Proceedings of the Iowa Academy of Science

Volume 75 | Annual Issue Article 58

1968

Mark-and-Recapture Methods for Studying Domestic Cockroach Populations

Frank J. Bulow
Iowa State University

Donald G. Huggins
Iowa State University

Recommended Citation
Bulow, Frank J. and Huggins, Donald G. (1968) "Mark-and-Recapture Methods for Studying Domestic Cockroach Populations," *Proceedings of the Iowa Academy of Science, 75(1),* 447-456.
Available at: https://scholarworks.uni.edu/pias/vol75/iss1/58

Mark-and-Recapture Methods for Studying Domestic Cockroach Populations

FRANK J. BULOW and DONALD G. HUGGINS[1]

Abstract. Mark and recapture methods were used to estimate populations of American cockroaches, *Periplenata americana* (Linnaeus), and brown-banded cockroaches, *Supella supellectilium* (Serville) inhabiting various rooms in the Science Hall, Iowa State University. These methods also permitted estimates of sex ratios, length-frequencies, movement, and activity patterns.

Food appeared to be the limiting factor in determining size of cockroach populations. Males outnumbered females in both species with total sex ratios being .8 and .6 for brown-banded and American cockroaches, respectively. Most of the American cockroaches caught were over 28.0 mm. with the 36.1 - 40.0 mm. class being the largest. The brown-banded cockroach catch contained two large length classes, 2.5 - 4.0 mm. and 12.5 - 14.0 mm., suggesting two major age classes. Room-to-room movement of cockroaches was limited, and over 93 percent of the catch occurred during the dark hours.

Domestic cockroaches have been the object of considerable research related to methods of control. However, the dynamics of cockroach populations inhabiting buildings has received little attention. The purpose of the present study was to estimate the number of American cockroaches, *Periplaneta americana* (Linnaeus), and brown-banded cockroaches, *Supella supellectilium* (Serville) naturally existing under various environmental conditions in the Science Hall, Iowa State University, and gain general information on their population dynamics. Mark-and-recapture methods for obtaining these data were a main consideration of this study.

MATERIALS AND METHODS

This study was conducted on the ground floor of the Science Hall with cockroach populations from four rooms and a hallway being studied. Cockroaches were live-trapped, anesthetized, identified, sexed, measured, marked and released at the point of capture. From the data gathered, estimates of population number, length-frequencies, sex ratios, movement, and activity patterns were made.

Description of the Study Areas. Populations were studied in the pheasant room (76), research room (65), fish room (58), limnology room (52), and a connecting hallway. Further description of each of these areas follows:

Pheasant Room (76). This room was used for holding living pheasants. It contained a sink on one wall and racks of pheasant cages against two other walls. Uncovered bags and barrels of feed were readily accessible to cockroaches. Illumination of the room was con-

[1]Department of Zoology and Entomology, Iowa State University, Ames, Iowa 50010.

trolled by a timer so that the room was illuminated for 12 hours and dark the remainder of each day. The room normally received little human disturbance.

Research Room (65). Two-thirds of this room was equipped as a laboratory; the remaining one-third of the room was partitioned off into three offices. The room received considerable human disturbance from 8:00 a.m. to 11:00 p.m., with lights being on between these hours and off at other times. There was no large food source, but several people ate lunch in this room each day and food was probably inadvertently made available to the cockroaches.

Fish Room (58). One-half of this room was taken up by five large fish-holding tanks which line the walls and extend out toward the center of the room. Four barrels of fish feed were kept covered, but were still accessible to the cockroaches. A sink, cabinet, freezer, and shelves containing miscellaneous equipment occupied the remainder of the room. The lights in this room were timed to be on from 8:00 a.m. to 8:00 p.m. and off the remainder of each day. The room normally received little human disturbance.

Limnology Room (52). Two-thirds of this room was occupied by shelving extending from the walls out toward the center of the room and from the floor nearly to the ceiling. These shelves contained jars and crocks of preserved fish as well as miscellaneous equipment. The remainder of the room served as a limnology laboratory and an office area. The room received periodic disturbance between the hours of 8:00 a.m. and 3:00 a.m. with lights being turned on and off many times between these hours. There was no large food source in this room. (It should be noted that this room served as the laboratory during this study and that lights were frequently on and the room used nearly 24 hours a day during this study.)

Hall. The area of hallway studied runs from Room 52 to Room 76 making four right-angle turns between. The hallway was occupied by several large storage cabinets and several large display cases. In addition to the four rooms involved in this study, 13 other rooms opened into the hallway within the boundaries included in this study. These additional rooms were six offices, four maintenance rooms, one darkroom, one teaching room, and one museum. Three exits also opened into this area. Hall lights were generally on from 7:00 a.m. to midnight. There was no large food source in the hallway, which was sprayed periodically for cockroach control.

Design of Trap and Method of Trapping. The cockroach trap was constructed by taping a lightweight cardboard funnel in an inverted position inside the opening of an eight-ounce baby-food jar. A polyethylene cap, covered with fiberglass screen, served as the bait container. Seventy-five such traps were used in this study.

Traps were baited with honey, bananas, sardines, or candy and distributed throughout the study areas. Traps were placed on the floor, tables, desks, sinks, and shelves in about equal numbers. The limnology, fish, and research rooms were equipped with 15 traps each while the hall was set with 20 traps and the pheasant room with 10 traps.

All traps were checked several times throughout the day. Checks were usually made during the following hours: 8 - 10 a.m., 3 - 5 p.m., 9 p.m. - midnight, and 1 - 4 a.m., C.S.T. In addition to the cockroaches caught by traps in the pheasant room, many were caught by hand. Trapping was begun December 19, 1967, and discontinued January 4, 1968.

Marking and Handling. Traps with cockroaches were covered with a standard baby-food jar lid and carried to the laboratory. A 24-slot pop bottle case served as a handy trap container for transport. In the laboratory the trap funnel was flipped open and the jar inverted over a similar jar equipped as an etherizer. Cockroaches were quickly anesthetized and could be readily handled. A stereoscopic microscope was used to observe the cockroaches while identifying, sexing, measuring, and marking. Each cockroach was measured to the nearest 0.5 mm. and marked with a dot of paint on the prothorax. Cockroaches below 3.5 mm. were not marked, but were counted and measured for length frequency analysis. Cockroaches from each area were marked with a distinct color: limnology room—yellow; fish room—green; research room—red; pheasant room—white; hall—blue.

Population Estimation. Population estimates were made with the multiple census method described by Schnabel (1938).

$$N = \frac{\Sigma\ (C_t\ M_t)}{\Sigma\ R_t}$$

where:

N = population estimate.

M_t = total marked cockroaches at large at the start of the t^{th} day (i.e., the number previously marked less any accidentally killed at previous recaptures).

C_t = total sample taken on day t.

R_t = number of recaptures in the sample C_t.

As a check on the Schnabel estimate, a second estimate was made using the method described by Chapman (1952, 1954).

$$N = \frac{\Sigma\ (C_t\ M_t)}{(\Sigma\ R_t) + 1}$$

Both of these methods have been widely used in estimating fish populations and are discussed in Ricker (1958). The Chapman method was proposed since the Schnabel method is believed to yield slightly high estimates (Ricker, 1958).

Certain basic assumptions must be true before marking and recovery methods can be used to estimate total populations (Ricker, 1958).

1. Marked individuals must become randomly distributed throughout the population.
2. Marked individuals are as vulnerable to the sampling methods as the unmarked.
3. The marked individuals suffer no greater mortality than the unmarked.
4. Marked individuals do not lose their marks.
5. All marks are recognized and reported on recapture.
6. Recruitment to the population is negligible during the time recoveries are being made.

It was believed that all these assumptions were met in the present study. To meet the first assumption, cockroaches were trapped throughout the room and released at the point of capture. There was sufficient time between trap checks to allow them to recover from anesthesia and disperse. There was no indication that previously trapped cockroaches avoided traps or were trap prone (assumption 2). As a check on assumptions 3, 4, and 5, 30 brown-banded cockroaches of various sizes were trapped, marked and held in captivity for nearly four weeks without mortality or loss of mark. After four weeks, there was one lost mark; after five weeks, three more lost marks; after six weeks, two lost marks and two deaths; and after eight weeks, two more lost marks. In addition, six American cockroaches were held for six weeks without loss of mark or mortality. Since each cockroach was examined under a stereoscopic microscope there was little chance of overlooking a mark. The fact that only cockroaches above 3.5 mm. were used in population estimates and that the study was run for only 16 days helped meet the last assumption concerning recruitment to the population. There was, however, some movement of cockroaches from one area to another as indicated by recapture data. This movement was quite limited and was not believed to have greatly affected the population estimates.

Confidence limits for the population estimates were established by substituting the Poisson or binomial limits for R in each of the above formulae.

Population estimates for brown-banded cockroaches included only those above 3.5 mm. in length while estimates for American cockroaches included the entire population (no American cockroaches below 12.0 mm. were caught).

Estimates for each room included only the recaptures displaying

the proper color for that particular room. An estimate for the entire study area, however, included all cockroaches regardless of color of mark.

Results

Population Estimates. The trap and methods employed in trapping were successful in obtaining cockroaches. As many as 16 cockroaches were caught in one trap during one set. Table 1 presents the totals for catch, marks, and recaptures for each area.

Schnabel and Chapman population estimates are given in Table 2. Population estimates were made for brown-banded cockroaches in each area plus American cockroaches in Room 76. An estimate for the entire area studied is also included.

Rooms 76 and 58 had the largest cockroach populations. As previously described, these rooms had large quantities of available food, especially Room 76. In addition, illumination in these rooms was controlled by timers and a uniform 12-hour cycle was maintained.

Table 1

Total Number of Brown-Banded Cockroaches Caught, Marked, and Recaptured in Each Area Studied[1]

Room	Total Number Caught	Total Number Marked	Total Number Recaptured[2]
65	83	70	10
Hall	100	63	28
58	92	63	7
76	436	307	37
76[3]	65	55	9
52	46	38	5

[1]Includes cockroaches above 3.5 mm. in total length.
[2]Recaptures for each room include only those marked with appropriate color for that room.
[3]American cockroaches.

A comparison of densities in numbers per square foot of floor space is presented in Table 3. The large populations of Rooms 76 and 58 are again evident, with the density of Room 76 being even more clearly displayed. Population density was lowest in Room 52 which had the largest amount of habitat area and cover, but probably the least amount of food.

Table 2

Cockroach Population Estimates and Confidence Limits of All Areas Studied

Room	Schnabel Estimate	Confidence Limits (95%)		Chapman Estimate	Confidence Limits (95%)	
65	215	104	538	188	95	443
Hall	126	86	190	121	84	182
58	429	209	1,073	375	190	883
76	988	767	1,388	971	756	1,360
76[1]	118	56	240	96	52	204
52	117	50	366	97	45	266
Entire area	1,617	1,339	2,040	1,602	1,328	2,019

[1]American cockroaches. All other estimates are for brown-banded cockroaches.

Table 3

Square Feet of Floor Space and Number of Cockroaches per Square Foot for the Four Rooms Studied

Room	Area in Square Feet	Number (Chapman Estimate)	Number per Square Foot
65	387	188	0.49
58	331	375	1.13
76[1]	80	1,089	13.61
52	679	97	0.14

[1]Includes both American cockroaches and brown-banded cockroaches. All other estimates are for brown-banded cockroaches only.

Movement. A total of 10 cockroaches (all brown-banded) were captured in an area other than the one in which they were marked (Table 4). One cockroach moved from Room 58 to Room 65 (45 feet), but all other movement was either from the hall into a room or from a room into the hall. Cockroaches moved from the hall into all rooms studied except Room 76 which had the highest population pressure. Only one cockroach moved out of Room 76, and it was captured just outside the door.

The numbering of traps allowed for study of habitat preference within each room. There did not appear to be any favoring of traps and cockroaches were caught in fairly equal numbers throughout each room.

Table 4

Cockroach Movement Between Areas Studied

		Out Of				
	Room	65	Hall	58	76	52
In To	65	—	1	1	0	0
	Hall	0	—	2	1	2
	58	0	1	—	0	0
	76	0	0	0	—	0
	52	0	2	0	0	—

Activity. The fact that cockroaches are nocturnal was substantiated in this study. Over 93 percent of the cockroach catch occurred during the dark hours.

Sex Ratio. Sex ratios were calculated using only the mature population of American cockroaches and only brown-banded cockroaches 8.0 mm. or longer since these were most easily sexed.

In the American cockroach, a female-to-male ratio of 0.6 was found using all of the cockroaches collected and marked in the study. Sex ratios for all five study areas were calculated for the brown-banded cockroach and ranged from 1.9 (19 females and 10 males) in Room 52 to 0.6 (16 females and 25 males) in Room 58. Table 5 shows number of females and males along with a ratio for each room. A sex

ratio of 0.8 was figured using the total data collected (479 cockroaches) except those hand caught in Room 76.

In both species, males always outnumbered the females—the total sex ratio of brown-banded cockroaches was 0.8 while that of the American cockroach was 0.6. It should be noted that the sex ratios for the different species using the hand-caught and trap-caught samples of Room 76 were almost identical.

Table 5

Number of Males and Females, and Sex Ratios for Each Area Studied

	Brown-banded (8 - 18 mm.)			American (mature)		
Area	Number Females	Number Males	Ratio	Number Females	Number Males	Ratio
Room 65	29	41	0.7	0	1	—
Hall	29	28	1.0	0	0	—
Room 58	16	25	0.6	0	0	—
Room 76	151	197	0.8	16	24	0.7
Room 76 Hand Caught	28	38	0.7	16	21	0.8
Room 52	19	10	1.9	0	0	—
Total[1]	244	301	0.8	16	25	0.6

[1]Total includes all cockroaches except those caught by hand.

Length Frequency. In both species, there was a trend toward greater numbers of older individuals. The brown banded cockroach population exhibits a bimodal age class structure.

American Cockroach. The maximum length was found to be 39.0 mm. while the female maximum was 39.5 mm.

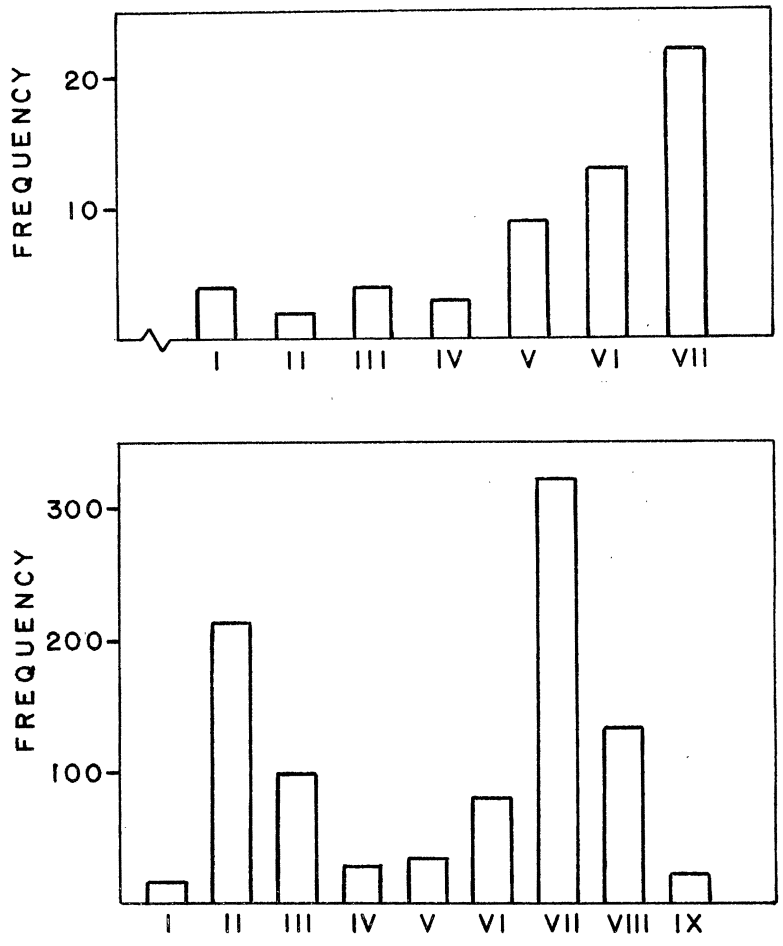
Figure 1(A) shows that the majority of the population studied was composed of larger and presumed older individuals. No individuals below 12.0 mm. were caught during the 16-day study.

Brown-banded Cockroach. Males of this species obtained a maximum length of 17.5 mm., but no females over 17.0 mm. were found.

Size group II was the predominant size group for Rooms 58, 52, and the Hall. Rooms 65 and 76 showed group VII to be the largest. The combined data for all the study areas (Figure 1(B)) indicated group VII the most predominant followed by group II. As was the case in the American cockroach population, the brown-banded population consisted mostly of older individuals.

Discussion

The use of mark and recapture methods appears to have merit for estimating populations of cockroaches. Cockroaches were readily trapped, anesthetized, identified, measured, sexed, marked, and released for subsequent recapture to yield useful information. Laboratory experiments indicated that these procedures did not impose a selective mortality and marks were held for at least four weeks.



No.	Length (mm.)
I	12.0 - 16.0
II	16.1 - 20.0
III	20.1 - 24.0
IV	24.1 - 28.0
V	28.1 - 32.0
VI	32.1 - 36.0
VII	36.1 - 40.0

No.	Length (mm.)
I	< 2.0
II	2.5 - 4.0
III	4.5 - 6.0
IV	6.5 - 8.0
V	8.5 - 10.0
VI	10.5 - 12.0
VII	12.5 - 14.0
VIII	14.5 - 16.0
IX	16.5 - 18.0

Figure 1. Length-frequency histogram for the American cockroach (A) and the brown-banded cockroach (B) using all data collected.

Food appeared to be the limiting factor in determining the size of cockroach populations studied as a room with the largest amount of available food had the highest population. The other rooms followed

the same pattern, with populations decreasing with decreasing amounts of available food. Although regularity of light-dark periods and human disturbance may have played a part, space and cover did not seem to be as important. Moisture and temperature were fairly constant in all areas.

Length-frequency analysis of brown-banded cockroaches for the entire study area indicated two large peaks, possibly corresponding to two large age classes. Since both small (2.5 - 4.0 mm.) and large (12.5 - 14.0 mm.) were caught in large numbers, the trap did not appear to be selective for size.

Room 76 seemed to support a mature cockroach population while Room 58 had a young or expanding population. The fact that Room 76 had a large food supply for a considerably longer period of time than Room 58 offered some explanation for this observation.

Maximum lengths for both of the species were above those lengths reported by other authors (Helfer, 1963; Mallis, 1960). All measurements were made with the cockroach anesthetized and laid out completely flat. The usual position of the cockroach is with the head bowed beneath the forepart of the prothorax.

Movement of brown-banded cockroaches between rooms, as measured by recaptures, was limited although one did move a considerable distance. No such American cockroach movement was observed. Jockson (1961), however, found that American cockroaches migrate a considerable distance in moving from sewer manholes into buildings.

In all the areas studied, there were more males than females caught. Gould and Deay (1940) found that numbers of the two sexes under natural conditions varied from season to season. They found a ratio of 0.5 (87 females and 162 males) involving a population of American cockroaches. A month later the ratio had changed to 5.3 (74 females and 14 males). Laboratory-reared cockroaches usually had equal numbers of males and females. A comparison was made between the trap-caught sex ratio and a hand-caught ratio in Room 76. The trapped ratio was 0.8 (151 females and 197 males) while the hand-caught ratio was 0.7 (28 females and 38 males). Nearly complete agreement of ratios for this room suggested that there was no trap selectivity between sexes. The activity patterns of the two sexes seemed to be of a similar nature with both entering the traps in the same proportion.

ACKNOWLEDGMENTS

The authors express appreciation to Doctors Kenneth D. Carlander, Jean L. Laffoon, and Larry P. Pedigo for their critical review of the manuscript.

Literature Cited

Chapman, D. G. 1952. Inverse, multiple and sequential sample censuses. Biometrics, 8:286-306.

———. 1954. The estimation of biological populations. Ann. Math. Statistics, 25:1-15.

Gould, G. E., and H. D. Deay. 1938. The biology of the American cockroach. Ann. Ent. Soc. Amer. 31:489-498.

Helfer, J. R. 1963. How to know the grasshoppers, cockroaches and their allies. Wm. C. Brown Co. 353 pp.

Jockson, W. B. 1961. Additional studies of dispersion patterns of American cockroaches from sewer manholes in Phoenix, Arizona. Ohio Jour. Sci. 61(4):220-226.

Mallis, A. 1960. Handbook of pest control. 3d ed. MacNair-Dorland Co. New York. 1132 pp.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull 119. 300 pp.

Schnabel, Z. E. 1938. The estimation of the total fish population of a lake. Amer. Math. Monthly. 45(6):348-353.

