Pest Management Grants Final Report

TITLE PAGE

"Biorational Approach for Suppressing American Cockroaches in Sewage Systems"

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TABLE OF CONTENTS

ABSTRACT

The objective of the project was to develop a biorational approach to control cockroaches in sewage systems. Sewers in the City of Santa Monica, California were visually inspected for infestations of American cockroaches, *Periplaneta americana* (L.). The level of infestation and the adult/nymphal composition were estimated for each sewer shaft. Approximately, 30 g of 0.01% fipronil or 0.05% imidacloprid gel bait were placed in each of five sewers in a bait station constructed with PVC pipe. Adult parasitoid wasps, *Aprostocetus hagenowii* (Raxeburg), were released in five sewer shafts in parastized American cockroach egg capsules. Adult female wasps lay eggs in cockroach egg capsules and the larvae kill the cockroach embryos as they develop. The parasitoid wasps were also released in combination with both fipronil and imidacloprid bait. Bait stations were replaced after 12 weeks because moisture accumulated on the bait and cockroaches did readily enter the station. New bait stations constructed from a plastic card (12 by 15 cm) and a piece of evaporative cooler pad glued to the surface to hold approximately 30g of bait on the card. There were 56 and 71% reductions in numbers of cockroaches at 12 weeks in sewers with imidacloprid and fipronil bait alone, respectively. After installation of the new bait stations, reductions increased to 89 and 87 % in 9 weeks. Baits + parasitoids provided similar levels of control, suggesting no detectable reductions resulted from the parasitoids.

EXECUTIVE SUMMARY

The objective of the project was to develop a biorational approach to control cockroaches in sewage systems using low impact insecticidal baits and parasitoids. The efficacy of baits containing imidacloprid or fipronil, parasites, or baits + parasitoids was determined. Sewers in the City of Santa Monica, California were inspected for infestations of American cockroaches, *Periplaneta americana* (L.), beginning in September 1998. The level of infestation and the adult/nymphal composition were visually estimated for each sewer shaft several times before treatment. Five infested sewers were assigned to each of 6 treatments so that each series had similar levels of infestation. Unparasitized *P. americana* egg capsules (oothecae) were placed in sewers and on telephone poles close to the sewers on November 12, 1998 and December 3, 1998 to determine if any cockroach parasitoids existed in Santa Monica.

Bait stations were constructed from PVC pipe (20.3 cm by 10.2 cm diam.) so that the stations could be hung in the sewer and attached to the wall of the sewer with a piece of Velcro. A 8.9 by 6 -cm section was cut from the center of the pipe to permit cockroaches’ access to the bait and allow weighing boats filled with bait to be removed and refilled. Approximately 30 g 0.01% fipronil or 0.05% imidacloprid gel bait were placed in the bait station in each of five sewers. Laboratory studies with starved cockroaches indicated that an adult *P. americana* consumed 0.02 g fipronil and 0.03 g imidacloprid bait; consequently, based on initial assays 30 g should last about 3 weeks in the shaft. The sewers were treated with bait alone on March 16, 1999. Each sewer shaft was visually inspected every 3 weeks and bait replaced as needed.

The parasitoid wasp, *Aprostocetus hagenowii* (Raxeburg), was released in five sewer shafts by placing infested oothecae hung inside small cages (8 by 5 by 3 cm) constructed from 1/4-inch hardware cloth to protect them from rodents. Parasites were also released in combination with both fipronil and imidacloprid bait. Parasitized oothecae were also held in the laboratory to determine emergence rates and viability of the parasites. Parasitized oothecae were placed in sewers on March 12, 1999.

Initial surveys with sentinel oothecae between November 1998 and March 1999 indicated that there was a low probability of oothecal parasites in Santa Monica area. Of the parasitized oothecae placed in the sewers on March 31, adult wasps emerged from only 23% compared with 97.7% in the laboratory. There were no detectable reductions from the first release of parasitoids in the parasitoid alone or bait + parasitoid combinations. Sentinel oothecae set out on May 12, 1999 were not parastized, suggesting that none of the parasitoids initially released successfully developed. A second release was made on June 24, 1999. Wasps emerged from 86.7% of the oothecae compared with 93.3% in the laboratory. It is too early to determine if the second release reduced the number of cockroaches or if the wasp has become established.
There was, however, a 40-57 % reduction in cockroaches at 12 weeks in sewers treated with fipronil or imidacloprid bait. Bait stations were replaced at week 12 because of problems with moisture and fungus grew on the bait in the station. In addition, cockroaches did not readily enter the station. Laboratory studies indicated that the fungus did not reduce feeding. Studies in the laboratory suggested that cockroaches had difficulty entering the PVC bait stations. New stations replaced old ones. The new stations consisted of a plastic card (12 by 15 cm) and a thin piece of evaporative cooler pad (12.7 by 10.2 by 1.25 cm) glued to the surface. The cooler pad held about 30 g bait smeared onto it. New bait stations increased reductions to 75-93% within 9 weeks.

BODY OF REPORT

INTRODUCTION

American cockroaches, *Periplaneta americana* (L.), frequently inhabit sewers, steam tunnels, and drainage systems in California. It is the predominate species found in sewers in the United States (Ebeling 1975). They may breed to enormous numbers in these protected places and besides being a nuisance, they often move from sewers into commercial establishments and homes where they contaminate items with their saliva and excrement (Eads et al. 1954, Mackie 1969). Because at least 22 species of pathogenic bacteria, virus, fungi, and protozoan, and five species of helminthic worms have been isolated from field-collected *P. americana* (L.) (as reviewed by Roth & Willis 1960, and Brenner et al. 1987), these insects pose a potential public health problem wherever they exist. For example, Psittacine birds including cockatoos acquired a fatal disease, *Sarcocystis falcatula,* from *P. americana* that had fed on fecal material from opossums (Clubb and Frenkel 1992). Okafor (1981) cultured several pathogenic organisms such as *Candida albicans*, *Escherichia coli*, and *Salmonella typhimurium* from the intestines of cockroaches collected from kitchens and pit and flush toilets.

American cockroaches inhabiting local sewers in large numbers have presented an ongoing problem to municipalities throughout the country. Concerns over worker safety and comfort as maintenance employees access such infested sewer lines have prompted efforts to eradicate these pests. Control efforts are pitting the protection of human health with that of environmental concerns. The traditional method of control involves spraying sewer access walls with a paint-like chemical usually containing the organophosphate chlorpyrifos (ie. Killmaster II, Super IQ). Visual demonstrations of this application method have shown that these products repeatedly end up in sewer effluent either by drift or dripping down the walls of the sewer.

The objective of the study was to develop a biorational approach for controlling American cockroaches in sewers, with an emphasis on integrating baits and parasites. The intent was to control cockroach populations while simultaneously reducing the amount of insecticide applied. The application of baits at discrete sites will reduce the likelihood of contaminating sewer effluent and eliminate exposure to potentially hazardous materials by maintenance personnel. The ultimate objective was to develop a cost effective program that can be used by environmental and public works management departments.

Movement of cockroaches out of infested sewers is seasonal and is probably related to the density of the cockroach population. The ability of American cockroaches to enter buildings by way of the plumbing is well documented and is often observed by people living near infested sewers. In fact, controlling cockroaches in these sewers decreases infestations in adjacent buildings (Roth and Willis 1960). Jackson and Maier (1955) found little dispersion of cockroaches from manholes in Phoenix, Arizona in August, about 6% of tagged cockroaches being recovered from yards, homes or in other areas of the sewer system up to 350 yards away from the release site. However, when they repeated the study in January and June when it was cooler, the movement pattern was dramatically different (Jackson and Maier 1961). Minimal dispersal from sewers occurred in January, but numerous tagged cockroaches were caught around structures and in nearby sewers in

June. Cockroaches left the manholes during the evenings. Similarly, Mackie (1969) found that cockroaches emerge from manholes and enter nearby buildings. Of 271 food-handling establishments inspected, 40 (15%) had American cockroaches. Typically they found large nymphs and adults suggesting that *P. americana* were moving from the sewers. He speculated that most of movement occurred from above-ground routes.

The seasonality of *P. americana* population development was shown by Bao and Robinson (1988) who reported a distinct seasonal size and composition of populations in Virginia. Large numbers of nymphs were trapped in the fall representing about 67% of the population. The numbers of nymphs and adults were lower during the rest of the year, with about equal proportions of each. The number of oothecae increased in the spring. In California, about 60% of the population in sewers were adults in June decreasing to about 25% in the winter months (Rust et al. 1991).

Insecticidal dusts or sprays are typically recommended to control American cockroaches in sewers. No longer available, 5% chlordane spray provided about 1-year control (Mackie 1969). Chadwick and Shaw (1974) reported that thermal fogs of 0.15% bioresemthrin plus 0.15% piperonyl butoxide in kerosene treated sewers, fresh, 4, and 8 weeks, and then every two months. In the drier climates, bioresmethrin and cismethrin thermal fogs provided similar results (Chadwick et al. 1977). Chlorpyrifos sprays provided >80% reductions in cockroaches for 12 months in sewers in central California whereas dust formulations of Drione and boric acid greatly reduced populations quickly and provided about 6 months control. Resurgence was probably due to oothecae hatching after residues had deteriorated or washed away. Boric acid and hydramtheylnon baits provided inconsistent control, probably because the large numbers of cockroaches in the sewers consumed all the bait or the baits became moldy and unpalatable to the cockroaches (Rust et al. 1991).

As has been found for other species of cockroaches, Smith and Appel (1996) reported that quick-knockdown agents such as chlorpyrifos and avermectin were repellent to American cockroaches. Solid and gel baits containing hydramtheylnon and sulfluramid that take 2 to 5 days to kill were not repellent and provided best results, killing 100% of the cockroaches within 14 days. Barlow and Robinson (1997) reported that adults and nymphs fed predominately on exposed foods and not those in a bait station, but only small nymphs showed no preference between bait in and outside a bait station.

The oothecae of *P. americana*, rather than the adults or nymphs, are susceptible to parasitism. The oothecae incubate for 4 to 7 weeks only partly concealed in a crack or crevice or sometimes openly exposed. As listed by Lebeck (1991), there are several hymenopterous predators and parasitoids of cockroaches. Among the most prominent are the predator *Ampulex compressa* F. and the parasites *Evania appendigaster* (L.); *E. sericea* Cameron; *Anastatus umae* Boucek; *Aprostocetus (Tetrastichus) hagenowii* (Raxeburg); *A. asthenogmus* (Waterston); and *Tetrastichus periplanetae* (Crawford). Cameron (1955) reported that *A. hagenowii* was more useful as a control organism than *E. appendigaster* because *A. hagenowii* is gregarious, has a short development time (24 to 40 days), and develops even if oothecae are disrupted. Surveys of urban areas in Texas and Louisiana showed that of collected *P. americana* oothecae, 20.4% were naturally parasitized by *A. hagenowii* (Piper et al. 1978). Similarly, 16% of *P. americana* oothecae collected from hostels, hotel kitchens, and huts in Sri Lanka were parasitized by *A. hagenowii* (Narasimham and Sankaran 1979).

Longevity of this wasp in laboratory was 3.4 days when starved and 7.3 days when they were fed. Males live up to 3.3 days when fed honey or sugar water. Edmunds (1955) showed that adult female wasps fed raisins lived up to 45 days. The wasps develop in 31 to 60 days at 21.1 to 26.7° C. Kumarasinghe and Edririsinghe (1987) found that *A. hagenowii* did not have a preference for any particular age of cockroach ootheca. However, wasps only emerged from oothecae <28 days old.

Hagenbuch et al. (1989) released *A. hagenowii* 3 times a week for 5 weeks into experimental chambers containing *P. americana*. Up to 98% of the egg capsules were parasitized and wasps emerged, indicating the potential for sustaining a population of wasps. Hydramethylnon bait did not affect the parasitoids. Studies with the wasp *Comperia merceti* (Compere) and the brownbanded cockroach, *Supella longipalpa* (F.), suggest that effectiveness of may be limited to high densities of cockroaches (Coler et al. 1984). Thus augmentation (mass release of parasitoids) may be necessary to suppress populations of cockroaches (Slater et al. 1980).

MATERIALS AND METHODS

Inspection and Survey of Sewers. - Beginning in September 1998, sewers were visually inspected by City of Santa Monica personnel in three different regions of the city (Fig. 1). Sewers in the restaurant district, a residential area and a beach area were inspected and those containing more than 50 cockroaches were selected. Only sewers with metal rung ladders and brick and masonry construction were used for bait treatments and parasitoid releases. Visual counts were made with the aid of a mirror or seal beam lamp and the ratio of adult/nymphal cockroaches was estimated for each sewer hole. Pretreatment counts were made in November and December and at the time of treatment.

Field Monitoring for Parasites.- Large numbers of adult *P. americana* were isolated and maintained in 3.8-liter jars provisioned with food, water and harborage to produce oothecae. Oothecae were collected weekly. Oothecae 7 to 14 days old were put in bags made of fiberglass window screen (5 by 6 cm) and stapled closed. The bags were placed inside a small wire cage made of 1/4-inch hardware cloth (8 by 5 by 3 cm). The hardware cloth protected the oothecae from rodents and wild animals. One cage with oothecae was attached to a stainless steel wire and lowered about 1 m into the sewer shaft and secured to the metal rungs with a brass clip. Another cage was stapled to a telephone pole in a protected site. The cages and oothecae were left in the field for 21 days.

The oothecae were returned to the laboratory and placed in a 2.5 dram plastic vials. The snap lid had small holes to allow for air exchange and a disk of filter paper to prevent the wasps from escaping. The oothecae were maintained at 25°C and 50% RH. The oothecae were checked daily and the number of cockroaches or parasitic wasps that emerged was counted.

Sentinel oothecae were placed in 13 sewer holes and placed on 13 telephone posts on 12 November 1998 and retrieved on December 3, 1998. Monitors were placed out in 15 sewer holes and 15 telephone poles from December 3, 1998 to March 16, 1999. The area was expanded to include 20 sewers and 20 telephone poles on May 12, 1999. The oothecae were returned to the laboratory on June 2, 1999.

Bait and Bait Stations- Bait stations were constructed from PVC pipe (20.3 by 10.2 cm diam.). A section of the pipe was cut (8.9 cm by 7.6 cm) to allow cockroaches to enter the pipe and permit the changing of the bait. Plastic caps were glued to both ends of the pipe. A piece of industrial Velcro (10.2 by 15.2 cm) was glued to the center back of the pipe. A hole was drilled in the top section of the pipe to attach a 30-cm piece of wire. To install the bait station in the field, a piece of Velcro (10.2 by 15.2 cm) adhered to walls of the sewer shaft with Henry Wet Patch Roof Cement (#208). The Velcro from the bait station was pressed against the Velcro on the wall and the wire attached to a metal rung to prevent the station from falling into the sewer.

Approximately, 30 g of fipronil bait or imidacloprid gel bait was placed in an aluminum weighing pan and placed in the bottom of the bait station. Bait stations were inspected every 3 weeks and the baits replaced.

New bait cards consisted of a plastic card (12 by 15 cm) and a thin piece of evaporative cooler pad (12.7 by 10.2 by 1.25 cm) glued to the surface. A 3 by 3 cm piece of Velcro was cemented to the back of the card. When the bait cards were placed in the sewer, the Velcro was secured to the piece of Velcro cemented to sewer shaft. To insure that the bait cards did not fall into the sewer, a brass clip attached to a 1-m piece of stainless wire was attached to a sewer rung and a small hole made in one upper corner of the bait card.

Laboratory tests with baits.- Various commercial and experimental baits were tested in the laboratory to determine their palatability and efficacy against adult *P. americana*. Five adult male and five adult female cockroaches were placed in a 3.8-l glass jar provisioned with a water jar, dry dog food, and a piece of cardboard harborage. The cockroaches were allowed to accumulate in the jar for about 7 days. The baits tested included 0.003 % fipronil granular fire ant bait, 1% granular hydramethylnon bait (Maxforce FG and Maxforce G), 2.15% imidacloprid white gel, 0.01% fipronil gel, 2% hydramethylnon disk, 1% hydramethlynon Maxforce Professional Granular Insect Control Granular, 0.001% fipronil disk, and 0.01% fipronil disk. About 0.5 g of each bait was placed in each of three jars along with competitive dog chow food and the number of dead cockroaches was counted regularly. Dead cockroaches were removed.

Laboratory tests with molded baits. − Cockroaches were given access to fresh gel baits and baits that had developed mold growth in the sewers to determine if mold and fungus decreased the activity of fipronil and imidacloprid baits. Glass jars with adult cockroaches were set up as previously described. About 0.5 g of fresh or molded bait removed from the sewers in the study were placed in each of three glass jars containing cockroaches per treatment. The number of dead cockroaches were removed from the jars and counted approximately daily for up to a month.

Parasite release in the field. − To release approximately 1,000 female wasps per manhole, 30 oothecae were placed in bags consisting of fiberglass window screen (5 by 6 cm) and stapled closed. The bags were placed in small hardware cloth cages (8 by 5 by 3 cm). The cages were attached to a 1-m piece of stainless steel wire and attached to the rungs. The cages and parastized egg capsules were left in the field for 21 days. Three lots of 30 capsules were held in the laboratory to determine the number of female parasitoids produced and the number of successfully parasitized egg capsules.

RESULTS AND DISCUSSION

Surveys for Parasitoids. None of the oothecae placed on the sentinel monitors were stung by any egg capsules parasitoids. There is a strong likelihood that there are not any parasitoids of *P. americana* oothecae established in Santa Monica. This is extremely interesting considering their prevalence in the southeastern United States.

Laboratory Tests with Baits. The 0.01% fipronil solid disk bait provided the fastest kill of *P. americana* (Table 4). Several other granular baits such as MaxForce G and 0.003% fipronil granular ant bait also provided complete kill within 21 days. When *P. americana* are provided alternative food sources, bait consumption was slow and some adults were still alive at 28 days. This suggested other available food may affect ultimate levels of control by bait alone.
One problem, however, was securing the solid baits to the plastic card with Elmer's white glue. Some baits were dislodged during the test. In the field, this material would have fallen into the wastewater. Even though the gels provided slower kill, they remained on the cards during the entire test.

Laboratory Tests with Molded Baits. The baits in the PVC pipes were typically very wet and covered with mold and fungus at the 3-week inspection. Fresh gel baits held at 100% RH in the laboratory did not grow mold and fungus. The source of the mold and fungus was clearly the sewer.

However, the mold and fungus on the baits did not reduce their efficacy (Table 3). When *P. americana* are provided an alternative food source, bait consumption was slow and some adults survived for at least 32 days.

Baiting, Parasite Releases and Baiting + Parasitoid Releases. Imidacloprid and fipronil bait provided 56.2 and 70.6% reductions in visual counts at week 12, respectively (Table 1, Fig. 2 and 3). Installation of the new bait stations improved the control to 89.4 and 86.8% for imidacloprid and fipronil, respectively. The reductions in visual counts in the bait + parasites for the first 9 weeks are similar to those of the baits alone. Installation of the new bait stations increased reduction to 89.6 and 92.9% with imidacloprid and fipronil baits + parasitoids, respectively. The populations increased in the controls and the sewers with parasitoids only.

Of the 300 parasitized oothecae placed in the sewers on March 31, 1999, 265 were recovered and examined. In the sewers, *A. hagenowii* successfully developed and emerged from 23% (Table 2). Another 17% were in various stages of development. However, 47% had dead wasps and were filled with a brown ooze. In the controls held in the laboratory, *A. hagenowii* successfully emerged from 98% of the capsules. Approximately, 8 times more female wasps emerged than did males. The reduced rate of emergence in the field may be due to lower temperatures in the sewer shafts or exposure to microbial pathogens.

The increased performance of the baits can be attributed to a change in the bait station design and the accessibility of the bait. The gel formulations were active but competitive food sources in the sewers probably contributed to the delayed reductions in visual counts.

Better emergence was obtained in our second parasite release on June 2, *A. hagenowii* emerged from approximately 87% of 450 capsules placed in the sewers. Only 5.5% of the capsules contained wasps in various stages of development. Dead wasps in egg capsules with brown ooze were found in 7.8% of the capsules inspected. In the laboratory controls, *A. hagenowii* developed and emerged in 93.3% of the parastized egg capsules.

Post-parasite Release Monitoring. None of the sentinel oothecae in May were stung by parastoid wasps. The unparasitized capsules were placed in sewers when *A. hagenowii* would be emerging even if their development had been delayed by cooler temperatures in the sewers during April. Sentinel egg capsules placed out in sewers after June 2 have not been evaluated yet.

SUMMARY AND CONCLUSIONS

The objective of the project was to develop a biorational approach to control cockroaches in sewage systems using low impact insecticidal baits and parasitoids. The efficacy of baits containing imidacloprid or fipronil, parasites, or baits + parasitoids was determined with the assistance of personnel from the Water and Wastewater Department of Santa Monica, California. Sewers were inspected for infestations of American cockroaches, *Periplaneta americana* (L.), beginning in September 1998. The level of infestation and the adult/nymphal composition were visually estimated

Bait stations were constructed from PVC pipe (20.3 cm by 10.2 cm diam.) so that the stations could be hung in the sewer and attached to the wall of the sewer with a piece of Velcro. A 8.9 by 6 -cm section was cut from the center of the pipe to permit cockroaches access to the bait and allow weighing boats filled with bait to be removed and refilled. Approximately 30 g 0.01% fipronil or 0.05% imidacloprid gel bait were placed in the bait station in each of five sewers. Each sewer shaft was visually inspected every 3 weeks and bait replaced as needed.

The parasitoid wasp, *Aprostocetus hagenowii* (Raxeburg), was released in five sewer shafts by placing infested oothecae hung inside small cages (8 by 5 by 3 cm) constructed from 1/4-inch hardware cloth to protect them from rodents. Parasitoids were also released in combination with both fipronil and imidacloprid bait. Parasitized oothecae were also held in the laboratory to determine emergence rates and viability of the parasitoid wasps. Parasitized oothecae were placed in sewers on March 31, 1999.

Initial surveys with sentinel oothecae between November 1998 and March 1999 indicated that there was a low probability of oothecal parasitoids in Santa Monica area. Of the parasitized oothecae placed in the sewers on March 31, adult wasps emerged from only 23% compared with 97.7% in the laboratory. There were no detectable reductions from the first release of parasitoids in the parasitoid alone or bait + parasitoid combinations. Sentinel oothecae set out on May 12, 1999 were not parastized, suggesting that none of the parasitoids initially released successfully developed. A second release was made on June 24, 1999. Wasps emerged from 86.7% of the oothecae compared with 93.3% in the laboratory. It is too early to determine if the second release reduced the number of cockroaches or if the wasp has become established.
There was, however, a 40-57 % reduction in cockroaches at 12 weeks in sewers treated with fipronil or imidacloprid bait. Bait stations were replaced at week 12 because of problems with moisture and fungus grew on the bait in the station. In addition, cockroaches did not readily enter the station. Laboratory studies indicated that the fungus did not reduce feeding. Studies in the laboratory suggested that cockroaches had difficulty entering the PVC bait stations. New stations replaced old ones. The new stations consisted of a plastic card (12 by 15 cm) and a thin piece of evaporative cooler pad (12.7 by 10.2 by 1.25 cm) glued to the surface. The cooler pad held about 30 g bait smeared onto it. New bait stations increased reductions to 75-93% within 9 weeks.

The gel baits were extremely effective in reducing the number of cockroaches in the sewers. Availability of the bait is extremely important. Bait placed on plastic cards sewer resulted in rapid reductions of cockroaches. In one instance, the imidacloprid gel was placed directly in spaces between the bricks near the top of the sewer. We had 90% reductions in the visual count within 21 days. However, in the vast majority of the sewers the reductions in visual counts did not usually occur until about 3 to 6 weeks after baiting. The slow action of the gel baits may be because of competitive food sources in the sewers. Emergence data from the early spring release of parasitoids suggests that environmental conditions may not be optimal for *A. hagenowii* during the winter and early spring. It is still too early to know if the parasitoid releases in the sewers have been effective. Monitoring should continue to determine if the parasitoid introductions were successful.

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APPENDICES

List of Tables

List of Figures

Table 1. Percent reductions of American cockroaches, *P. americana* (L.), in sewers.[a]

Treatment[b]	Parasitoid	Avg. no. roaches/sewer precount (total)	% Reduction at week[c]						
			3	6	9	12	15	18	21
Fipronil bait	No	292 (1458)	29.2	60.2	46.3	70.6	**85.0**	**83.1**	**86.8**
Fipronil bait	Yes	147 (734)	70.0	20.0	49.5	**92.9**	**79.4**	**75.7**	
Imidacloprid bait	No	269 (1345)	6.1	43.3	29.4	56.2	**76.1**	**87.2**	**89.4**
Imidacloprid bait	Yes	156 (778)	55.0	28.8	64.9	**89.6**	**92.6**	**92.6**	
No bait	Yes[c]	133 (666)	20.9	0.0	0.0	0.0	0.0	0.0	
-----	------	168 (841)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Visual counts.

[b] Five sewer shafts treated per bait, parasitoid, and bait + parasitoid combination. Bait alone tests initiated 16 March 1999. Parasitoid and bait + parasitoid tests initiated 31 March 1999.

[c] Bait station design was changed 2 June 1999 (reductions bolded); week 12 for the baits alone and week 9 for the baits + parasitoids.

[d] Parasitoids released 31 March and 24 June 1999. Week 0 and week 12.

Table 2. Parasitoid development and emergence from parasitized *P. americana* oothecae placed out in sewers March 31, 1999.

	SANTA MONICA COCKROACH PROJECT							
	Parasite release -3/31/99-4/21/99							
HOLE	empty oothecae	alive developed parasites, no ooze	dead developed wasps, with brown ooze	pupal wasps	larval wasps	contents desiccated		# recovered
1a	3	13	3		1			20
1b	3		17					20
1d	9	1	10					20
2a	0	1	15	4				20
2b	5	2	13					20
3b	13	3	3			1		20
6	3	1	14	2				20
7a	0		14		6			20
7d	15	2	3					20
12	0	1	16	3				20
13a	10		9		1			20
14	0		3			2		5
27	3	1	13	2	1			20
28	6	3	8	3				20
30		all oothecae missing						0
	70	28	141	14	9	3		265
%	**23**	**9**	**47**	**5**	**3**	**1**		**88**
	capsules	emerged	# females	females/cap	# males	males/cap	ratio	
control	20	20	1248	62	152	7.6	8.2	
control	20	19	1162	61	136	7.2	8.5	
control	14	14	868	62	107	7.6	8.1	

Table 3. Performance of fresh bait and 2-month-old bait retrieved from sewers adult American cockroaches, *P. americana* (L.).

		% dead at day					
Bait [a]	**Sex**	**1**	**3**	**8**	**15**	**25**	**32**
Imidacloprid bait							
Fresh	Male	33.3	73.3	100	100	100	100
Female	20.0	33.3	46.7	46.7	46.7	53.3	
Imidacloprid bait							
Field (white fungus)	Male	13.3	33.3	46.7	66.7	86.7	86.7
	Female	53.3	66.7	93.3	93.3	93.3	93.3
Fipronil gel							
Fresh	Male	0.0	40.0	75.0	75.0	86.7	86.
	Female	0.0	26.7	75.0	86.7	86.7	93.3
Fipronil gel							
Field (fungus)	Male	0.0	26.7	93.3	100	100	100
	Female	0.0	6.7	60.0	60.0	86.7	93.3
Control	Male	0.0	0.0	0.0	0.0	0.0	6.7
	Female	0.0	6.7	6.7	6.7	6.7	6.7

[a] Bait placed in each of three 3.8-l glass jars provisioned with food, dog chow, harborage and 5 male and 5 female cockroaches. Dead counted and removed periodically. Tests initiated April 9, 1999. Approximately, 0.6 ml of bait placed in aluminum, weighing pan in each container.

Table 4. Performance of various baits against adult American cockroaches, *P. americana* (L.), in laboratory tests with an alternative food source.

		% dead at day					
Treatment[a]	**Sex**	**1**	**3**	**7**	**14**	**21**	**28**
Fipronil, 0.003%							
Granular ant bait	Male	0.0	60.0	80.0	93.3	100	
	Female	0.0	52.9	88.2	94.1	100	
Fipronil, 0.01% gel	Male	13.3	60.0	66.7	80.0	100	
	Female	26.7	93.3	93.3	100		
Fipronil, 0.001%							
Solid 1/2 disk	Male	0.0	0.0	60.0	80.0	80.0	80.0
	Female	0.0	0.0	13.3	40.0	66.7	66.7
Fipronil, 0.01%							
Solid 1/2 disk	Male	86.7	100				
	Female	86.7	100				
Hydramethylnon, 2.0%							
1/2 disk	Male	0.0	0.0	53.3	100		
	Female	0.0	0.0	46.7	100		
Hydramethylnon, 1.0%							
1/2 disk	Male	0.0	0.0	60.0	80.0	80.0	80.0
	Female	0.0	0.0	13.3	40.0	66.7	66.7
Imidacloprid, 2.15%							
Gel	Male	66.7	73.3	86.7	86.7	86.7	86.7
	Female	40.0	66.7	66.7	80.0	86.7	86.7
MaxForce FG	Male	0.0	0.0	18.8	62.5	81.2	100
	Female	0.0	0.0	21.4	78.6	92.9	100
MaxForce G	Male	12.5	12.5	25.0	93.8	100	
	Female	0.0	0.0	31.2	100		
Control	Male	0.0	0.0	0.0	0.0	0.0	0.0
	Female	0.0	0.0	0.0	0.0	0.0	0.0

[a] Baits placed in each of 3.8-l glass jars provisioned with food, dog chow, harborage and 5 male and 5 female cockroaches. The dead counted and removed periodically. Tests initiated April 19, 1999. Approximately, 0.6 ml of bait or 1/2 of a disk of bait placed in each jar.

Table 5. Parasitoid development and emergence from parasitized *P. americana* oothecae placed out in sewers June 24, 1999.

	SANTA MONICA COCKROACH PROJECT						
	Parasite release -6/24/99-7/15/99						
HOLE	empty oothecae	alive wasps, not emerged	dead developed wasps, with brown ooze	larval wasps	contents desiccated		# recovered
1a	25	1		1	3		30
1b	26	2	2				30
1d	17	1	11	1			30
2a	26		2	1	1		30
2b	29				1		30
3b	29	1					30
6	30						30
7a	22		6	1	1		30
7d	29	1					30
12	21		7		2		30
13a	26	1	3				30
14	27			1	2		30
27	28		1	1			30
28	28		2				30
30	27	1	1	1			30
	390	8	35	7	10		450
# wasps							
%	**86.7**	**1.8**	**7.8**	**1.6**	**2.2**		**100**
	capsules	emerged	estimated females				
control	30	26	1222				
control	30	28	1316				
control	30	30	1410				
Held 20 oothecae individually, 19 emerged from 6/28/99 to 7/16/99							
Average emergence per capsule: 47 females, 5 males							
Average sex ratio equals 9.4 females to males							
Release goal was 1000 female wasps per manhole							

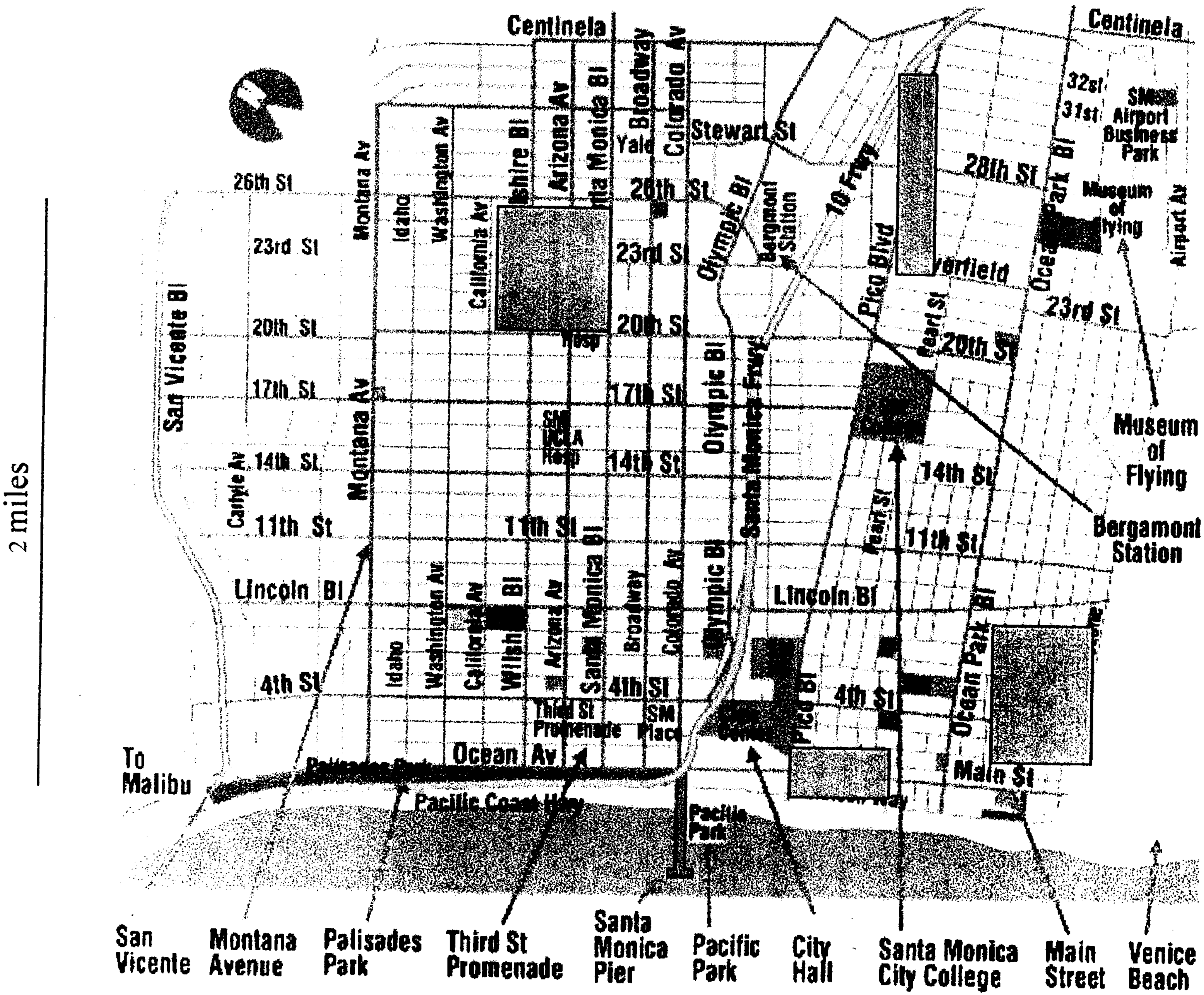
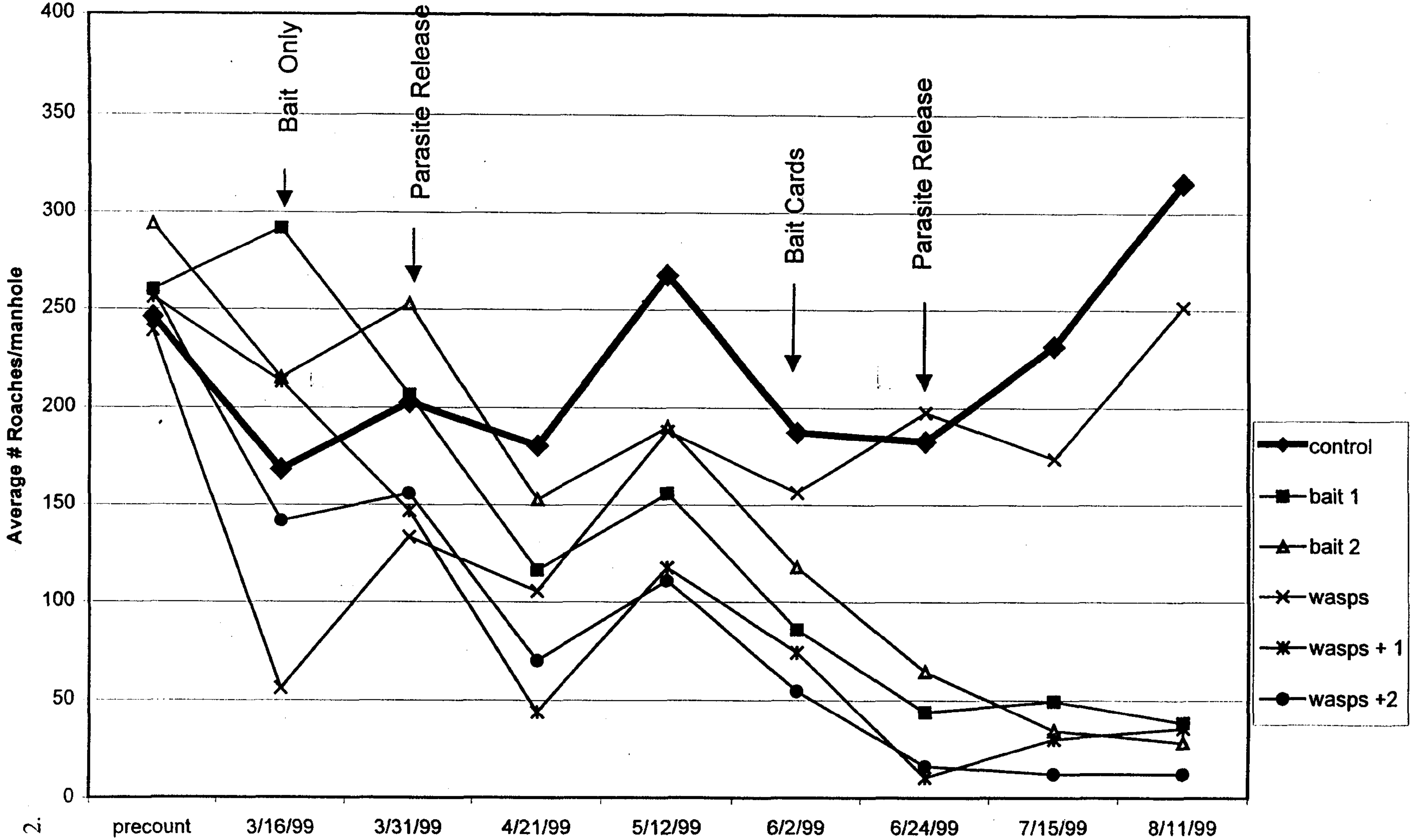


Figure 1. City of Santa Monica and test sites.



400
350
300
250
200
150
100
50
0
Average # Roaches/manhole
Bait Only
Parasite Release
Bait Cards
Parasite Release
precount
3/16/99
3/31/99
4/21/99
5/12/99
6/2/99
6/24/99
7/15/99
8/11/99
control
bait 1
bait 2
wasps
wasps + 1
wasps +2

Fig. 2.

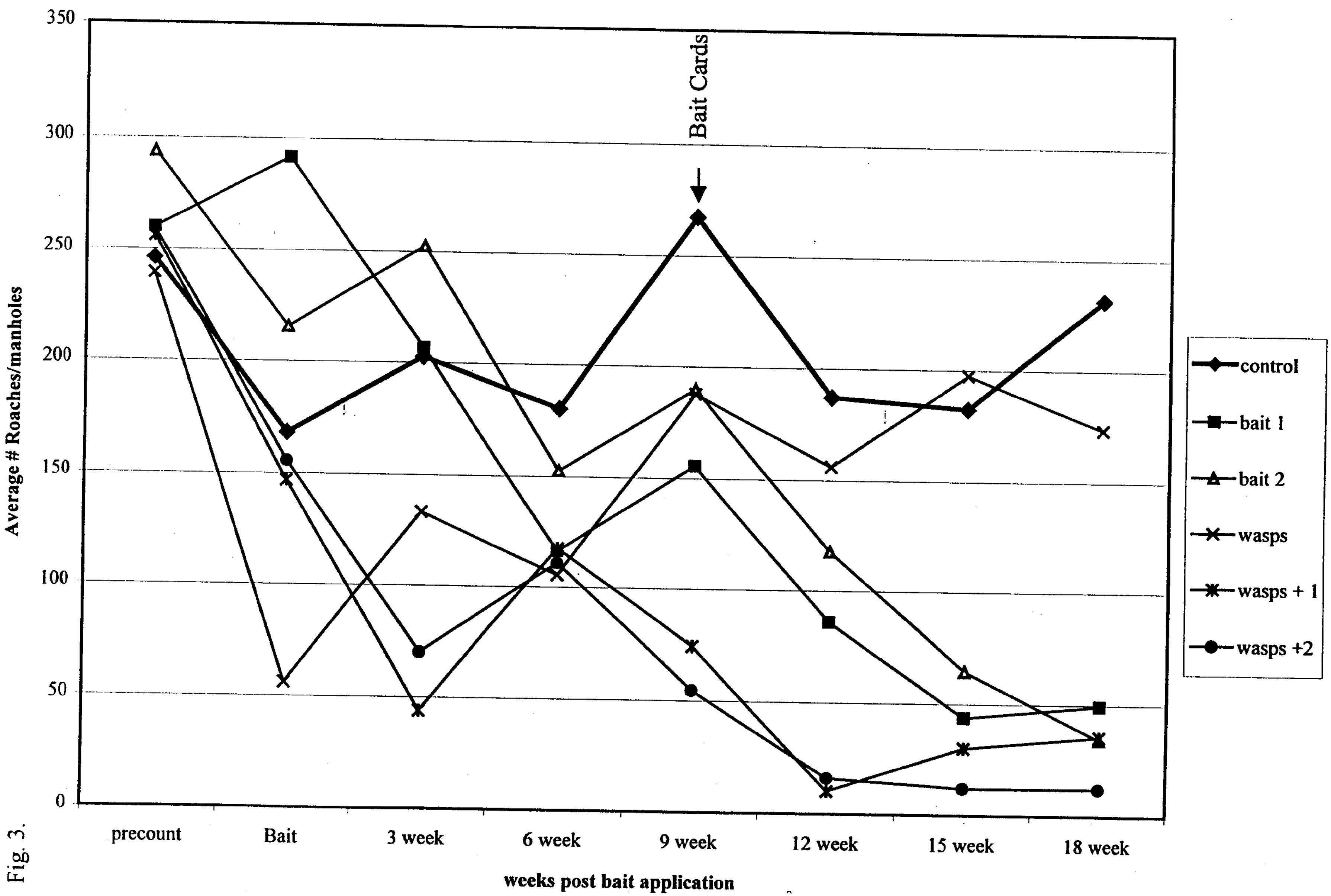

350
300
250
200
150
100
50
0
Average # Roaches/manholes
Bait Cards
precount
Bait
3 week
6 week
9 week
12 week
15 week
18 week
weeks post bait application
control
bait 1
bait 2
wasps
wasps + 1
wasps +2

Fig. 3.