index Count
OP	2	NA	NA	Index Count
QR	9	NA	NA	Index Count
S	7	NA	NA	Index Count
WX	4	NA	NA	Index Count
X	1	NA	NA	Index Count
Y	1	NA	NA	Index Count
WY	4	NA	NA	Index Count
WWW	0	NA	NA	Index Count
V	0	NA	NA	Index Count
Total	80		1359	
Total recaptures:	32			
FINAL POPULATION ESTIMATE FOR ALL SWALES COMBINED				
N-HAT	1786			
LCL	1559			
UCL	2013			

II. Tracks of routes surveyed for adults outside of the Conservation Area.

Survey Area in AAA, AA and A at North end of dune field



Survey Area in area C (Conservation Area A) and D to the south