FINAL REPORT FOR RARE PLANT MANAGEMENT PROJECTS:

Ecological factors affecting the recovery of Coastal milkvetch (*Astragalus tener var. titi,* Fabaceae), Hickman's cinquefoil (*Potentilla hickmanii,* Rosaceae) and Pacific Grove clover (*Trifolium polyodon,* Fabaceae).

And

Ecological factors affecting the recovery of Gowen cypress (*Cupressus goveniana ssp. goveniana,* Cupressaceae) and Monterey clover (*Trifolium trichocalyx,* Fabaceae).

Presented to:

California State Department of Fish and Game

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INTRODUCTION

This report discusses work conducted during 1998 and 1999 with the following federal- and California-listed rare plants of the Monterey region: *Astragalus tener var. titi* (coastal dunes milkvetch), *Potentilla hickmanii* (Hickman's cinquefoil), *Trifolium polyodon* (Pacific Grove clover), Gowen cypress (*Cupressus goveniana ssp. goveniana)* and Monterey clover (*Trifolium trichocalyx).* Our work was designed to investigate the current ecological status of these plants and to identify crucial factors affecting the population growth and maintenance of each species. The following topics were among those investigated for one or more of the species: seed bank dynamics, factors affecting recruitment and survival, factors affecting reproductive output, habitat preferences, monitoring and mapping of current populations, and trial establishment of new populations.

Because the questions and the methods used were different for each species, we have organized this report by taxon. For each of the five species, we present a synopsis of the current status, the questions we sought to address and the methods we used to do so, results, and the management and research recommendations we draw from these results. Finally, we end the report with a synthesis of these recommendations, and a prioritization of future management and research needs. Figures and tables pertaining to each taxon follow the text of the relevant section.

Astragalus tener var. titi - Coastal dunes milkvetch

Status and Concerns

Astragalus tener var. *titi* (henceforth ATT) is an annual legume currently endemic to a scattered set of neighboring locations within approximately 500 meters of the shoreline along Seventeen Mile Drive (see Figure 6 in Jones & Stokes 1996). The largest concentration of individuals is generally thought to occur within a 55 meter by 26 meter fenced exclosure established for the species, just north of the Bird Rock parking area. All of our work on the species has been performed in or directly adjacent to the exclosure. As with most annuals, populations fluctuate dramatically between years, as has been documented by David Allen since 1992 (Figure 1). During our three growing seasons of work (1998-2000), ATT numbers within the exclosure varied from hundreds in 1998 (a very wet el Niño year), to moderate numbers in 1999 (probably less than 200 plants), to no flowering plants at all in 2000. These annual variations are important for the careful interpretation of our results.

Our work with this species has focused on better characterizing occurrence patterns and habitat needs, evaluating the limitations imposed by competing species, and assessing the relative costs and benefits of disturbances caused by foot traffic and gopher activities. This last issue is motivated by observations that ATT may benefit from disturbance that eliminates or suppresses competing plant species. In addition, we conducted a detailed mapping of ATT density and individual performance (seed production) within the exclosure that can be used in future monitoring of the species.

Methods and Results

Mapping to determine biotic and abiotic limitations to distribution.

From February to mid-June of 1998, we conducted a fine-scale survey of ATT within the Seventeen Mile Drive exclosure, quantifying densities and individual performance, as well as percent cover of co-occurring plant species and several abiotic variables. During this work, the entire exclosure was mapped for all variables, although data was collected at a coarser scale in areas not supporting ATT. Table 1 summaries the data taken, as well as the spatial resolution used for each set of measurements.

We used a Sokia total survey station to ensure high accuracy. This level of precision was necessary to adequately characterize the fine-scale topography of the site, as well as to allow future monitoring of trends in ATT distributions and the distributions of other species that may strongly influence ATT, in particular Pansa sedge (*Carex pansa*). To facilitate future monitoring of the exclosure, we placed a rebar stake outside of the northwest corner to mark the origin point of our X and Y survey axes, with the X axis running eastward and the Y axis running southward from this point. We also tagged the point that we defined as north on the northern fence of the exclosure; this point is not completely accurate directionally, but will allow for precise realignment of the survey station should future surveys be conducted by the same system.

In total, we found 934 ATT individuals in the exclosure in 1998. We summarized the survey results in a series of ArcView maps for ATT densities, average ATT seed set, and microtopography. In addition, we mapped the extent and percent cover of Pansa sedge in the southwestern portion of the exclosure, in order to facilitate future monitoring of its spread. Maps of these variables are shown in Figures 2a and 2b; the CD accompanying this report also contains all these data layers. This detailed mapping illustrates that at least in 1998, ATT plants were restricted to the NW ½ of the exclosure. Densities were highest in the central swale area in this part of the exclosure (up to 125 ATT/m^2), but lower densities occurred throughout this ½ of the exclosure (Figure 2a). While there is no overlap of Panza sedge and ATT, there are also many areas in the NE and E areas of the exclosure with no sedge and also no ATT (Figure 2b). Seed set of ATT plants can be quite high, up to 270 seeds per plant. However, most plants produce fare fewer seeds. For all plants, mean seed set was 33.3 ± 3.4 (mean $\pm$ SEM); considering only those plants not damaged by gophers or other herbivores, mean seed set was 44.2 ± 4.3. There is no clear pattern of increasing seed set in areas of higher densities (Figure 2a).

We carried out a series of correlation and regression analyses to explore associations between

ATT density and performance and the abiotic and biotic habitat variables measured, initially focusing on factors that previous observations had suggested were important in limiting ATT. In particular, we assessed the degree to which ATT are restricted to swale microhabitats, and whether or not their distribution strongly correlates with soil moisture, disturbance, or the presence of competitors, particularly the common, introduced cut-leaf plantain (*Plantago coronopus*). We limited our analysis to the NW half of the exclosure, where all but two ATT individuals occurred, in order to avoid swamping out finer-scale trends in ATT distribution by inclusion of areas with no plants. However, overall results did not differ when data from the entire exclosure were included.

Our analyses confirm that ATT are associated with swales, but this relationship is surprisingly weak. Elevation is a good predictor of ATT presence or absence; mean elevation of quadrats containing ATT was significantly lower than that of those with no ATT (t-test, $p<0.001$). However, this relationship primarily reflects the almost complete absence of ATT from the higher-elevation, Eastern edge of the exclosure, and not the more localized influence of small swales. In order to explore the role of microtopography in driving ATT distribution apart from this larger-scale pattern, we first fit a multiple regression of spatial location (independent variables = X and Y coordinates and their interactions) on elevation across the exclosure. We then used deviations from this overall elevational gradient as a measure of local microtopography (i.e. negative residuals indicate localized depressions) and correlated them with ATT density. This analysis indicates a significant, positive relationship between ATT density and the presence of swales (Pearson's correlation, $p= 0.004$). However, even this correlation explains less than ten percent of the variation in ATT density, suggesting that the distribution of plants within the exclosure is associated with but not strongly restricted to swale habitat.

We found no other no strong relationships between either presence/absence or abundance of ATT and any of the other biotic and abiotic variables measured, including soil moisture, amount of bare ground, or percent cover of other plant species, either individually or by functional groups (Table 2). In particular, we found no evidence for any positive association of ATT with soil moisture or for any negative correlation with cover of other plant species, including *P. coronopus*. Similarly, mean reproductive success of ATT appears unrelated to any of the measured variables, with the exception of ATT density. Interestingly, mean seed set per plant declined with ATT abundance (Pearson's correlation, r=-0.498). This relationship suggests that either ATT compete significantly with one another at higher densities, or that habitats best for germination or accumulation of seeds (i.e. swales) are not optimal for subsequent growth and reproduction.

Overall, these results suggest that ATT may be less restricted in its habitat requirements than previously thought. ATT density weakly correlated with swale microhabitats in the exclosure, but we found no evidence for a strong dependence of ATT on swales, or for a major role of soil moisture or competitors in limiting its abundance. An important caveat is that the unusually wet El Niño conditions may have largely ameliorated the effects of soil moisture gradients and competitors, and these factors could well prove important influences on ATT distribution in drier years. However, the high reproductive success of many individuals located near the edges of the exclosure, outside the densest patches of ATT, provides additional evidence that these areas may be good potential habitat.

Finally, at a larger scale, during 1998 we searched for and mapped locations of flowering ATT plants along the ocean (Western) side of Seventeen Mile Drive and Bird Rock Road, and also along the Eastern side of Seventeen Mile Drive within ½ mile of the exclosure. We repeated these surveys in April of 2000. Figure 3 shows these population locations overlaid onto an aerial photograph of the area, and Table 3 lists the approximate areas and habitat characteristics of each population. The most striking findings were populations in a recently resurfaced vegetation island NW of the exclosure (populations A, B, C) and very dense ATT stands on open rocky areas to the East of 17 Mile Drive (population G). We found flowering plants in all these populations in 2000, a year when no flowering ATT were seen in the exclosure. In addition, all these populations are far drier and less vegetated than any part of the exclosure, suggesting that at least in years with heavy winter rainfall, the exclosure may not contain the best habitat for the species. Since these areas have not been censused before, it is not clear how large a flowering population they support in most years.

Experimental tests of competition and disturbance effects.

In 1998, to gauge the effects of interspecific competition on recruitment and survival of ATT, we performed removal experiments in 25 cm x 25 cm plots located within the exclosure. Plots were organized into blocks, each block with 2 treatments: clipped and unclipped. In clipped treatments all above-ground portions of plant species other than ATT were removed twice during the growing season at a two-week interval, once in early February (when plots were established) and once three weeks later. Because only the above-ground portions of plants were clipped, native perennials such as *Armeria maritima, Deschampsia caespitosa* and *Danthonia californica* were not severely harmed. Twenty-five blocks were established in and adjacent to areas where newly germinated ATT seedlings were found. In all plots, seedling germination and survival were followed; these data were recorded for the inner 22 cm x 22 cm of each plot to control for edge-effects. A week following the second clipping, die-off of ATT seedlings in the clipped plots was noticeable, and clipping was discontinued.

Thirteen plots in each treatment contained enough seedlings for inclusion in statistical analysis. The experiment showed no evidence of competitive effects of perennial plants on ATT (Table 4). This result further suggests that, at least in the swales in which this experiment was conducted, perennial plants, including the very common introduced cut-leaf plantain (*P. coronopus*), are unlikely to severely impact ATT performance. While the relatively late initiation of this experiment means that there may have been some confounding damage to young ATT plants in the removal treatments, the lack of treatment effects on per capita performance still suggests little strong competitive inhibition in swales. However, it is important to note that this experiment was carried out in an exceptionally wet El Niño year, which may have reduced competitive effects substantially.

During 1999, we conducted three additional studies to gauge the effects of both competition and disturbance on ATT:

1. While the 1998 results just mentioned suggest few competitive effects in swales, we observed that outside of swales ATT is often associated with past gopher disturbances, and that where it occurs outside of the exclosure, the species is often in lightly trampled areas. To investigate the role of gopher disturbance on ATT performance, during January 1999 we

marked ten 0.5m by 0.5m areas with clear, recent ground disturbance by gophers, and also paired nearby control areas matched for elevation and aspect. We recensused these plot in both spring 1999 and 2000 but found no ATT in any plots.

2. We also conducted an experiment to determine if ATT can successfully grow in the southern area of the exclosure. The SW area of the exclosure is now dominated by Pansa sedge, and no ATT were found in this area in 1998 surveys; the SE area is generally similar in vegetation to the northern portion of the exclosure, dominated by perennial grasses, annual grasses, and *P. coronopus*, but only two ATT were found in this area in 1998. In January 1999, we cleared two 1m by 1m areas within the Pansa sedge, removing all roots as well as above ground matter and leaf litter. In each of these areas we scattered 50 ATT seed pods, collected the year before from plants germinated at the Pebble Beach Company greenhouse. Similarly, we cleared vegetation from two 0.5m by 0.5m areas in the southeastern mixed vegetation area and scattered 25 ATT pods in each of these areas. There was no evidence of ATT germination or growth in these removal areas, either from scattered seed or a persistent seed bank, in either 1999 or 2000.
3. Finally, in January 1999 we started an experiment to examine the effects of both competition and trampling in facilitating seed germination or population spread of ATT. On the N and NW borders of the exclosure, areas without any significant ATT numbers but adjacent to high ATT densities, we established six 0.5x0.5 m. plots in two blocks of three plots each. Within a block, one plot was assigned to each of the following treatments: control, clipping of aboveground plants, trampling. Clipping consisted of trimming vegetation to ground-level at 5 to 14-day intervals. Trampling consisted of ten round-trip passes walking along the length of the plot, and ten round-trip passes over the width of the plot, with effort made to distribute trampling effort evenly. Trampling was conducted at the same time as clipping, every 5 to 14 days (but generally weekly). Simultaneously, plots were monitored for the emergence of ATT seedlings. Disturbance treatments were terminated in mid-April, at which point we had observed no ATT germination in any of the plots. We surveyed these plots again in mid-June 1999 and May 2000 and found no ATT individuals in any of the treatments.

Overall, these experiments did not show evidence of disturbance or competition effects on ATT.

However, positive effects are most likely to be observed in the year following growing-season manipulations. Because 2000 was an extremely low germination year for ATT in the exclosure, these experiments had very low power to detect any effects. One notable observation we made during the 2000 census was that vegetation cover in removal plots was essentially identical to that in control areas, indicating that any management for reduced competition would have to be done at very frequent intervals.

Reproductive biology and seed collection

We conducted preliminary observations to understand the possible importance of pollination biology in limiting seed set now or in the future for these highly reduced and fragmented populations. In the field, observations (a total of 180 minutes of formal timed observations and approximately 350 person-hours spent on other activities during bloom period) of flowering plants revealed only one possible pollinator visit, by a small unidentified black beetle (it is unclear whether this insect was a pollinator or a pollen herbivore). During 1998, we also obtained potted ATT from Bud Lopez, which we examined for seed set in greenhouses without obvious pollinators, as well as for flower morphology that would promote or inhibit selfing. We found high seed set in the greenhouse, as well as flower morphology that suggests selfing as the common form of pollination. (Seed pods were collected from these plants, with the total collected numbering in the low hundreds. A fraction of these seeds have been used in the vegetation clearing experiments described above, and the remainder are in storage at UCSC.)

Dissecting flowers at various stages of development revealed that the anthers curl over top of the stigma, and begin to dehisce pollen before the stigma is receptive; thus, it is impossible for the stigma to receive out-crossed pollen before receiving self-produced pollen. Further, our field surveys of seed production revealed no pods that did not contain developing seed – implying that a lack of pollen transfer is not limiting seed production in these plants (Figure 4). These observations suggest that pollinator services are unlikely to be a strong concern in the establishment and maintenance of ATT populations.

Management and Research Recommendations

Management of existing populations

While our results confirm that small swales represent good habitat for ATT within the exclosure, it is unclear what is driving this result. Our analyses for both competition and soil moisture effects yielded insignificant results. However, our field observations suggest that ATT does well in areas of low-level disturbance, caused by gophers, light pedestrian traffic, or more dramatic but infrequent vehicular disturbances. We recommend that the importance of disturbed areas outside the exclosure be recognized in ATT management efforts. While the exclosure is certainly the best habitat for ATT in some years, recognition of and management for the other ATT populations shown in Figure 3 should be given high priority. Specific measures for maintenance of these areas could include:

- erection of low fencing (similar to that of the exclosure) along the coastal access roads to discourage vehicular traffic over ATT areas, while allowing walking over these areas.
- more control of Pansa sedge and ice plant in areas adjacent to existing ATT concentrations, especially within the exclosure

Establishment of additional populations

Our results suggest several strategies important in future creation of new populations:

- Establishment of initially quite small populations is likely to be a reasonable approach, as Allee effects due to pollinator limitations appear unlikely.
- Because little cross-pollination seems to occur in this species, the use of greenhouse-cultivated seeds for establishment of new populations or augmentation of existing ones is acceptable given two conditions: the seeds are no more than two greenhouse-generations removed from a natural population, and at least 50 seed pods were used in starting the greenhouse plants. Under these conditions, genetic swamping of natural populations is unlikely.
- Coastal areas characterized either by small swales, relatively high levels of gopher

disturbance and/or very low cover of other vegetation (often due to disturbances) are likely to be most suitable for ATT establishment.

- The existence of ongoing management to control exotic (e.g., ice plant) or native (e.g., Pansa sedge) invaders is important for reestablishment sites to have promise of long-term success.

Monitoring and Research

There are three clear priorities for future work with ATT:

- Experimental removal of Pansa sedge and ice plant and experimental vegetation disturbances over two to three years, both within the Seventeen Mile Drive exclosure and in other nearby areas. This would follow up on some work which has already begun, and allow a clearer assessment of the role of particular competitors in limiting ATT populations, as well as of the effects of general disturbance in facilitating ATT population health.
- Monitoring of existing populations, with an emphasis on aerial extent of populations and individual plant performance rather than exact population counts. While population count data give valuable information on rare plants, for annuals, counts of above-ground plants are highly erratic from year to year. Therefore, monitoring the extent of populations may give much more information on the gradual spread or shrinkage of limited populations and on habitat affinities. Since past monitoring of ATT has almost exclusively targeted the exclosure area, it is important to extend monitoring to the other, more scattered, and less protected parts of the Seventeen Mile Drive population.
- Establishment of new populations at sites identified by J&S, using an experimental approach. Establishment of new populations of rare plants has a dismal record of success (see Fiedler, 1991). Therefore, we suggest that establishment of ATT populations be approached as an experiment, with blocked out-plantings of seeds in areas of Pt. Lobos State Reserve, including both control areas and sites manipulated to increase ground disturbance and/or reduce above-ground competition. Such an experiment would be beneficial in understanding how best to target both establishment programs and also ongoing management of existing populations.

Table 1. Type and scale of data collected during ATT-related surveys within the exclosure on Seventeen Mile Drive.

Data type	Scale of surveys and sampling units
ATT densities and distribution	All ATT in exclosure were tagged, located and recorded.
ATT seed set[1]	$0.25m^2$ quadrats placed on a 1x1 m. grid
Elevation[2]	Points on a 1x1 m. grid
Vegetative cover[3]	$0.25m^2$ quadrats on a 2 m. x 2 m. grid in northern ¾ of exclosure $0.25m^2$ quadrats on a 4 m. x 4 m. in grid southern ¼ of exclosure
Soil moisture[4]	Points on a 4 m. x 4 m. grid

[1] A 0.5x0.5m quadrat was centered on each survey-point on a 1x1m grid in the exclosure. Two ATT plants were randomly selected for sampling at each census point when more than two were present. Number of pods per inflorescence was recorded, as was number of floral buds if any were remaining. We opened a subset of pods to record viable seeds produced per pod: if six or more pods were present on a plant, two pods were opened; if 3-5 pods were present, only one was opened; if fewer than three pods were present, none were examined. Finally, we multiplied seeds/pod by pods/plant to estimate seed set per plant for each quadrat.

[2] Elevation was recorded as point-data at each 1x1m gridpoint and also wherever notable changes in microtopography occurred between gridpoints.

[3] Percent cover of each plant species or plant grouping (i.e. perennial grass, annual grass) was recorded within a 0.5x0.5m quadrat centered on each gridpoint.

[4] Soil cores of 0.5 in. diameter and 8 in. depth were collected at each gridpoint on 5/23/98; in the lab, cores were weighed to determine wet-weight, dried in a drying oven, and weighed again to determine dry weight, and thus moisture loss.

Table 2. Pearson's correlation coefficients indicating the strength of associations between *Astragalus* density, percent cover of associated vegetation and abiotic factors. Correlations are shown for: number of *Astragalus* individuals; percent cover of bare ground, perennial grass, annual grass and *P. coronopus*; and elevation and soil moisture. None of the correlations are significant, although more detailed analysis suggests a relationship between *Astragalus* density and local differences in elevation (see text).

	Astragalus	**Bare soil**	**Grass (per)**	**Grass (ann)**	***P. coronopus***	**Elevation**	**Soil moisture**
Astragalus	1	.	.	.	.	.	.
Bare soil	0.007	1	.	.	.	.	.
Grass (per)	-0.064	-0.113	1	.	.	.	.
Grass (ann)	-0.043	-0.147	-0.281	1	.	.	.
P. coronopus	0.087	0.348	-0.133	0.06	1	.	.
Elevation	-0.032	-0.157	-0.165	0.373	0.233	1	.
Soil moisture	0.003	-0.252	0.109	0.022	-0.035	-0.103	1

Table 3. Populations of ATT found external to the exclosure area.

Population code (from Figure 3)	Estimated population size 1998	2000	Location	Habitat description
A	<10	<10	At NW end of vegetation island Between 17 Mile Dr. and pullout road	Recently disturbed- resurfaced, with very low cover of perennial species.
B	<50	<50	Extensive area NE of pull-out road	Same as area A
C	<10	<10	SW of pull-out road	Same as area A
D	2+	0	~25m south of exclosure	Similar to enclosure area
E	<100	<100	~20m south of southmost log in habitat area between Bird Rock parking lot and 17 Mile Dr.	Adjacent to road and trail, lightly walked and driven over with moderate perennial cover.
F		<100	Along riding trail to E of 17 Mile Dr.	On and adjacent to riding trail, with moderate cover of other plants.
G		>1000	In several scattered openings on bank between riding trail and 17 Mile Dr, across from and NW of Bird Rock turnout.	Very open, gravelly, well-drained areas sandwiched between the road and trail and bordered by iceplant stands.

Table 4. Survivorship and performance of ATT in clipping experiment. N = 13 per treatment.

	Survivorship Mean (S.D.)
Clipped plots	0.572 (0.360)
Unclipped plots	0.645 (0.331)

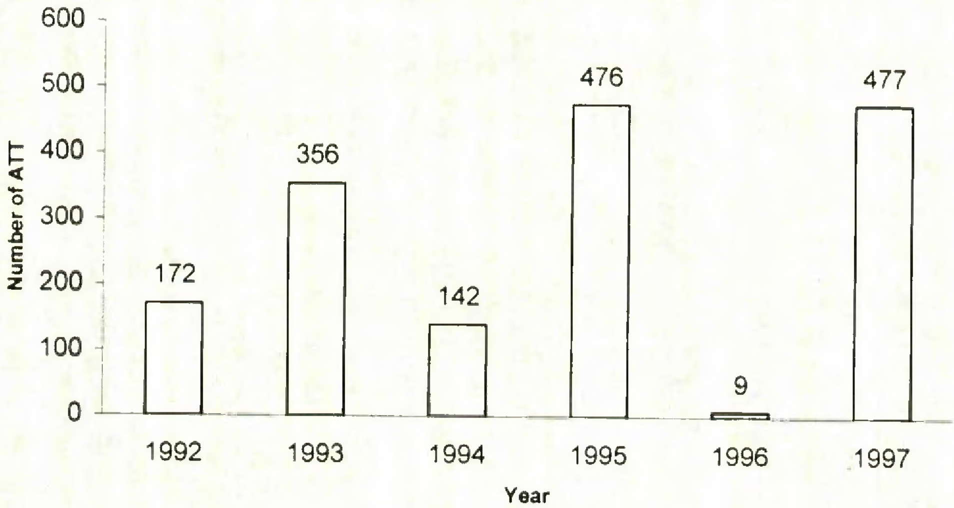

Figure 1. Number of ATT from 1992-1997, as documented by David Allen.

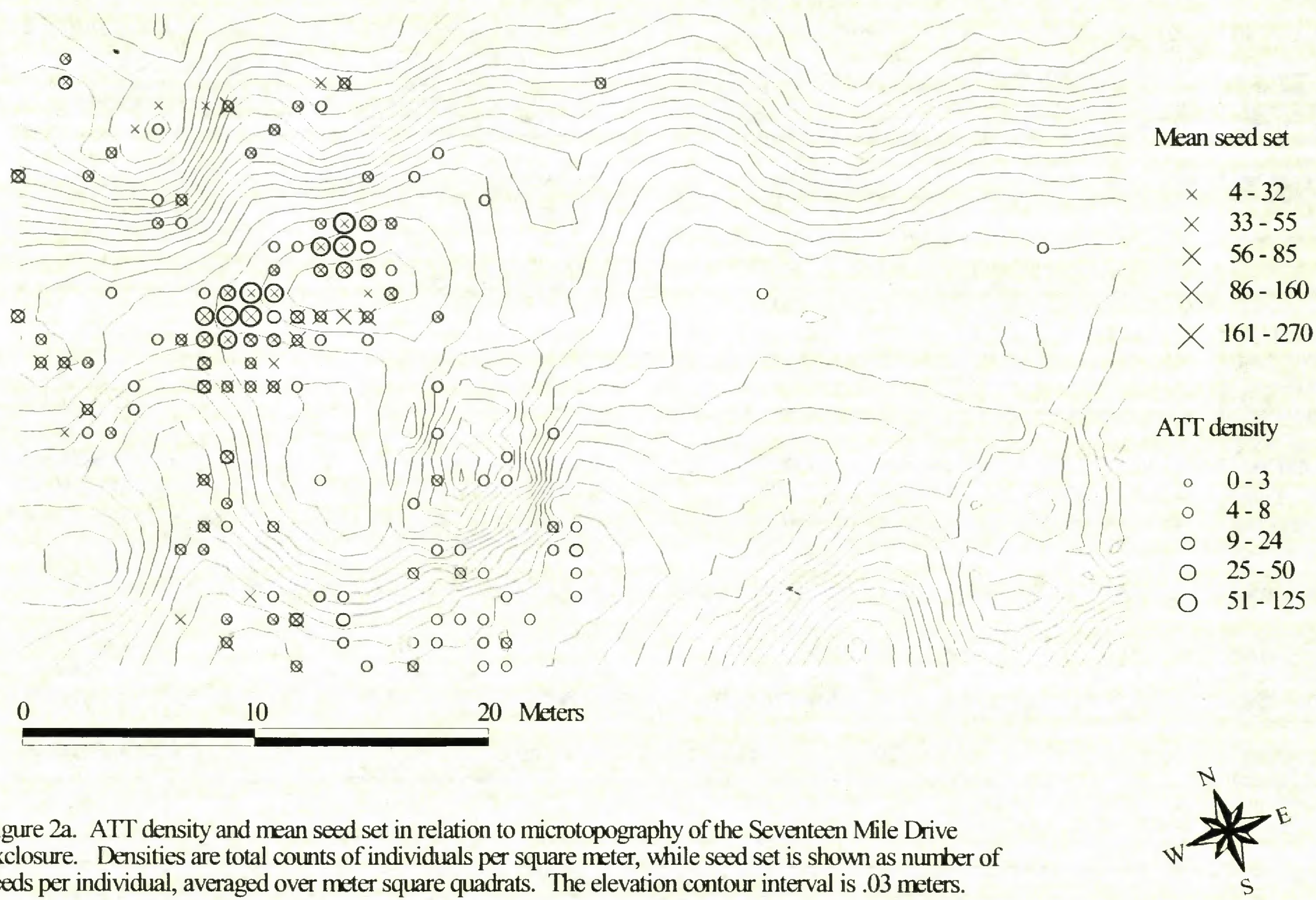

Figure 2a. ATT density and mean seed set in relation to microtopography of the Seventeen Mile Drive exclosure. Densities are total counts of individuals per square meter, while seed set is shown as number of seeds per individual, averaged over meter square quadrats. The elevation contour interval is .03 meters.

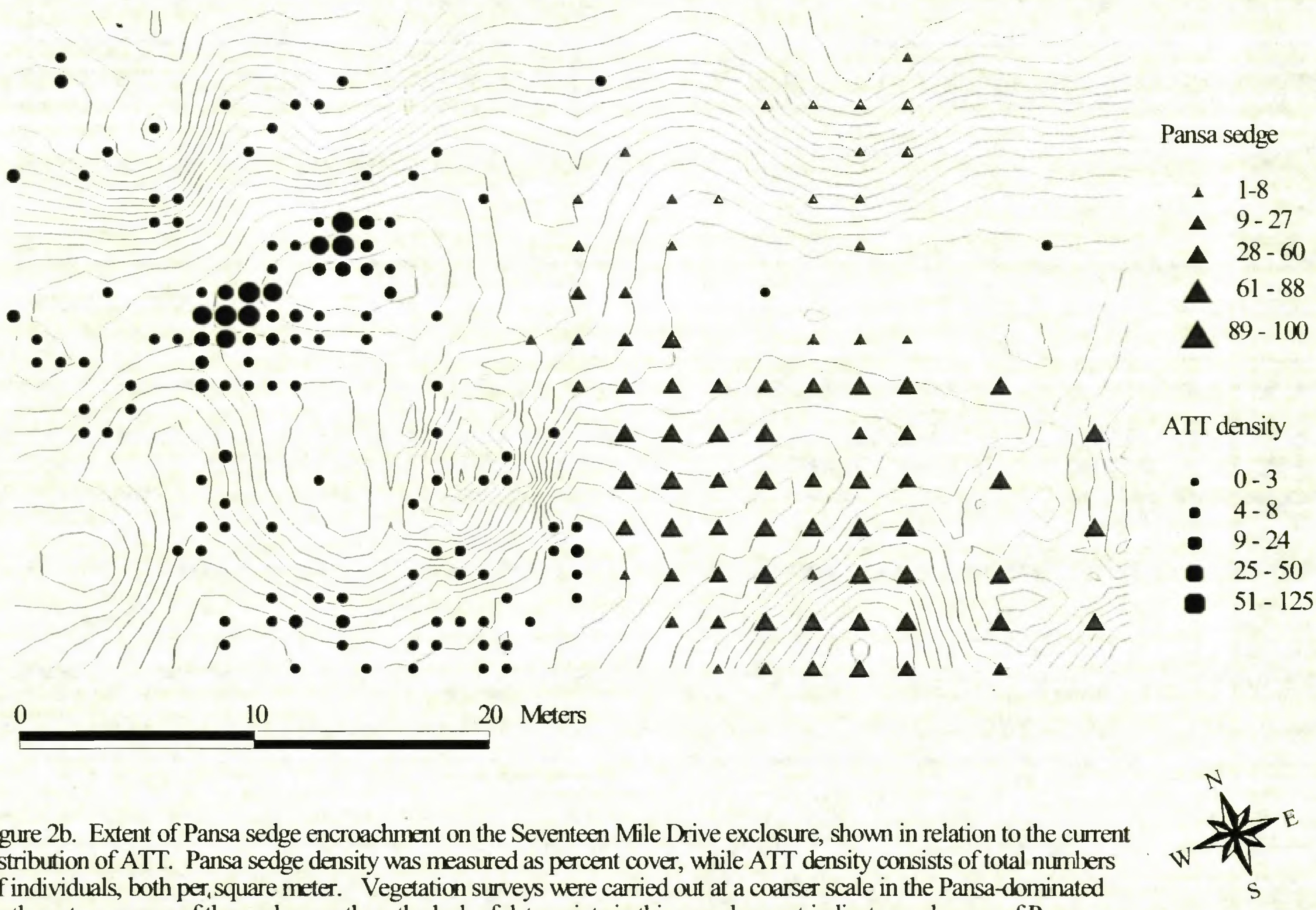

Figure 2b. Extent of Pansa sedge encroachment on the Seventeen Mile Drive exclosure, shown in relation to the current distribution of ATT. Pansa sedge density was measured as percent cover, while ATT density consists of total numbers of individuals, both per square meter. Vegetation surveys were carried out at a coarser scale in the Pansa-dominated south-eastern corner of the exclosure; thus, the lack of data points in this area does not indicate an absence of Pansa.

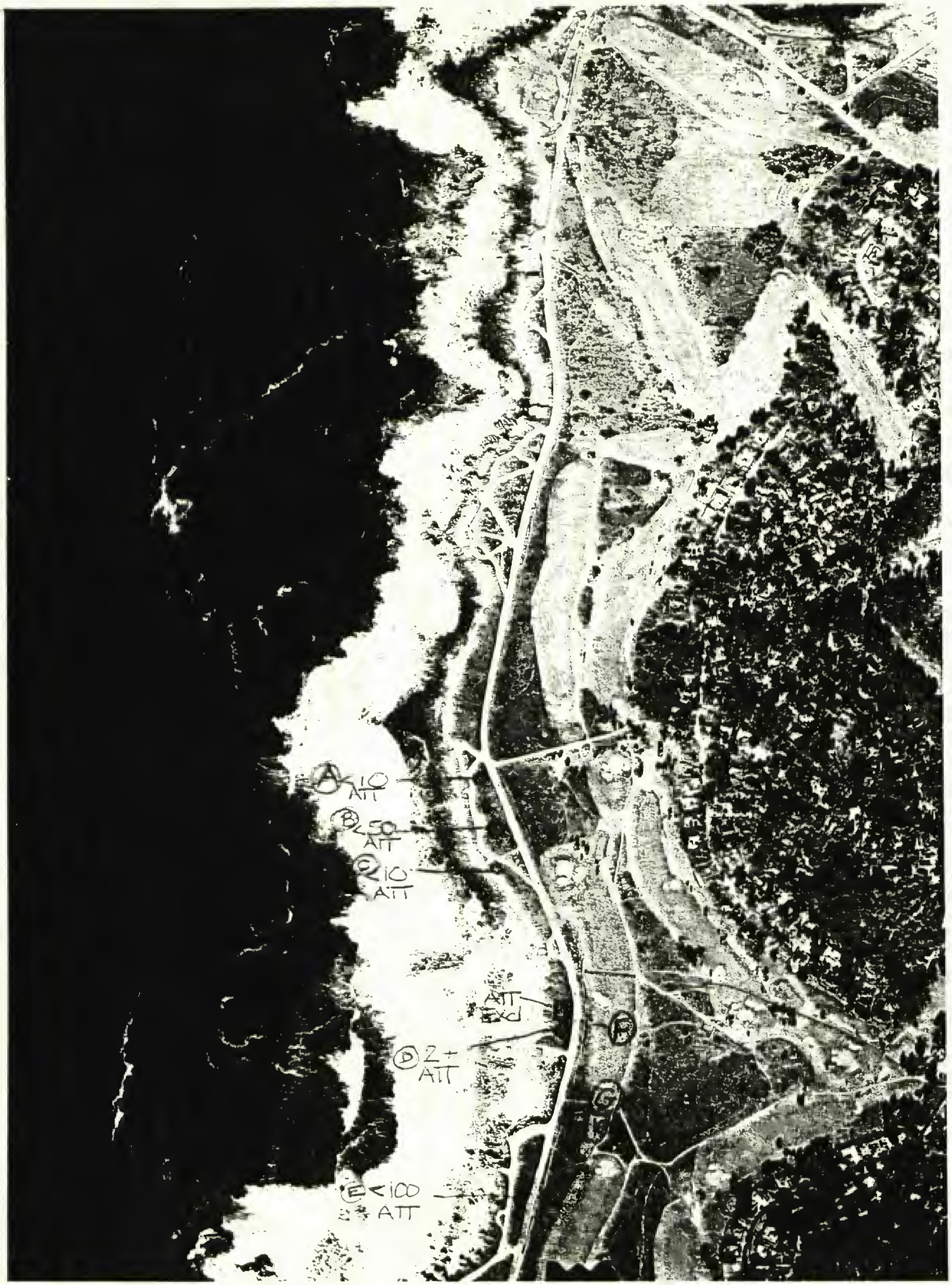

Figure 3. Locations of ATT populations found during 1998 and 2000 surveys along Seventeen Mile Drive, and approximate numbers of ATT found during the 1998 survey.

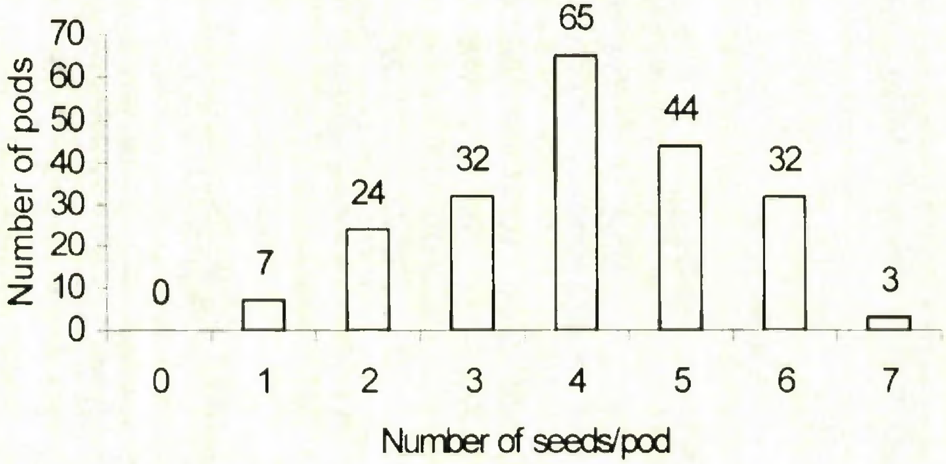

Figure 4. Frequency distribution of numbers of seeds per ATT pod. Since individuals producing fewer than three seed pods were not sampled to avoid potential impacts on reproductive success, these data may underestimate the frequency of low seed set. However, the generally high numbers of seeds per pod in spite of low observed pollinator visitation suggest a large degree of successful selfing in this population.

Potentilla hickmanii - **Hickman's cinquefoil**

Status and Concerns

Potentilla hickmanii (Rosaceae) is a perennial forb endemic to the central California coast. Only two natural populations are known: the extremely small Indian Village population on Pebble Beach lands, and a much larger northern population near Montara in San Mateo County. While the Montara population consists of several thousands of individuals (although in a single restricted area) the Indian Village population has fallen to as low as 14 individuals and presently consists of fewer than 40 plants (see below for details) on less than one hectare of land. Most of our work has concerned the Indian Village population, and unless otherwise stated, all work described below has been with plants in or from this population.

The Indian Village population is largely restricted to a fenced exclosure in a matrix of both native and exotic annual and perennial grasses. The exclosure is situated in a larger, probably artificial, clearing in mature Monterey pine forest. While the exclosure currently protects all naturally established individuals of *P. hickmanii* (henceforth PH) from direct human disturbance, it has not been altogether apparent that complete prevention of anthropogenic disturbance is desirable. The exclosure area and its surroundings were formerly a horseshoe pit, and it is not clear whether the resulting trampling and other disturbances may have had some benefits for the species. In the recent past, the population would generally have declined or been stable each year were it not for the outplanting of greenhouse-grown individuals into the area.

Our work on PH has centered on two basic questions: first, how much natural recruitment occurs and how can it be increased?; and second, does reproductive failure limit population growth, especially at small population sizes? In addition to work on these issues, we have also quantified adult growth and response to clipping of competitors, carefully mapped both natural plants and transplants, and started an experimental population at Pt. Lobos.

Methods and Results

Mapping and basic demography

During both the 1998 and 1999 field seasons, we conducted careful searches for all PH individuals in or near to the Indian Village exclosure, using maps produced by Tony Morosco as our starting point. These searches were conducted between 11 February and 2 March 1998, and between 20 February and 1 April 1999. We measured the number of basal leaves and the length of the longest leaf, and calculated the product of these to obtain nondestructive estimates of plant size for each individual. We also measured total numbers of flowers and inflorescences, and inflorescence length. The total number of flowers per plant and the proportion of capsules with maturing seeds were quantified during the 1999 survey.

Reports from Vern Yadon suggest that PH individuals may spread vegetatively, and therefore rosettes may not necessarily be unique individuals. Our field observations lead us to believe that several of the plants in the Indian Village population may have multiple rosettes, but most rosettes are probably unique individuals.

With this information, we assembled a current count of PH rosettes, broken down by both size and by status (natural adult, seedling, or transplanted adult) (Table 5) and maps of the current locations of all known plants (Figure 5a,b,c,d). See Appendix for a listing of the ID numbers for plants in each cage mapped. Data for naturally established plants suggest several patterns important for both PH conservation and future study:

- At least in 1998 (an El Niño year), substantial natural seedling establishment did occur, with a total of 13 seedlings found, or about one seedling per every three adult plants (Table 5). This contrasts with past reports of low to nonexistent seedling establishment. Furthermore, survival of 1998 seedlings to 1999 (a moderately wet year) was reasonably good (69% to May 1999) and 100% of these survivors lived from 1999 to 2000. Thus, at least in wet years, there is a reasonable potential for natural population growth, although this pattern might be quite different in years of low rainfall. A further point is that all successful seedling establishment in the extremely wet 1998 season occurred in the drier, northern part of the exclosure, while the only successful recruit in 1999 (a much drier year) established in the wetter, southern part of the exclosure (although this seedling died between the 1999 and 2000 censuses).

- In the dry, northern area, no adults died from 1998 to 1999; however, adult mortality in the wetter, southern area was quite high (23%). This pattern of much higher mortality in the wetter area was maintained from 1999 to 2000 (Table 5). While the causes of this adult mortality are unknown, our observations suggest a possible role for high vole herbivory and also soil inundation. Overall, the population experienced 91% survival from 1998 to 1999 and 78% survival from 1999 to 2000. From 1998 to 1999, most surviving adults remained the same size or grew slightly (mean percent change in size= 24.6%, SD= 81.4%; excluding one outlier that more than tripled in size, mean= 13.3%, SD= 51.1%). While these data suggest that, on average, adults are doing reasonably well, the small sample sizes and the availability of only a single year-to-year transition to measure growth warrant little confidence in these demographic estimates.

Mapping and basic demography of Transplanted Plants

In January 1998, we received twenty potted PH plants for transplanting from Bud Lopez at the Pebble Beach Company greenhouse. All these plants are clones of a single individual collected by Vern Yadon at Indian Village. We planted 10 of these individuals outside the exclosure at Indian Village (see Figure 5), and the remaining ten at Carmello Meadows, Pt. Lobos State Reserve, a site identified by Jones & Stokes as potential PH habitat. Transplants were periodically monitored during the spring and summer of 1998, and again in the winter and spring of 1999. In addition to these transplants, Tony Morosco had transplanted 12 PH prior to 1997, of which four had survived and one seedling had been produced. Thus, in 1997, there were a total of 15 plants in the transplant areas.

As summarized in Table 5, survival of transplanted individuals at Indian Village was reasonably high for 1998-1999 (73%) and somewhat lower for 1999-2000 (64%). Individuals transplanted at Pt. Lobos were considerably less successful, with only 4 of 10 plants surviving to spring 1999 and none surviving till spring 2000. We observed no new recruitment likely to have come from the outplanted individuals at Indian Village, while one seedling was found during the 1999 survey at Pt. Lobos. While these results indicate only mixed success for establishing self-sustaining populations of PH, they also suggest, at least in Indian Village, good potential for population augmentation for this species. Further, high mortality among the Pt. Lobos transplants in 1998-1999 was largely driven by the deaths of five individuals planted at a single localized site with a dry, rocky substrate; four of the other five outplants survived this first year. Given selection of appropriate microhabitats for transplanting, Pt. Lobos may still be a good candidate location for introduction of a new population.

Experimental tests of competition and disturbance effects.

We have conducted two experiments to examine the effects of competition and disturbance on PH growth, survival and establishment. First, in 1998 we randomly assigned isolated PH adults, or clumps of adults, to either control (N=19) or competitor clipping (N = 17) treatments. In clipping treatments, an area approximately 10 cm in radius around each focal plant or aggregation was clipped to near ground level, removing leaf and stem tissue of all other species. These treatments were maintained throughout the 1998 growing season, with periodic re-clipping. Response variables, measured in 1999, were plant size, flower production, and seedling establishment near adults.

Results of this experiment all suggest some benefit to PH due to clipping of competitors (Table 6). However, none of the results are statistically significant. Importantly, we were unable to evaluate the effects of clipping on seedling survival. The only seedlings observed in the course of this experiment were those that had already recruited prior to initiation of this experiment. Treatment plots were assigned randomly, and by chance, all seedlings occurred in clipped plots only; no control data was available for comparison.

Given that seedling establishment appears to be far more important in limiting this population than adult performance, a better understanding of how competitor removal affects seedlings is critical to a clear evaluation of the costs and benefits of mowing or clipping as a management strategy. Clipping might well be expected to benefit seedlings more than adults, since established plants are often less sensitive to competitive effects than seedlings. However, extreme caution must be used in carrying out any mowing treatments in order to avoid damaging the small and difficult-to-spot PH seedlings.

To further explore this issue, we carried out a second set of competitor removals in 1999. These experiments were designed both to alter the competitive environment more dramatically and to evaluate more clearly treatment effects on different life stages. On 2 April 1999 and 7 April 1999, we established two experimental blocks of six 0.5x0.5 meter plots each. The two blocks are adjacent to the northern, dry end of the PH exclosure and inside the wetter, southern end (Figure 5). In each block, one plot was assigned to each of six treatments for slug and snail control and for competitor removal (see Table 7 for treatments). While the motivation for the competitive treatments is clear, that for slug and snail control needs some explanation. In our work measuring plant sizes and also in studying the pollination biology of PH (see below), we have observed high levels of slug and/or snail damage on both vegetative and reproductive structures. Especially since few, if any, of the common land mollusks at Indian Village are likely to be native (most common slugs and snails in central California are exotic), it is possible that these very common herbivores are seriously impeding survival, growth and reproduction of PH.

In each plot of this experiment, we established two PH adult transplants (24 total), one to two transplanted seedlings (germinated in the UCSC greenhouse) and also 10 seeds collected during the 1998 field season (Table 7). Plots were 0.25 m^2 , with adults and seedling arrayed on the outer four corners. Seeds were planted along a grid in middle of each plot and marked with toothpicks. In clipped treatments, all vegetation excluding PH was clipped to near ground level and removed. In vegetation removal plots, plots were turned over with a spading fork and all above and below-ground vegetation removed. Slug treatments were conducted using Correy's Slug Death, a commercially available slug dessicant that is harmless to pollinators and other insects, applied according to the manufacturer's recommended rates in a cm-wide line around the perimeter of each treatment plot. All of the plots were caged to exclude vertebrate herbivores.

The adult outplants used in this experiment were progeny of either a single plant collected from Indian Village, raised by Vern Yadon and hand-divided by Bud Lopez; of adults grown from seed collected by Vern Yadon in 1995 and then hand-divided by Bud Lopez; or, were produced by cross-pollination of plants within the Pebble Beach greenhouses, yielding progeny of mixed parentage. Using this array of out-plantings maximized our ability to distinguish treatment effects on different life stages, and also represented the best use of the various plant materials at our disposal. Response variables measured in 1999, were seed germination rate and seedling establishment, seedling size, presence of herbivory, and reproductive output. As of May 1999, no germination had occurred in any of the plots. Censuses of this experiment in May 2000 found no sign of any seed germination in any plot. All adult transplants in the North end plots had survived and were flowering, while only a single adult transplant in the wet, Southern end plots was alive (in plot S5, with a baiting and clipping treatment). Similarly, in the Southern end plots, all transplanted seedlings were also dead, except for one in plot S5. The only informative results about the experimental treatments came from transplanted seedlings in the Northern end plots. While sample sizes were too small for statistical analysis, there is no evidence of an effect of herbivore removal, but strong evidence for a competition effect (Figure 6). Increasing the level of vegetation removal from none to clipping to complete removal corresponded to increases in both survival and flowering of seedlings in May 2000, suggesting that competition from other plants strongly suppresses the survival and reproductive performance of young PH plants.

Reproductive biology and seed collection

During both 1998 and 1999, we conducted experiments to explore the possibility that pollination limits PH seed production, and also to determine how such limitation might vary temporally through the species' extended flowering season (approximately January to June). This work was motivated in part by the observation that PH has protogynous flowers, and thus limited potential for self-pollination. A crucial constraint in this work was the need to avoid limiting natural seed set; therefore, we did not perform any bagging of flowers. Rather, we used two flower-level treatments: an unmanipulated control, and a pollen augmentation treatment in which we transferred non-self pollen to stigmas. Flowers in the two treatments were paired, on single plants, with the same day of treatment. Between one and three pairs of flowers were marked and treated on a given day, with 31 total pairs in 1998 and 11 to date in 1999. We revisited plants every one to two weeks and recorded the number of mature seeds present at ripening for each experimental flower. We also collected seeds from these flowers for further work.

Results of this experiment from 1998 show some evidence for pollen limitation of seed set, with a mean of 4.78 ± 3.70 (mean ± SD) seeds per pollen-augmented flower compared to 3.17 ± 3.54 seeds for control flowers ($p = 0.089$ for paired, one-tailed t-test. $n = 23$ pairs). We also found that pollen augmentation significantly reduced the probability of reproductive failure; pollen-augmented flowers never completely failed to produce seed, while 39% of the 23 control plants did (G test, $p<0.001$). This result suggests that pollinator visitation or pollen dispersal may often be low enough to result in reproductive failure. The only potential pollinator we have observed on PH flowers is a small beetle, suggesting that pollen may be dispersing only short distances in this population. Interestingly, in 1999 we observed that aggregated individuals, defined as those located within at least 50 cm of their nearest conspecific neighbor, developed mature seed in a significantly higher proportion of capsules than did isolated plants (clumped= 0.575 ± 0.229, isolated= 0.185 ± 0.170; t-test, $p= 0.001$); this provides further evidence of a role for pollen limitation in reducing seed set. In contrast, we found no differences in the effects of pollen augmentation treatments on early versus late flowers for the 1998 data, suggesting that seasonal changes in pollinator populations did not effect seed set. However, pollen addition in 1998 began in early May, well into the flowering season of individuals in the northern part of the exclosure.

In 1999, we conducted limited greenhouse trials to determine if there is evidence of either outcrossing vigor or depression between the Montara and Indian Village populations. We transported ten potted plants from the UCSC greenhouse to Montara, transferred fresh pollen from Montara plants to the potted individuals, and then returned these plants to the greenhouse. The results provide some support for differentiation and reproductive incompatibility between the two populations. With a wide range of ovules aborting on individual plants (0 to 100%), there was no plant or flower level difference in seed set as a result of pollen source. However, pooling all ovules in each treatment, only 47% of ovules given Montara pollen produced seed, as opposed to 62% treated with Indian Village pollen ($n = 85$ and 74 ovules, respectively). This difference is marginally significant (G-test, $p = 0.0566$) and suggests that there may be significant genetic differences between the populations. All progeny from these experimental crosses were destroyed to ensure that they are not used for future seed rearing or outplanting.

Management and Research Recommendations

Our results indicate several important directions for future management and research of this species:

- More experimental transplants to establish limits of the species' habitat preferences and tolerances (with extreme care and attention paid to the parentage of transplants, and attempts made to maximize potential genetic diversity of these individuals). While our results indicate that PH is able to recruit at its current location in Indian Village, this site is clearly one with changing characteristics. Thus, current habitat conditions may provide little information helpful for selecting areas in which to expand the current population or establish new ones. The most useful future work would be to rear plants under greenhouse conditions and transplant them into 1) areas at Indian Village farther from the exclosure, including within the forest canopy, farther from the canopy, and in both wetter and drier sites, and 2) into a greater range of habitats at Pt. Lobos. All these transplants should include follow-up work to quantify four measures of demographic performance of the individual plants: vegetative growth from year to year, survival, seed production, and recruitment. In light of the changing characteristics of Indian Village, transplant strategies could also be improved through ecological surveys of conditions at the healthy Montara population.
- Continued monitoring and research on competition and herbivory effects on recruitment, as well as expansion of this work to include effects of disturbance on all life-history stages of PH. The uncertain history of the Indian Village population and its obviously poor past recruitment require a careful evaluation of what natural and human factors currently limit population growth. In particular, since PH appears to be most limited at the seedling establishment stage despite relatively high seed production, work should be done to ascertain what factors are responsible for poor seedling performance and what strategies may result in increased seed germination. This work could easily be combined with the experimental out-plantings just described. Also, the degree to which the cover and composition of the

background vegetation is affected by periodic clipping may provide information about the long-term efficacy of clipping or mowing as a management strategy, especially given the dominance of aggressive exotic grasses in the wetter, southern part of the exclosure.

- Genetic analysis to determine the degree of differentiation or similarity of the two extant populations. Future management of the species could be strongly influenced by genetic data supporting or refuting the need to keep material from the two populations distinct, especially when establishing new populations. Ideally, this work would involve the use of several techniques to clearly ascertain relatedness between the two populations, as well as the extent to which the Indian Village individuals are inbred and/or the population is homozygous.
- Study of limits on seed dispersal. All of the PH seedlings censused thus far have been found within several cm of the parent plants. Without effective dispersal, PH individuals are more vulnerable to localized stochastic events, such as gopher disturbance, as well as intraspecific competition. This work could be combined with disturbance treatments since disturbance may contribute to seed dispersal.
- Finally, more work is needed on pollinator limitation. Our data suggest that isolated plants receive little pollinator visitation and/or ineffective pollen transfer, indicated by the relatively low proportion of flower capsules containing mature seed. Thus low seed set due to small population size (and the resulting low pollinator visitation) may be compounding already-poor seed germination and establishment. Experimental outplantings at varying densities and distances should be done to quantify the threshold distance and aggregation size at which effective pollination occurs. The results from this work could be of critical importance for future efforts to establish self-sustaining populations of PH, as well as for the isolated individuals at Indian Village which may contribute little to the genetically effective population size or to the demography of the population.

Table 5. Fates of *Potentilla hickmanii* individuals from 1998-2000.

Status and Location	Data	Size class (number basal leaves x longest leaf length)					
		0-30 cm	31-90 cm	91-180 cm	181-360 cm	>360 cm	Total
1998 Seedlings *(Indian Village)*	Number in 1998	(size data not recorded)					13
	Number in 1999	9	0	0	0	0	9
	Number in 2000	(size data not recorded)					9
1999 Seedlings *(Indian Village)*	Number in 1999	(size data not recorded)					1
	Number in 2000	(size data not recorded)					0
Natural adult *(Indian Village)*	Number in 1998	2	26	4	2	1	35
	Number in 1999	3	20	7	1	1	32
	Number in 2000						25
	Growth (percent change in size, 1998 to 1999)	0.45	1.15	1.21	4.76	2.36	1.25 (avg. for all nat'l adults)
Outplanted adults, 1998 *(Indian Village)*	Number in 1998	(size data not recorded)					15*
	Number in 1999	(size data not recorded)					11
	Number in 2000	(size data not recorded)					7
Outplanted adults, 1998 *(Pt. Lobos)*	Number in 1998	(size data not recorded)					10
	Number in 1999	1	1	0	2	0	4
	Number in 2000	(size data not recorded)					0
1999 Seedlings *(Pt. Lobos)*	Number in 1999	(size data not recorded)					1
	Number in 2000	(size data not recorded)					0

* Includes one seedling recently produced by a transplanted PH adult. This seedling died before the 1999 census.

Table 6. Means and standard deviations of PH performance measures in clipped and unclipped treatments.

Variable	Clipped (N=17)		Control (N=15)	
	Mean	SD	Mean	SD
Percent growth	0.33	0.96	0.15	0.63
Number inflorescences (1998)	5.65	2.88	4.5	4.58
Number flowers (1998)	2.88	1.54	2.56	1.92
Number inflorescences (1999)	5.41	3.22	4.53	4.63
Number flowers (1999)	0.88	0.7	0.53	0.92

Table 7. 1999 PH competitor/mollusk control experimental treatments. Each plot was planted with two adult PH and ten seeds. Most plots received two transplanted seedlings, but due to limited material, three plots were planted with only one seedling each.

Cage ID	**Treatment**	**Number of seedlings** North plot, South plot)
N4, S3	Control (no slug bait, no vegetation treatment)	1,2
N3, S6	Slug bait[5], no vegetation treatment	1,2
N2, S4	No slug bait, vegetation clipped[6]	2,2
N6, S5	Slug bait[5], vegetation clipped[6]	2,2
N5, S2	No slug bait, vegetation removed[7]	2,2
N1, S1	Slug bait[5], vegetation removed[7]	1,2

[5] Correy's Slug Death applied according to manufacturer's recommended rates every 2 weeks.
[6] All above-ground vegetation was clipped to ground-level prior to planting of PH.
[7] Above-ground vegetation and below-ground root matter were removed using a spading fork prior to planting of PH.

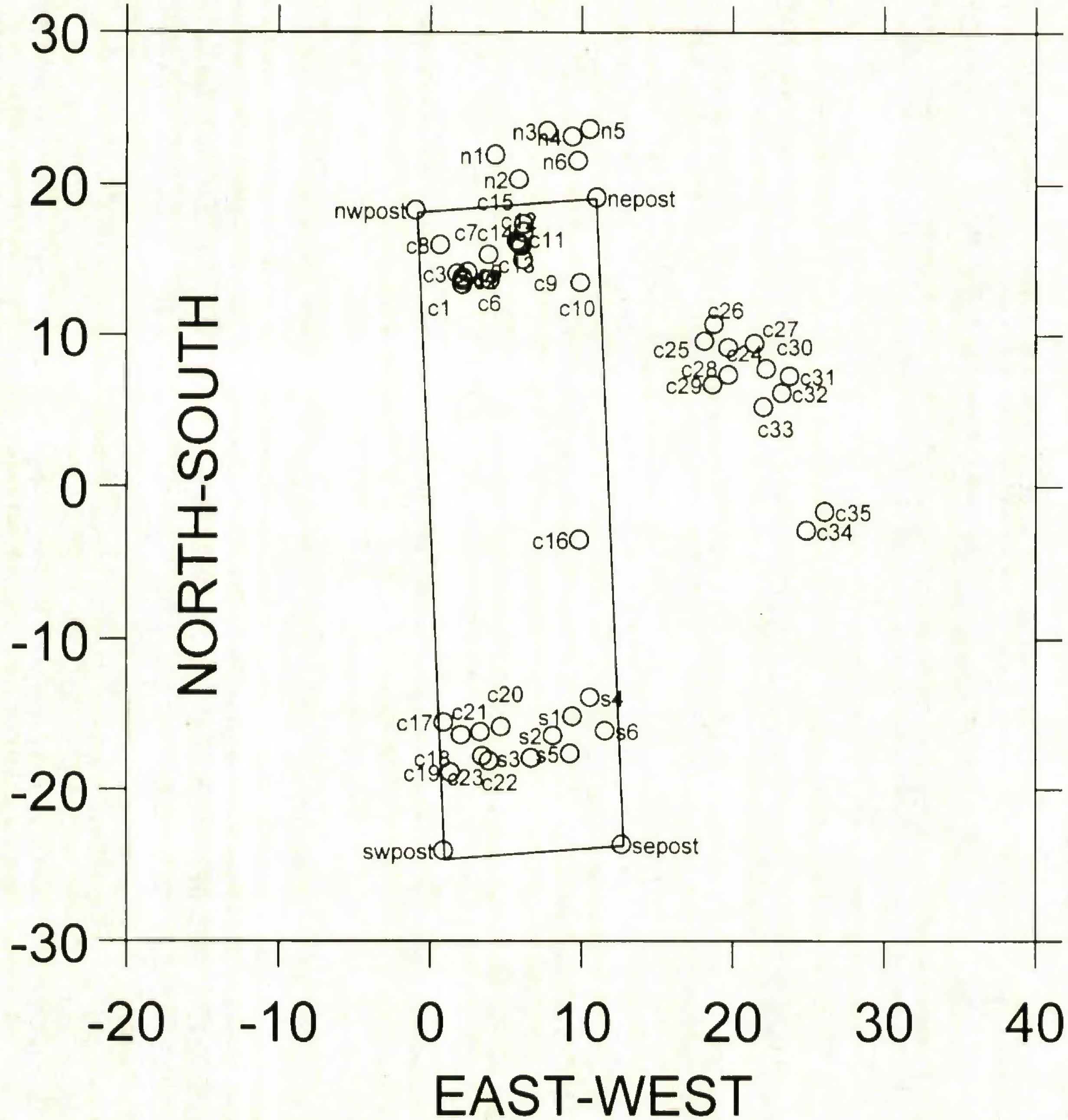

Figure 5A. Mapping of cages containing Potentilla hickmanii individuals at Indian Village. A. Map of entire enclosure and surrounding cages.

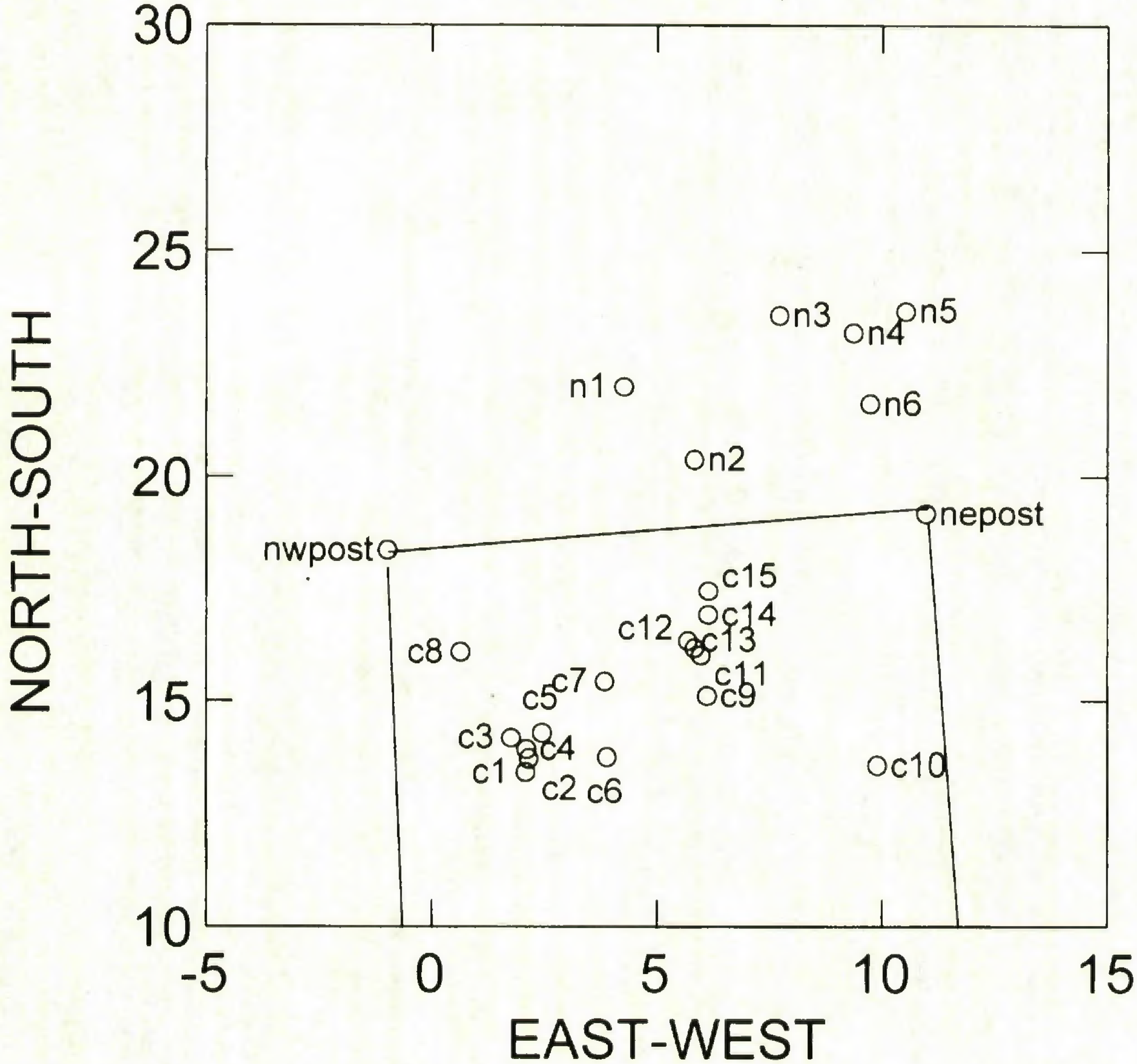

Figure 5B. North end of enclosure. Circles marked ‘C#’ are cages with natural plants; those marked ‘N#’ contain plantings of PH for the 1999 Competition/herbivory experiment.

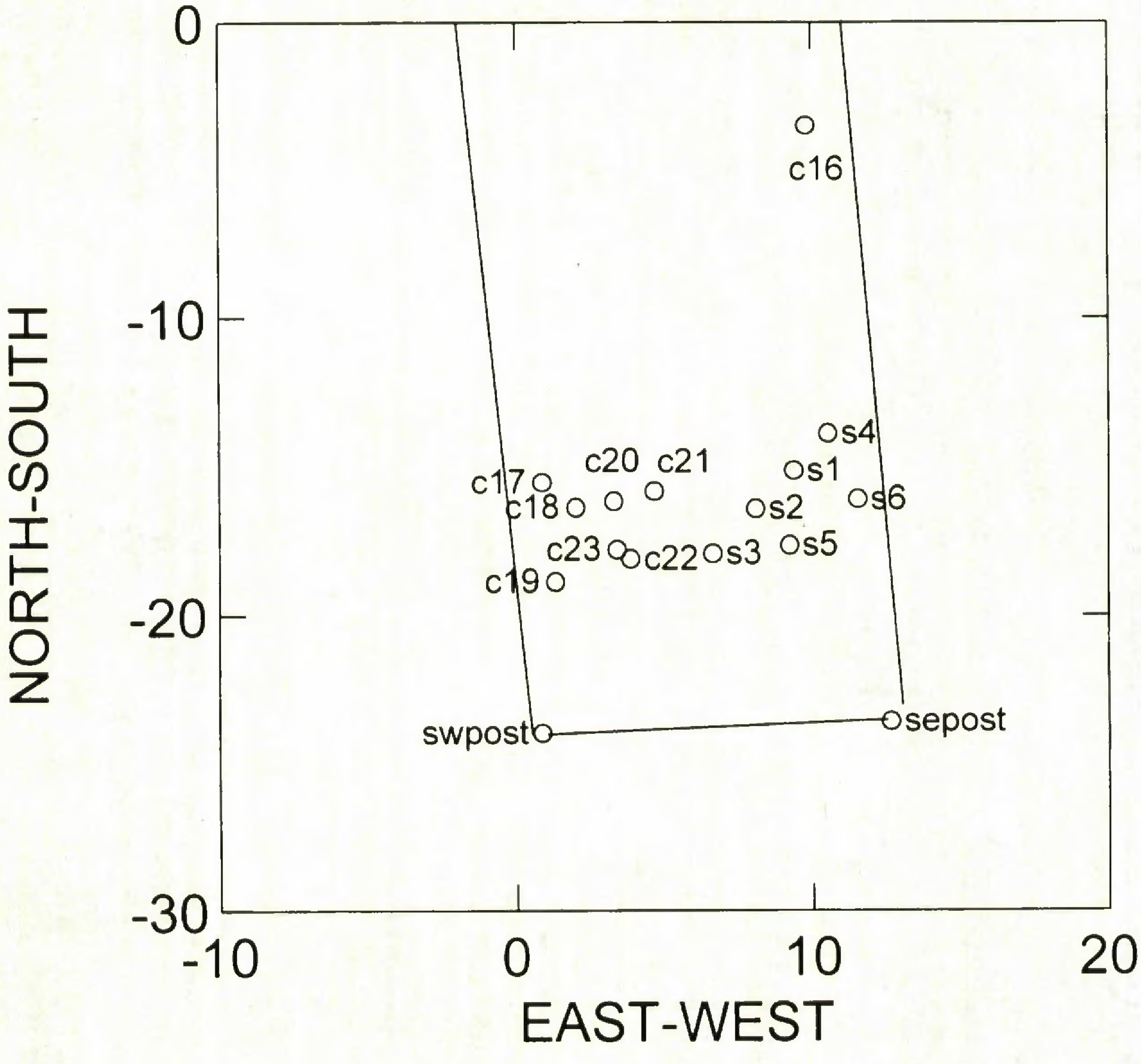

Figure 5C. South end of enclosure. Circles marked 'C#' are cages with natural plants. Circles marked 'S#' are cages housing the 1999 Competition/Herbivory Experiment.

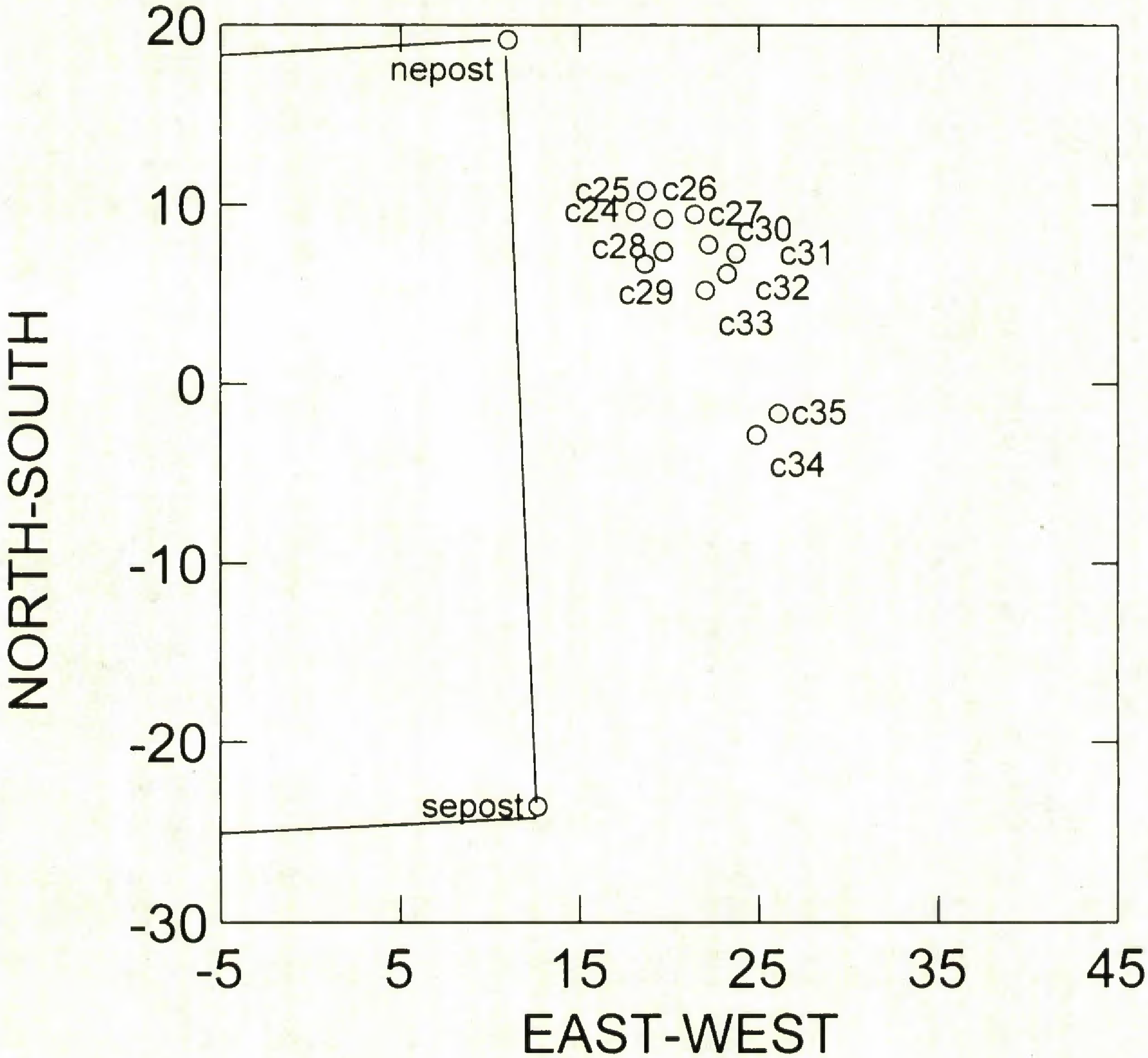

Figure 5D. Cages to East of enclosure. All circles are cages with outplanted PH plants.

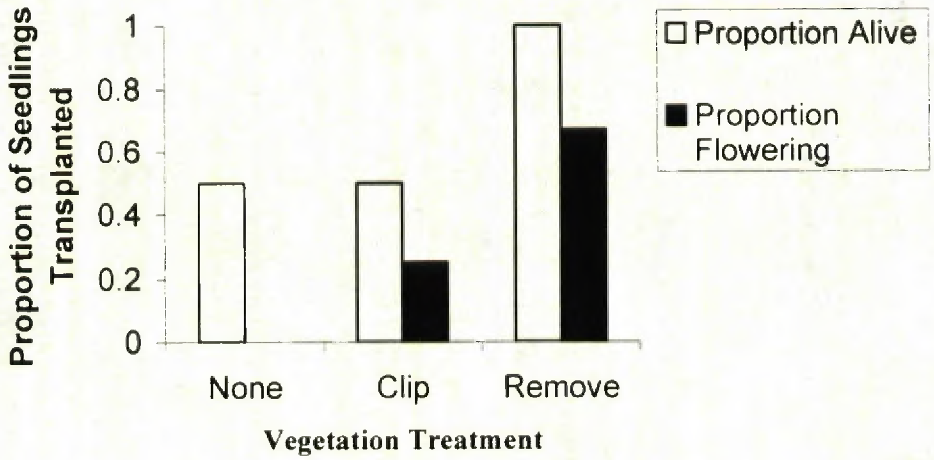

Figure 6: Survival and flowering of seedlings transplanted into 1999 Herbivory/Competition Experiment. Results from May 2000 are shown for seedlings placed in different vegetation removal treatments in the North end plots only; all but one seedling died in the south end plots. There was no evidence of any herbivore removal effect. Sample sizes are too small to allow statistical testing: n = 2,4, and 3 for the none, clip, and remove treatments, respectively.

Trifolium polyodon - Pacific Grove Clover

Status and Concerns

Trifolium polyodon (henceforth TP) is an annual clover endemic to the Monterey and Point Lobos area. Although rare, the species occurs in many small populations (see J&S Fig. 8 for map of occurrences and J&S Table 3 for population counts; however, we caution that population sizes often fluctuate drastically for annual plants). As for all species considered in this report, habitat destruction is the most pressing concern. However, what biotic and abiotic factors help or hinder the species is less certain. We did not conduct work specifically targeted towards TP management. However, the species occurs in the habitat of and adjacent to populations of both *Astragalus tener* var. *titi* and *Potentilla hickmanii*. Therefore, we recorded responses of TP to our manipulations of these other species, and discuss the results of this work below.

Methods and Results

Work at Indian Village:

In 1999, we observed TP growing in the wet areas to the south of the exclosure at Indian Village, though no TP individuals were observed within the exclosure. We also confirmed the identity of TP individuals growing along the path leading up to Indian Village from SW, and noted numerous non-blooming *Trifolium* plants that we suspect were TP in the picnic area and the grassy area across the path. These latter areas are likely to be more trampled, possibly controlling competing plant species.

We did not observe any TP germination as a consequence of our clipping of vegetation around PH, nor did TP appear in any of the plots of our vegetation control/slug baiting experiment.

Work at *Astragalus tener* var. *titi* exclosure on 17 Mile Drive:

In 1999, we have not observed any TP in the ATT exclosure, although J&S (Table 3) document

10 individuals in this area in 1995. No TP emerged in response to either our vegetation clearing experiment (south end of the exclosure) or our vegetation clipping/trampling experiment (north end of the exclosure).

Management and Research Recommendations

Research work on this species seems less crucial than for several of the other species discussed in this report. The most important future work to be done on the species is careful monitoring of the many small populations on a yearly basis, to determine the long-term viability of naturally or artificially isolated and reduced populations. Such monitoring should include both censusing for numbers of individuals and sampling to estimate mean and variance in per individual seed production each year in each population.

Cupressus goveniana ssp. goveniana - Gowen cypress

Status and Concerns

C. goveniana ssp. goveniana (henceforth CGG) is a small conifer that forms a sparse sub-canopy in Monterey and Bishop pine forests, dwarf forests and maritime chaparral in the Monterey and Pt. Lobos area. While CGG grows in a variety of habitats, and can persist for many years without obvious disturbances, it apparently requires mineral soil surfaces and unshaded conditions for successful recruitment. The species has closed cones that remain on the trees for many years in the absence of fires. Fires will stimulate cone opening and also clear forest soils and canopies, providing the disturbance necessary for recruitment in most area where CGG occurs.

Our work with CGG was limited to observations of range and recruitment patterns at both of the main populations (Gibson Creek, above Pt. Lobos and Huckleberry Hill at Pebble Beach), and to more detailed mapping and aging of trees at Gibson Creek. This more intensive work was designed to allow inferences about recruitment patterns in different habitats and also to establish the longevity of adult trees.

Methods and Results

CGG is commonly referred to as a fire-dependent species, and certainly massive recruitment occurred on Huckleberry Hill in areas burned in the 1987 fire. However, we also observed that recruitment is ongoing in areas of Huckleberry Hill that are both human-disturbed (resulting in very low canopy cover and open mineral soil surfaces) and also close to adult CGG. These areas include the fire-breaks surrounding parts of the 1987 fire area as well as margins of roads adjacent to mature CGG. While we did not directly measure seed-fall from living trees, examination of cones shows that, while CGG is a close-coned species, cones do open with age, potentially allowing recruitment in the absence of fire. Furthermore, our observations clearly indicate that the important role of fire is to open the ground for seedling establishment, and that heat, smoke, etc. are not required for CGG germination and recruitment.

To confirm these ideas, and also to more generally establish the age structure of CGG populations, we conducted two pieces of work at the Gibson Creek population. First, we used GPS and GIS to delineate the extent of this population, allowing continued monitoring of the population extent and defining the limits of the area that should be managed for CGG at this site (Figure 7). Second, we took increment cores of trees in this population, allowing estimation of tree ages and average growth rates. These efforts provide some useful basic information on the distribution of CGG at the Gibson Creek site, as well as important data on the structure of the CGG population.

In general, we observed CGG growing in two distinct habitats at Gibson Creek: mixed conifer forest and maritime chaparral. Within the chaparral, CGG grows as a dense, dwarf forest and is the only tree species with significant representation. This chaparral habitat extends roughly from the center of the range map east to the uphill extent of Gowen cypress. From the center of the range map and west, CGG occurs as larger but much sparser individuals within the mixed pine habitat. Unfortunately, no clear patterns of distribution emerged from our mapping efforts. That is to say, it is not clear from our observations alone what factors govern the distribution of the Gibson Creek population. At its eastern extent, for example, CGG borders a dense chaparral community which possibly prevents recruitment. However, no identifiable demarcation exists along the northern, southern, and eastern boundaries. Most likely, the current distribution of CGG is a result of the historical sequence and severity of fires within the Gibson Creek area.

To better understand CGG demography across these distinct habitats, we cored 64 trees at 15 sites located throughout the population. Within each site, trees were chosen in a quasi-random manner with the aim of obtaining a representative sample of the population. Increment cores were glued into permanent core mounts and sanded to allow inspection of the annual rings under a microscope. Precise age estimates for this tree species were difficult to obtain for two reasons. First, where trees are spaced close together or growing on poor soils, CGG grows extremely slowly, making it difficult to resolve individual ring boundaries. Second, CGG growing on the Gibson Creek site sometimes display two distinct ring boundaries within one calendar year. We believe this is caused by a burst of early growth during warm winters, followed by the usual accumulation of wood during spring. In most cases, we were able to distinguish these "false" rings by the characteristics of early and late wood, and cell size.

We found fairly distinct differences between the age structure of trees in the mixed pine and the chaparral habitats (Figure 8). Trees in the mixed pine habitat were more even-aged than the chaparral, with most age classes represented, including younger ages. The chaparral age structure, however, is notably skewed towards the older age classes, with close to 30% of the population between the ages of 75 and 85 years old. Observations of recruitment (seedlings and small saplings, which could not be cored) bear out a similar trend. Some recent recruitment was found in almost all mixed pine sites, while less than half of the chaparral sites had recruitment of any kind. These results suggest that CGG are most likely recruitment-limited by the chaparral plant community. Perhaps, as well, a pulse of recruitment occurred approximately 75 to 85 years ago after fire burned through the chaparral habitat, opening up the ground for seedling germination and growth. The maximum age of trees from all sites ranges from approximately 85 to 127. To a first approximation, this suggests that management for disturbances to allow CGG recruitment should occur at least every 85 years, although we caution that these longevities may be highly site and habitat specific.

We also obtained average growth rates for trees sampled within the two habitats (Figure 9). Growth rates were calculated simply by dividing the length of the core sample (from center to outer ring) by the estimated age of the tree. Average growth rates were higher in the mixed pine habitat (1.05mm/year) than in the chaparral habitat (.76 mm/year), and this difference was marginally significant (Anova, p=.067). These results are best explained by the density of CGG in the two habitats; growth rates were higher in the less-dense, mixed pine habitat, and lower in the chaparral habitat where CGG grows as a dense thicket.

Management and Research Recommendations

Our work suggests one major management strategy for this species. The majority of CGG habitats form closed canopies and ground covers without disturbance. Our results confirm that disturbances are needed to maintain CGG populations. Both the ground surface and the canopy (the shrub layer in particular) must be cleared to obtain reasonably high establishment rates –

such removal will generally be easier and more reliable using controlled burns than by artificial means. However, our findings also indicate that it is probably possible to promote CGG recruitment without fires on sites where burning is difficult. This could be accomplished with mechanical removal of ground cover as well as canopy species.

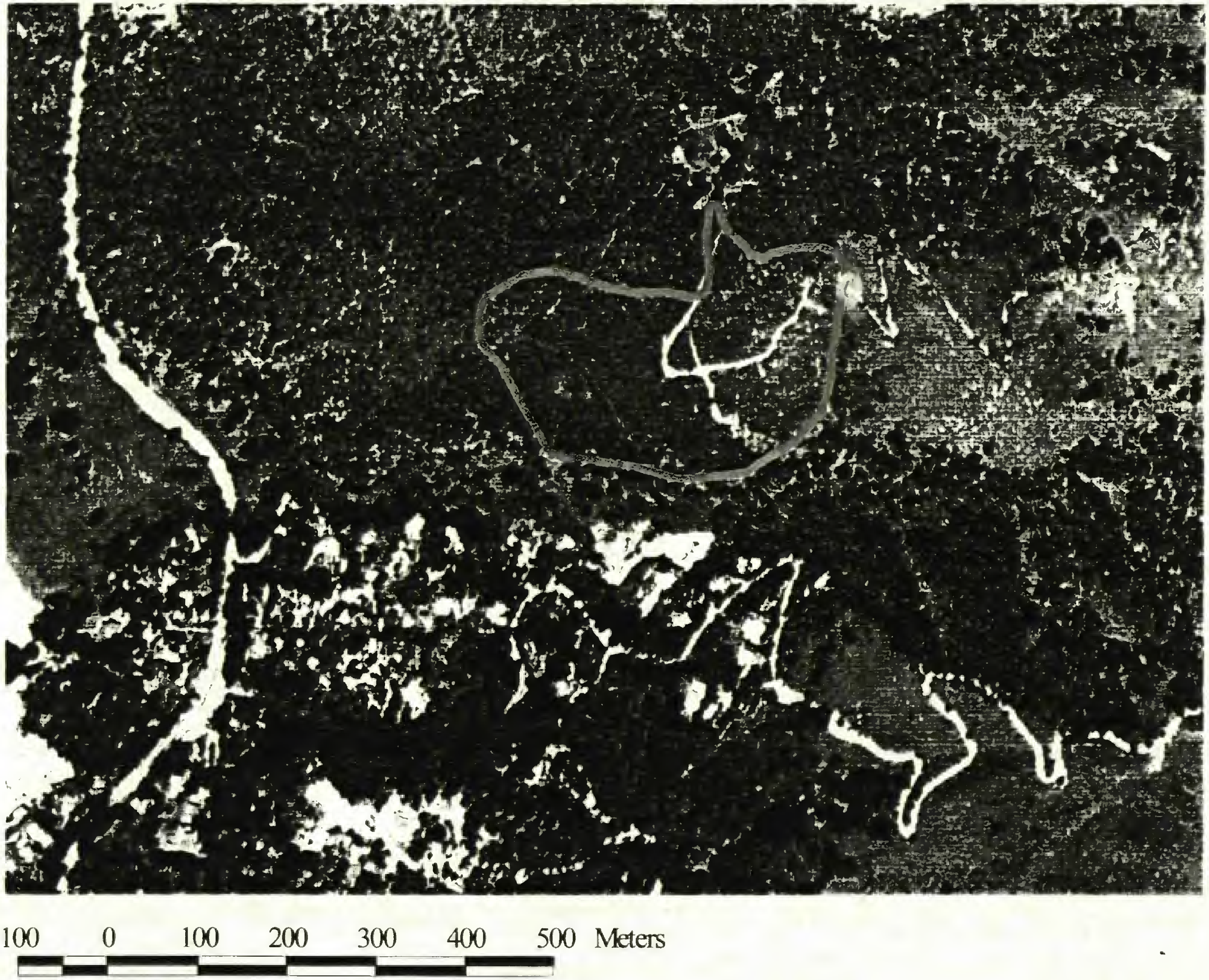

Figure 7. Range of CCG at Gibson's Creek above Pt. Lobos, shown on an aerial photograph of the region.
The red line demarcates the area currently supporting CCG populations.

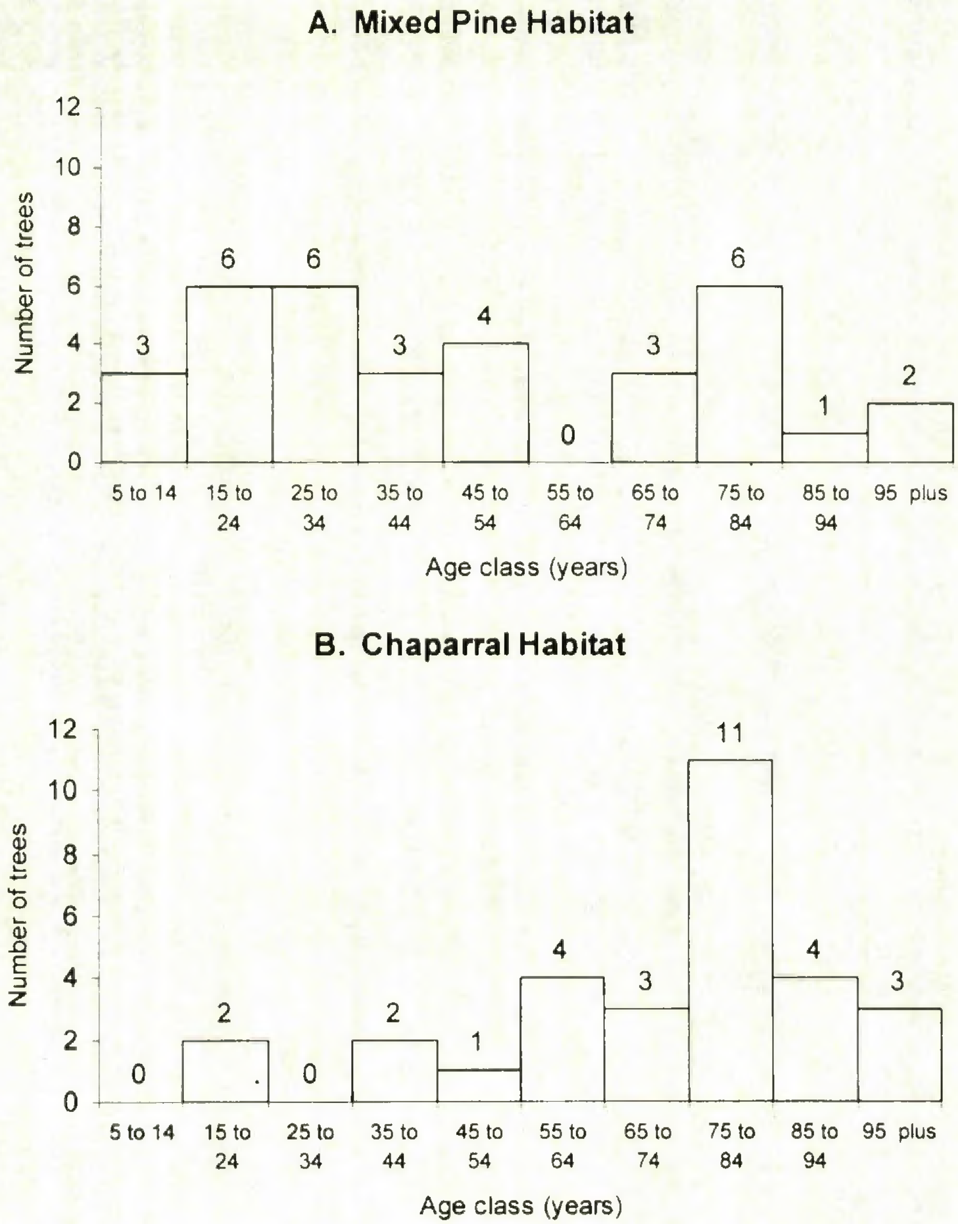

Figure 8. Estimated age distribution of Gowen Cypress in a) mixed pine forest and b) chaparral habitats. Older age classes are over-represented in both habitats, particularly the chaparral, even though our sampling specifically targeted smaller trees in order to maximize the ability to detect recruitment. However, some recent recruitment has clearly taken place even in the absence of fire; recruitment rates appear higher in the mixed pine habitat.

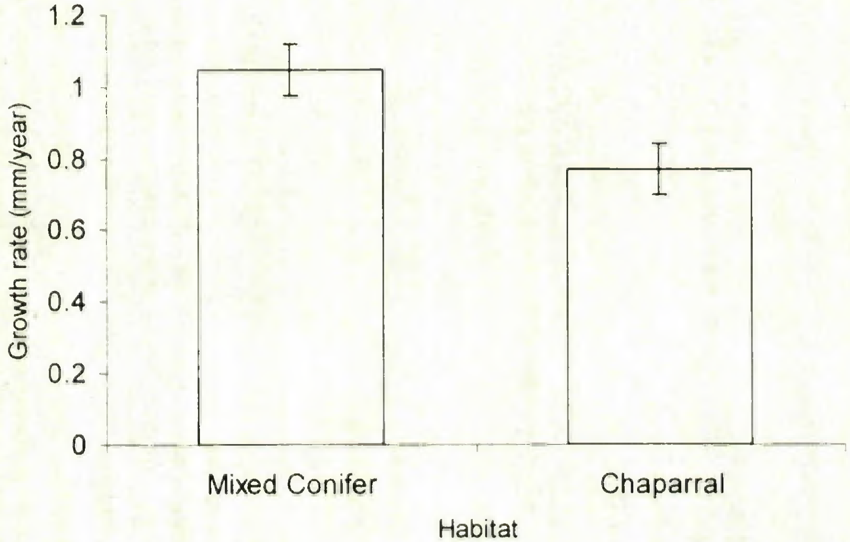

Figure 9. Estimated growth rates, in millimeters per year, of Gowen Cypress in mixed pine forest and chaparral habitats. Growth rates in the mixed conifer habitat are marginally significantly higher than in the denser chaparral (t test, p= .067).

Trifolium trichocalyx - Monterey clover

Status and Concerns

Trifolium trichocalyx (henceforth TT) is an annual clover endemic to limited areas of the pine forests of the Monterey Peninsula. TT is a classic 'fire-follower' species; in the year following a forest fire that removes vegetative cover, seeds germinate and plants successfully reproduce. However, within only a few years following a fire, numbers of TT plants rapidly decline to zero, and the population is reduced to a persistent seedbank that awaits the next fire, which may be decades away.

This life history, most of which consists of difficult-to-see seeds in the soil, presents challenges that leave us with little knowledge on the distribution or ecology of TT. In particular, censuses of the species' range have relied solely on surveying for adult plants, which are usually non-existent. Our work with this species has focused on determining how soil samples may be used to establish the presence of TT seed banks, and also to understand the germination cues needed by this species.

Methods and Results

In November of 1998, we collected 32 soil samples from Huckleberry Hill, both in sites burned during the 1987 fire and adjacent areas to the south of the fire zone at similar slope and elevation. Most collection sites in the 1987 burn area were within the region just below Costanilla Way supporting post-fire TT populations until 1995 (J&S Figure 10). To collect each sample the top layer of organic matter was removed from a 0.5xo.5 m. area and the material below (soil with some rock and organic matter) collected to a depth of 5-10 cm. After drying at room temperature, each soil sample was homogenized by hand. Samples were sifted using a No. 10 Standard Testing Sieve (2 mm mesh), and an 800 ml sub-sample from each site was then spread over greenhouse loam in 24 cm by 24 cm seedling trays and placed in a greenhouse. These germination trays were watered and kept under natural light. All seedlings emerging from the trays were examined; *Trifolium* seedlings were allowed to develop to flowering and subsequently identified, while competing seedlings were clipped.

After 20 weeks, only one TT had emerged from the soil samples. This individual came from a sample taken from the site at which adult TT were last found by Jones and Stokes in 1995, in the firebreak just downhill from Costanilla Way. The generally negative results of the germination trials could indicate either that TT seeds require specific germination cues (probably from the heat or smoke of fires), or that the seeds are sparsely or patchily enough dispersed that even the large volume of soil collected was insufficient to obtain appreciable numbers of seeds. To test these possibilities, we performed two other experiments. First, we obtained 100 TT seeds from the USDA Agricultural Research Service. We attempted to germinate twelve of these seeds on filter paper in the greenhouse with no further treatment. While none of the twelve seeds germinated in the first three weeks, after ten weeks all but one had germinated and subsequently flowered. These results confirm observations by Vern Yadon that TT has no specific germination requirements with the exception of light. However, seeds buried in soil may require cues quite different from those which have never been buried, such as those that we and Yadon germinated.

In order to further test for the presence of seed banks on Huckleberry Hill and our ability to detect them, we performed a clearing experiment. We removed all above-ground vegetation and root mass from ten 1 m by 1 m plots and raked the surface. These plots were established in February 1999, in the same general areas in which our earlier soil samples were collected. As of late April 1999, no TT plants were seen in any of the clearings.

Management and Research Recommendations

Our work emphasizes the difficulty of investigating the distribution and population ecology of TT. The following recommendations summarize both the approaches that must be taken in managing for this species, as well as the most promising directions for future work:

- Further germination trials should be conducted, using seed collected from greenhouse offspring of TT seed from the USDA Agricultural Research Service. These trials should focus on mimicking natural soil conditions and germination cues to establish more clearly the conditions needed to facilitate germination. This work could involve burial of seeds in nylon mesh bags for the fall and early-winter months, followed by germination trials in the late-winter and early spring under various treatments to simulate different potentially important fire effects.

- To test for the suitability of the experimentally cleared areas for TT germination, cleared plots should be subdivided and some of the above-mentioned seed scattered in half of each plot, with lawn-edging separating the treated and control halves of the plot to prevent migration of seed. Sowing should be done early in the autumn, permitting normal over-wintering of seed, and plots should be censused in the following spring season.
- Burn box experiments on Huckleberry Hill provide perhaps the most direct way to expand our surveys for seed banks of TT. While we used much larger soil samples than are typically collected, burning or clearing 2x2 meter or larger areas in the field would be useful in establishing the presence of TT at specific sites, in addition to helping determine germination requirements.
- A second, but probably less promising, method of surveying for seeds is to use seed isolation procedures to collect *Trifolium* seeds from large soil samples, and then to attempt germination of these seeds to establish their identity as TT. This method is worth trying, although the effort required to carefully isolate seeds from large soil samples is substantial.
- Until better means are established to determine distributions and numbers of this species, it is crucial to put little or no faith in past distribution maps of TT (e.g., J&S Figure 10); these surveys are likely to be as much the product of recent fire history as of the actual distribution of the species. In the face of this considerable uncertainty, the only sites that can with any safety be ruled out as not supporting TT populations are those that burned in the recent past (e.g. the 1987 fire), and that were thoroughly censused in the two years following the fire.

Final Recommendations and Research Priorities

In summary, several of the specific recommendations that we discuss above present themselves as extreme priorities for the maintenance of these rare plant populations:

- Research to better understand and manage for increased establishment of *Potentilla hickmanii* seedlings and determination of demographic performance in different habitat types.
- Continued efforts to establish new populations of *P. hickmanii* at Point Lobos and other potential sites.
- Further clarification of competitive interactions and habitat needs of *Astragalus tener* var. *titi*, to better understand limitations to the distribution of this species at both large and small spatial scales.
- Monitoring of all *A. tener* var. *titi* populations to determine the range and relative qualtity of the diverse habitats (mostly unprotected) in which this taxon is known to occur.
- Further research on the seedbank of *Trifolium trichocalyx* – in particular, how to reasonably predict its size and distribution. This work would simultaneously refine our understanding of germination, and hence of management, requirements.

While we strongly urge the establishment of additional ATT populations as one of the most urgent conservation priorities, we caution that this should not be perceived as an alternative to rigorous protection and management of the existing population. While worth attempting, rare plant introductions historically have had extremely poor success rates (see Fiedler, 1991) and should not be viewed as a primary means for preserving species.

References

Fiedler, P. 1991. "Mitigation-related transplantation, relocation, and reintroduction projects involving endangered and threatened, and rare plant species in California." (Final report to CA Dept. of Fish & Game).

Jones & Stokes, 1996. "Recovery Strategies for Six Coastal Plant Species on the Monterey Peninsula." (Final report to CA Dept. of Fish & Game).

APPENDIX: Locations of individual *Potentilla hickmanii*, by cage. Only plants still alive in May 2000 are listed, although some newly empty cages have been left in place and are listed. See Figure 5 for cage locations.

Location	Cage Name	Adult plant ID numbers	Seedling ID numbers
North End	C1	9	3
	C2	5,6,7,8	1,4,5,6,7,8
	C3	2	
	C4	4	
	C5	3	
	C6	39	
	C7	no live plants	
	C8	1	
	C9	15	
	C10	19	
	C11	14	
	C12	13	
	C13	12	
	C14	18	
	C15	16,17	10,11
South End	C16	33	
	C17	20	
	C18	21,23,24,25	
	C19	29	
Outplanting to			
East of Enclosure	C24	41	
	C25	none alive	
	C26	none alive	
	C27	none alive	
	C28	45	
	C29	none alive	
	C30	46	
	C31	47	
	C32	49	
	C33	50	
	C34	none alive	
	C35	35	
		Number of living plants (not individually marked):	
1999 Comp/Herb			
Experiment	N1	4	
	N2	4	

	N3	3	
	N4	2	
	N5	2	
	N6	3	
	S1	0	
	S2	0	
	S3	0	
	S4	0	
	S5	1 (possibly 2)	
	S6	0	

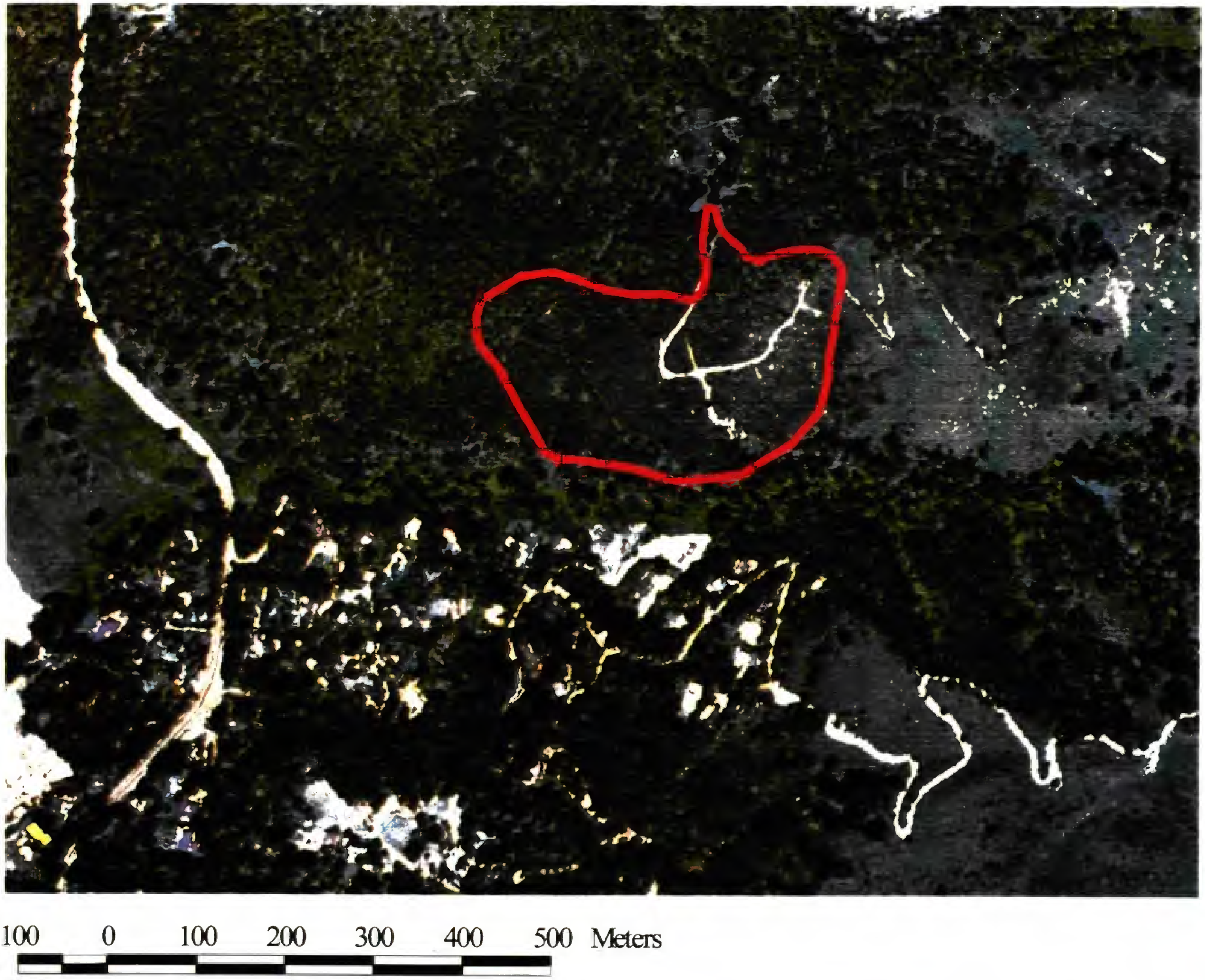

Figure 7. Range of CCG at Gibson's Creek above Pt. Lobos, shown on an aerial photograph of the region. The red line demarcates the area currently supporting CCG populations.

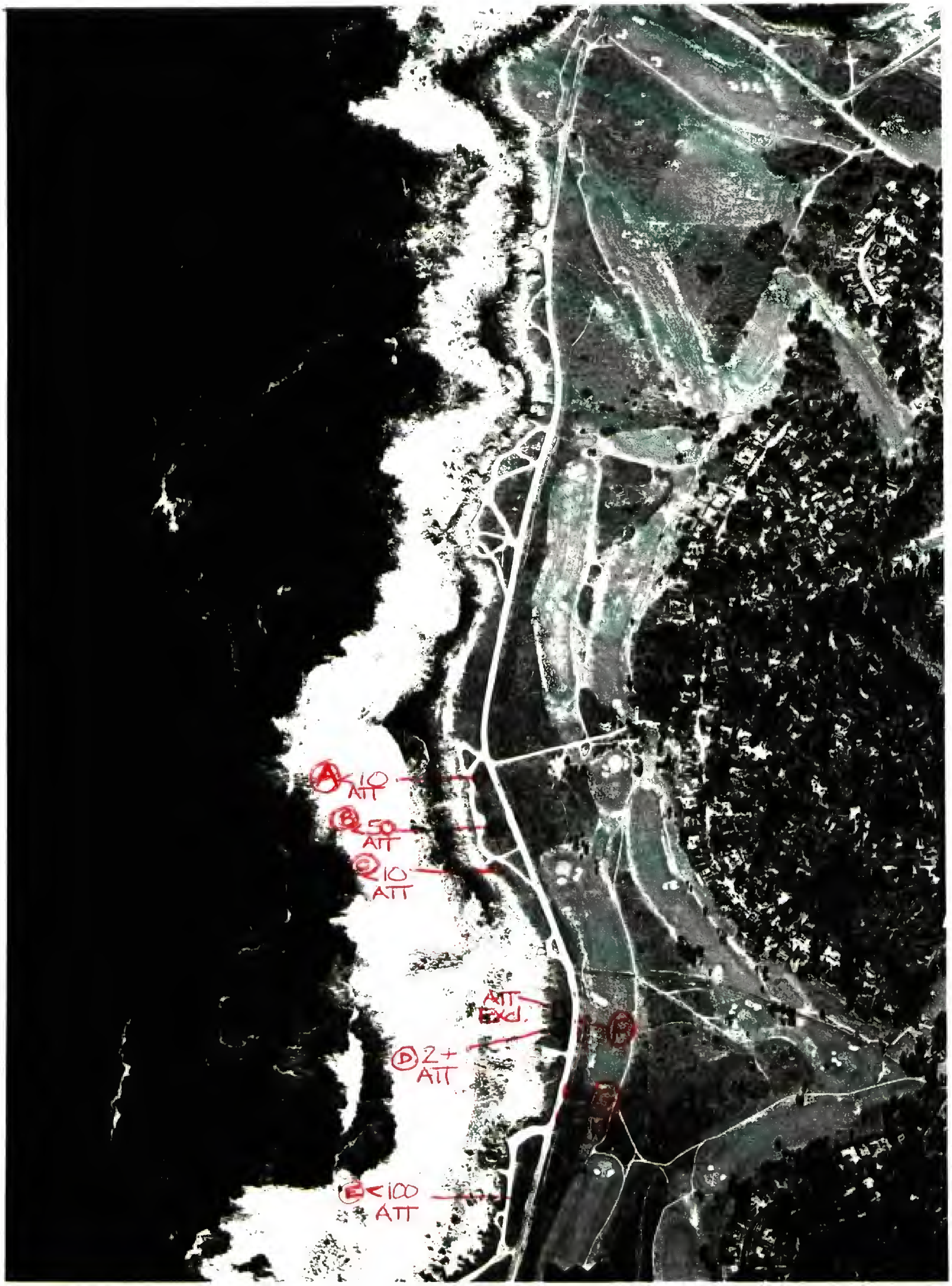

Figure 3. Locations of ATT populations found during 1998 and 2000 surveys along Seventeen Mile Drive, and approximate numbers of ATT found during the 1998 survey.

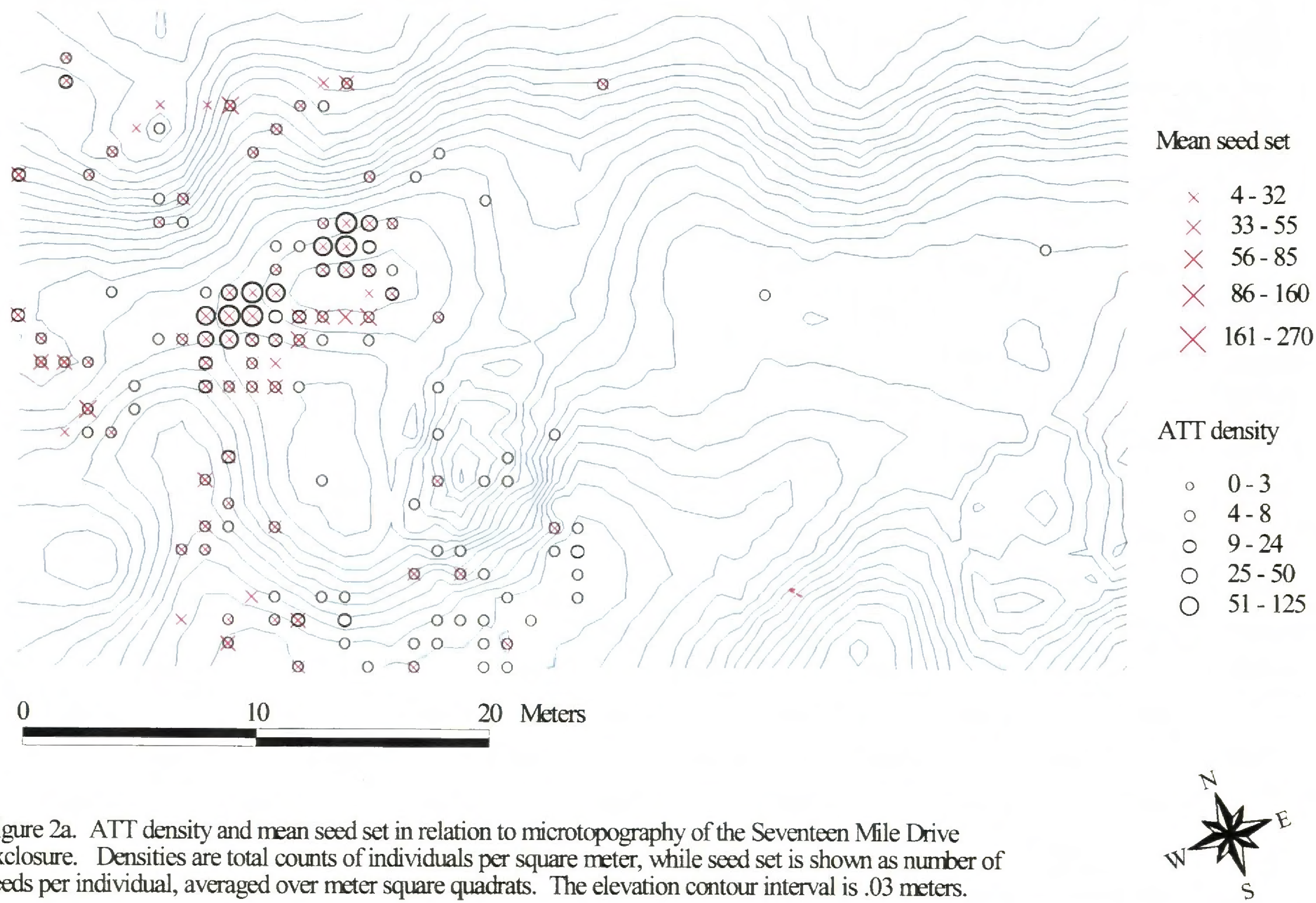

Figure 2a. ATT density and mean seed set in relation to microtopography of the Seventeen Mile Drive exclosure. Densities are total counts of individuals per square meter, while seed set is shown as number of seeds per individual, averaged over meter square quadrats. The elevation contour interval is .03 meters.

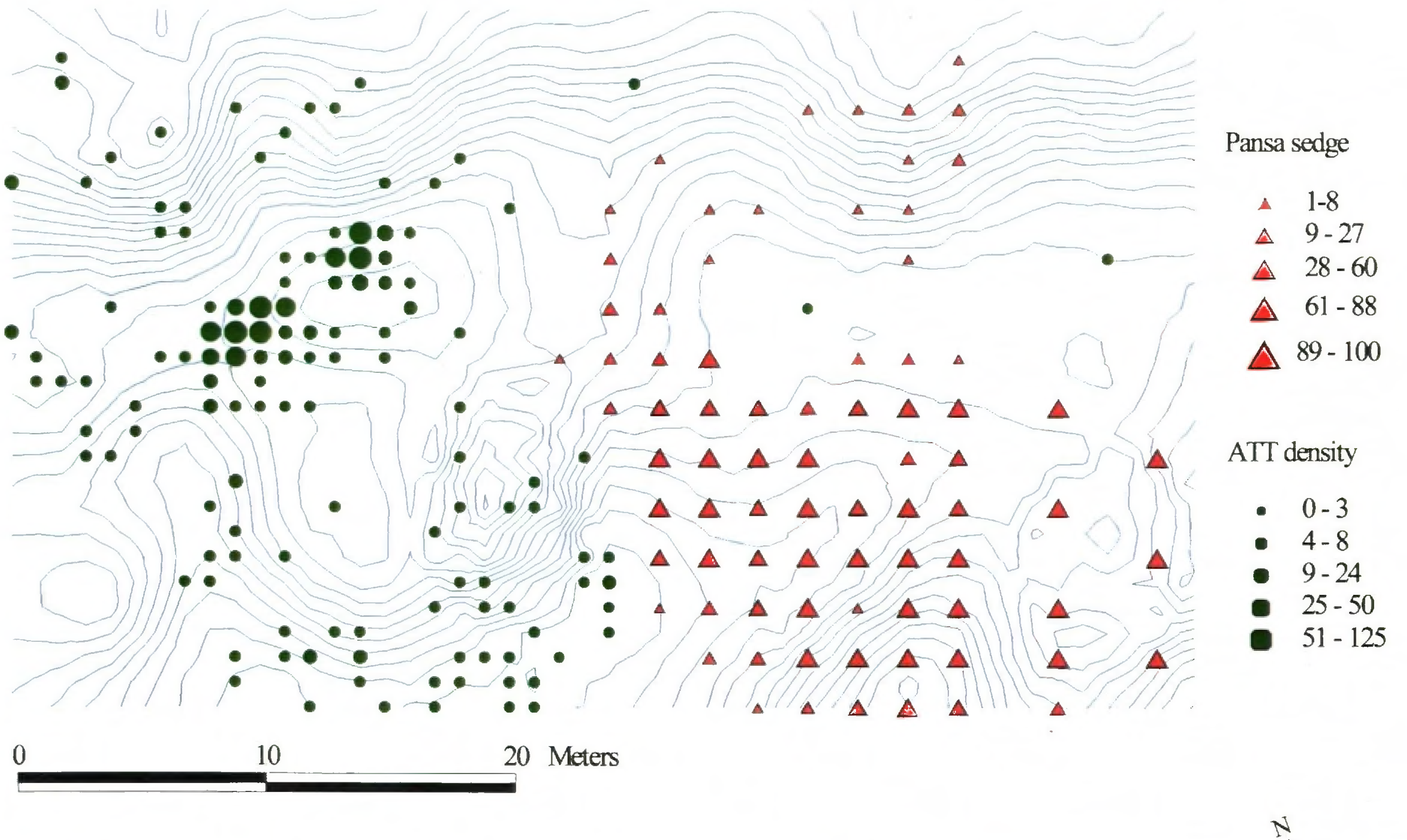

Figure 2b. Extent of Pansa sedge encroachment on the Seventeen Mile Drive exclosure, shown in relation to the current distribution of ATT. Pansa sedge density was measured as percent cover, while ATT density consists of total numbers of individuals, both per square meter. Vegetation surveys were carried out at a coarser scale in the Pansa-dominated south-eastern corner of the exclosure; thus, the lack of data points in this area does not indicate an absence of Pansa.