REMOVAL OF EUROPEAN HONEY BEES FROM THE SANTA CRUZ ISLAND ECOSYSTEM

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ABSTRACT

In 1988, we began to remove European honey bee colonies from Santa Cruz Island, California, in order to restore native bee populations and pollination systems in the Channel Islands National Park. Of the five islands in the Park, only Santa Cruz Island had honey bees, introduced more than 120 years ago. Initially, we located colonies by improved beehunt techniques and began to eliminate colonies on the eastern half of the island at the end of the third season. We also recorded swarms trapped in decoy hives and in cavities formerly occupied by colonies, eventually tallying nearly 300 colonies on the 25,000 hectare island. Midway in the program, drastic changes in the ecology (e.g., cattle removal, spread of exotic weeds, abundant rainfall) led us to employ a biological control agent to eliminate the remaining colonies. In December 1993, January 1994, and February 1994, we loaded a total of 85 mites (*Varroa jacobsoni*, parasitic only on bees of the genus *Apis*) onto foraging bees at a few sites on the eastern half of the island. Colony mortality remained unchanged in 1994 and 1995 but escalated in 1996 and 1997. All 117 of the routinely monitored feral colonies had perished by January 1998.

Keywords: Feral honey bees, *Apis mellifera*, native bees, ecosystem restoration, exotic weeds, biological control, *Varroa jacobsoni*, Santa Cruz Island.

INTRODUCTION

An earlier contribution in this series (Wenner and Thorp 1994) provided comprehensive coverage of the rationale, goals, scope, and progress to date in our long-term feral honey bee (*Apis mellifera* L.) removal project on Santa Cruz Island. The question addressed at that time: Will removing an introduced insect species change habitat quality for native plants and pollinators and also restore and/or increase species diversity and abundance?

That earlier report placed the study into ecological perspective, reviewed foraging behavior and the role of honey bees in ecosystems, outlined the seasonal sequence for nectar and pollen production by native and introduced plants, and summarized the distribution, abundance, and mortality of feral honey bee colonies as of that time. That report also contained a summary of results from studies of plant visitation by insects; honey bee removal on the east half of Santa Cruz Island had altered the relative insect representation on plant species under study in favor of native forms (Figures 2 and 3 in Wenner and Thorp 1994).

By the end of the first five years of this project, several events forced a change in approach. In particular, after removal of most sheep and cattle, exotic weeds (a primary food resource for the exotic honey bees) dramatically increased in island coverage. In addition, the long-term series of drought years had ended. Those two factors combined provided a vastly increased food supply for honey bee colonies, enhancing colony replication via swarming.

Unexpectedly, and a factor in line with our goals, another development impinged on our project, as outlined briefly in the Wenner and Thorp (1994) report. Some honey bee colonies in Florida and Wisconsin had perished due to a parasitic mite (*Varroa jacobsoni;* Oudemans 1904) infestation the very month (October, 1987) that we received approval to initiate this project.

That voracious, blood-sucking mite had crossed over from parasitization of the Asian honey bee (*Apis cerana* F.) to the European honey bee (*A. mellifera*) three decades earlier in central Asia (e.g., Mobus and de Bruyn 1993) and became rapidly and unwittingly transported around the world by beekeepers and bee researchers. Within only a decade after first discovery in the United States, varroa mites occurred in all of the mainland states and Alaska (Wenner and Bushing 1996). Colony mortality was recorded in Ventura County, California as early as October 1989.

We recognized the inevitability of invasion of Santa Cruz Island by varroa mites and pre-empted that eventuality with a deliberate use of those mites as a biological control agent against the European honey bee, in line with our

original goal to eliminate those exotic bees from the island. Fortunately, varroa mites fit all nine criteria insisted upon by The Nature Conservancy before release of biological control agents into their preserves (Randall et al. 1994, unpublished and updated list). Of greatest importance, perhaps, is the fact that this mite species is "highly specialized to survive and reproduce on its honey bee host" (De Jong 1990:205). Any eventuality of an adverse crossover to a native bee species thus seemed highly unlikely.

This report covers progress on the honey bee removal portion of our long-term pollination/bee visitation study, with special emphasis on the efficacy of the varroa mite as a biological control agent in the Santa Cruz Island ecosystem.

MATERIALS AND METHODS

Locating and Monitoring Honey Bee Colonies

Throughout this project we found and plotted locations of European honey bee colonies on topographic maps. At the end of the second year (Fall 1990), colony extermination began on the eastern half of the island. In most cases, colonies were anesthetized with methyl chloroform (i.e., 1-1-1 trichloroethene) and then suffocated by closing off all entrances to the colony. Colonies in fractured rock crevices, etc. often required two or more attempts.

Eventually, we also had approximately 150 swarm hives (e.g., Schmidt and Thoenes 1990) in place throughout the island, with fresh swarm attraction/settling lures inserted into most of them each winter. As logistics permitted, we checked as many as possible several times each season for the presence of new swarms. If located on the eastern half of the island, the new swarms so caught were routinely killed until the spring of 1994 — at the time our biological control program began.

We also occasionally checked most cavities (time permitting) that had formerly held colonies, several times each season, to ascertain if they had been re-occupied. Again, if on the eastern half of the island, we killed new colonies until the spring of 1994. That inspection activity collectively amounted to hundreds of visits to swarm hives and former cavities during the first 11 years of this project.

Varroa Introduction and Monitoring

In December of 1993, and in January and February of 1994, we attached a total of 85 varroa mites (*Varroa jacobsoni*) to foraging worker honey bees — but only at select sites on the eastern half of the island. We extracted those mites from drone brood obtained from a single colony in an apiary located at the University of California, Santa Barbara.

The innoculation process involved placing a mite in a mason jar along with a foraging worker bee collected from a flower. After the mite could no longer be seen in the jar, we allowed the worker bee to return to its colony. Most mites were released in the Prisoners and Coches Prietos drainages, with a smaller total number placed on foraging honey bees near the U.S. Navy facility. From that time on, we did not kill bee colonies anywhere on the island but instead waited for colony demise by natural mite spread.

We know from the literature that only a small percentage of the mites introduced would have been viable (e.g., Martin and Kemp 1997); hence, the innoculum of 85 mites would have amounted to a very few dozen viable mites.

In addition, we established three standard beekeeping wooden monitoring hives in Prisoners, Islay, and Laguna drainages (with island colonies obtained from swarm hives) to enable us to better assess mite reproduction and spread. Initially, we introduced ten mites directly into the Prisoners stream hive; later, we introduced some of their offspring to the hive in Islay Canyon. The Laguna hive later gained its infestation by natural mite spread.

Each established beekeeping hive had a removable tray inserted below the brood combs. By inspecting such trays during each island visit we could ascertain the degree of varroa mite infestation (e.g., Martin and Kemp 1997). In addition, we could insert a miticide strip into the hive and examine the mite drop after a few hours.

RESULTS

In the 11-year period (through the 1998 season), we found or captured a total of 292 honey bee colonies (Table 1). During the first four drought years, existing colonies produced only a few swarms. Once the drought broke (1991-1992), our attention necessarily became focused increasingly on checking known colonies, monitoring the installed swarm hives for occupancy, and examining cavities where colonies had been killed earlier. Extensive elimination of colonies on the east half of the island continued for the next two seasons (1992 and 1993; Figure 1).

Table 1. Total number of feral honey bee colonies dealt with on Santa Cruz Island during an eleven year period.

	Rainfall (Prior Winter)		Original Colonies	Swarms	Total
Season	inches	mm	Found	Caught	Colonies
1988	15.6	396	27	0	27
1989	8.9	226	35	0	35
1990	6.4	163	28	0	28
1991	15.6	396	27	9	36
1992	20.4	518	11	27	38
1993	25.2	640	7	46	53
1994	15.4	391	2	22	24
1995	45.1	1146	2	38	40
1996	15.6	396	0	11	11
1997	23.4	594	0	0	0
1998	43.3	1100	0	0	0
Totals			139	153	292

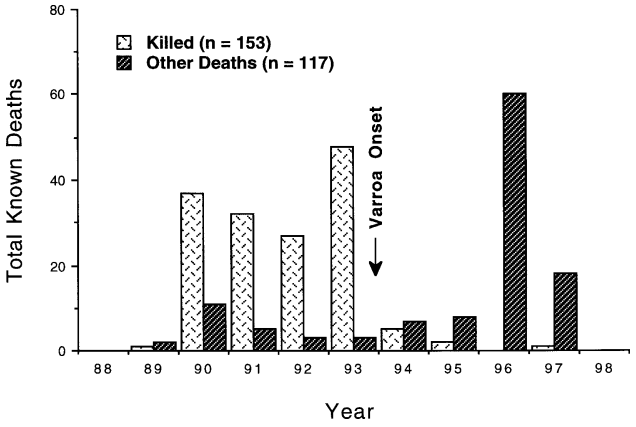

Figure 1. Total mortality of monitored feral honey bee colonies on Santa Cruz Island during an 11-year period. Deliberate elimination of colonies on the eastern half of the island continued until the onset of a varroa mite infestation (winter of 1993-1994). After a two-year period, mites eliminated the remaining monitored colonies.

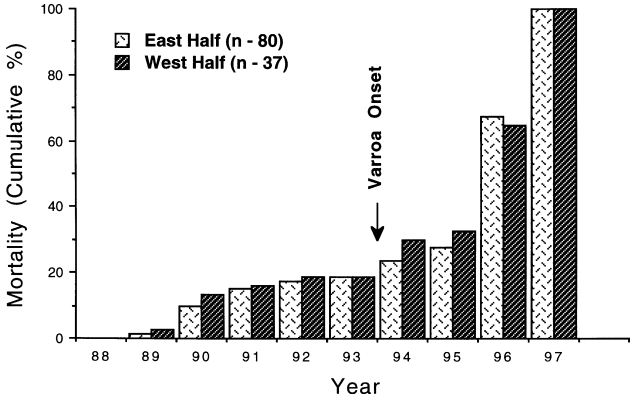

Figure 2. Cumulative mortality of monitored feral colonies on the two halves of Santa Cruz Island, aside from those colonies deliberately eliminated (as in Figure 1). By the end of 1997, all monitored colonies had perished.

As indicated in Wenner and Thorp (1994), we killed no colonies until the third season. By the end of the 1993 season, we had methodically eliminated virtually all known colonies on the eastern half of the island (Figure 1 herein; Table 5 of Wenner and Thorp 1994). The plentiful rains of the 1992-1993 winter, however, resulted in an excessive swarm rate (Table 1), forcing us to turn to use of the varroa mite as a biological control (Materials and Methods section).

Beginning in 1994 (after mite release), we increased the inspection rate of colonies, swarm hives, and vacated cavities in order to record swarm incidence and mortality — both natural mortality and that due to varroa mite infestation. During the entire 1994 and 1995 seasons, natural colony mortality remained at the same level observed in earlier years (Figure 1).

We detected no colony mortality in those two seasons that could be attributed to varroa mite infestation. As an example, a total of 16 such examinations of the Prisoners stream monitoring hive during a more than two-year period after innoculation revealed no visible adverse effect of mite infestation during that time. Beginning in early 1996, however, colony demise escalated; the colonies in hives and most remaining monitored Santa Cruz Island honey bee colonies collapsed that year (Figures 1 and 2).

The initial presence of mites only on the eastern half of the island permitted us to assess how rapidly those mites would cause colony collapse on the western half of the island as well. That demise, in fact, occurred almost as rapidly as on the eastern half of the island (Figure 2). By the end of the 1996 season, some colonies in the Laguna and Pozo drainages (southwest portion of the island) had already perished.

By January 1998, all monitored honey bee colonies were dead (Figure 2). However, on visits later in 1998 we found an occasional honey bee (at most one per minute) foraging midday on yellow star thistle plants (*Centaurea solstitialis* L.) between the main ranch buildings and the Portezuela region, as well as very few foragers visiting horehound (*Marrubium vulgare* L.) at the entrance to the east pine forest.

By contrast, the steady hum of European honey bees that pervaded all parts of the island a dozen years ago no longer exists. Now, foraging honey bees on Santa Cruz Island are vastly outnumbered by native bees on the island (e.g., preliminary results in Thorp et al. 1999).

By employing beelining techniques (Wenner et al. 1992) in September 1998, we determined that at least two colonies still persisted in the central portion of the island. The approximate locations: in the upper reaches of Cañada de la Mina and Gallina Canyon. All colonies surrounding those locations had perished from mite infestation in the 1996 and 1997 seasons.

DISCUSSION

Schmitz and Simberloff wrote:

> "The Nature Conservancy, which operates the largest private U.S. reserve system, views non-indigenous plants and animals as the greatest threats to the species and communities its reserves protect. It can ill afford the increasing time and resources that introduced-species problems cost, and the progress it makes on its own properties is almost always threatened by reinvasion from surrounding lands." (Schmitz and Simberloff 1977:36).

While one can readily appreciate the damage to an ecosystem occasioned by introduced pigs, sheep, or weeds, the adverse effects of an exotic insect species usually go unnoticed. We began our honey bee removal project more than a decade ago with the above considerations in mind.

In contrast to conditions on the mainland, removal of honey bees from Santa Cruz Island would unlikely be followed by "reinvasion from surrounding lands." For example, Santa Rosa Island — located less than 10 km away — has apparently never had honey bees, despite the fact that honey bees have been present on Santa Cruz Island for more than a century (Wenner and Thorp 1993).

In fact, it was the relative ecological diversity of flower-visiting insects on Santa Rosa Island — compared to what one could have observed previously on Santa Cruz Island plants — that inspired us to launch this project (Wenner and Thorp 1994). In contrast to observations on Santa Rosa Island, exotic (European) honey bees dominated flower-visitation on Santa Cruz Island when we began our study, a circumstance that posed a special challenge as an ecological study.

Whereas native bees thrive in certain seasons, honey bee colonies exist year-round, partly by virtue of the fact that they store honey and pollen and can survive adverse conditions by relying on those stores. In good rainfall years, honey bees — by foraging primarily on exotic plant species — likely provide no appreciable competition with native bees.

During drought years, on the other hand, honey bees may no longer have adequate nectar and pollen input from the locally ill-adapted foreign weed sources. As an ultimate generalist forager (e.g., Thorp et al. 1994), the honey bee can instead exploit emergent pollen and nectar sources of drought-resistant native plants normally visited only by native bee species. Once that exploitation of extraordinary food supplies occurs, competition between honey bees and native bees would become intense. Native species may likely fail to complete their life cycles in most parts of the island once such adverse conditions arise.

We thus have a phenomenon of episodic competition through time (that is, through a many year period), rather than a competition at all times (as treated in most ecological theory, but see Wiens 1977). The casual observer can easily miss the severity of honey bee competition as it relates to native bee survival. This study thus began on the assumption of a potential long-term impact of honey bee competition on native bee populations.

Initially, the methodology we employed to find (Wenner et al. 1992) and remove colonies during the first few years of our European honey bee elimination project served us well. By the end of the 1993 season, few colonies remained on the eastern half of Santa Cruz Island. At that same time, however, unforeseen changes in the island ecology (as outlined in the Introduction) occurred and stimulated us to exploit the varroa mite as a biological control agent.

Within three years after introduction, the varroa mite had effectively brought the honey bee population under control and rendered that exotic species ineffective in competition with native bee species.Our find of a two-year latency period after innoculation and before colony collapse apparently represents a first. Worldwide, beekeepers and bee researchers have been caught by surprise when colonies collapsed — without knowing when varroa mites first arrived in their area. Will the varroa mites completely eliminate the honey bee colonies on Santa Cruz Island? A very few colonies still functioned during the 1998 season. However, we know that a swarm sometimes leaves an infested colony just before its collapse and survives for another year or two before it, in turn, succumbs to mite infestation.

Earlier assessments, based mainly on data from 1993 to 1995 when the effects of varroa mite introductions were first felt in California (e.g., Kraus and Page 1995; Thorp 1996), suggested that feral honey bee swarms in California did not survive more than one year after leaving parent colonies. However, on the nearby mainland (unpublished documentation during 1998 in the city of Santa Barbara, Cronshaw 1998) and elsewhere in California (R. Thorp, pers. obs. 1998) feral honey bee colonies have apparently experienced a resurgence in survival time more recently.

Will feral honey bee colonies on Santa Cruz Island undergo a resurgence from the few colonies that still exist there? That remains to be seen — conditions on the island differ in important ways from those on the mainland. In particular, swarms on the mainland can emit from managed colonies kept alive by miticide inserts and can re-occupy existing cavities depopulated earlier by varroa mite infestations. Santa Cruz Island, by comparison, harbors no such managed colonies.

Is one of the few remaining colonies on Santa Cruz Island resistant to the mites? That is highly unlikely, since an allozyme study (R. Page, pers. comm. 1990) revealed that the island honey bees, isolated for more than a century, had little or no genetic variability and constitituted a clone of sorts.

On the other hand, if continued survival did occur, a truly resistant colony could prove a boon to beekeepers, since no such strain has been found in the world to date. Surveys taken during the 1999 season should reveal whether honey bee colonies still remain on Santa Cruz Island or whether a total eradication has been achieved.

ACKNOWLEDGMENTS

We thank the late Dr. Carey Stanton for permission to proceed with the project in October, 1987, as well as Al and Russ Vail for providing access and logistic support during visits to Santa Rosa Island. Thanks also go to Dr. Lyndal Laughrin and Brian Guererro of the University of California's Natural Reserve System for their steady support through the years. Scores of volunteers, including Joe Alcock, John Bishop, Dan Meade, and Chris Spohrer, assisted us during the decade. Dr. Barry Schuyler and the United States Navy provided valuable transportation to and from the island. Justin Schmidt and Steven Thoenes of the United States Department of Agriculture in Tucson, Arizona provided swarm hives and fresh lures each season. The National Science Foundation, The Nature Conservancy, the College of Creative Studies at the University of California, Santa Barbara,

and Faculty Research Funds from the University of California at the Santa Barbara and Davis campuses provided partial funding.

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