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PERMANENT TRAPS FOR MONITORING BUTTERFLY MIGRATION: TESTS IN FLORIDA, 1979–84

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ABSTRACT. Three models of a flight trap made principally of hardware cloth were tested at Gainesville, Florida. All models had a 6 m long central barrier of ½ inch mesh hardware cloth. Butterflies encountering opposite sides of the barrier were trapped separately, allowing calculation of net movement up or down the Florida peninsula. The most efficient model has a barrier 3.7 m high and a two-stage trapping superstructure of ¼ inch hardware cloth. It catches 22–70% of migrant *Phoebis sennae, Agraulis vanillae,* and *Urbanus proteus.*

Migrating butterflies characteristically fly in a straight line a few meters above the ground and rise and fly over obstacles rather than deviating laterally (Williams, 1930). Beginning in 1975, I have used stationary flight traps that intercept and trap migrant butterflies at Gainesville, Florida (Walker, 1978, 1980; Walker & Riordan, 1981). My first traps were made of polyester, which ripped in strong winds and deteriorated in sunlight. They consequently required frequent repair and annual replacement. Furthermore, they lost about 90% of the migrants they intercepted.

In this paper I describe the development of a hardware-cloth trap that will work for years without repair and that promises, with specified improvements, to catch more than 70% of the migrants that encounter it.

THE TRAPS

Three models of permanent flight traps were tested. All resembled the polyester traps in having a 6 m long central barrier oriented ENE–WSW (perpendicular to the Florida peninsula) and a holding device at either end. All kept the butterflies that had encountered the barrier from the migratory direction ±90° separate from those that had encountered it from the opposite direction ±90°.

Model #1. The first trap (Fig. 1, right) was constructed during February 1979 in a pasture with scattered trees, northwest of Gainesville (NW¼, sec. 31, tp. T9S, R19E). The central barrier was of ½ inch hardware cloth attached to three pressure-treated "4×4" posts (i.e., 9 × 9 cm). The roof, also of ½ inch hardware cloth, was 1.2 m from ridge to eave and was fastened laterally and medially to treated "2×4's" (4 × 9 cm). Its ridge slanted upward from the center post (3.4 m high) to either end post (4.0 m), in imitation of a polyester trap (see fig. 1 of Walker, 1978). The roof sloped 30° toward its eaves. Migrant but-

FIG. 1. Models #3 (**left**) and #1 (**right**) of a permanent flight trap for migrating butterflies.

terflies were to encounter the central barrier, be detained between the roof and the barrier, and work their way upward to the nearest end. There they were to continue upward through an 8 × 24 cm opening, through an immovable hardware cloth "valve," and into a holding cage of plywood and ¼ inch hardware cloth. Watching migrants encounter model #1, I discovered that most individuals shunned the offered openings and instead flew out and over the roof or around the end "wall" (i.e., panels of ½ inch hardware cloth that extended 1.2 m from either end of the central barrier and perpendicular to it).

Model #2. During August of 1983 I constructed a second trap immediately ENE of the first. It differed from model #1 in having a 13 cm slot along the entire upper edge of each roof panel. These slots gave access to a longitudinally partitioned 6.0 × 0.4 × 0.4 m duct of ¼ inch hardware cloth that prevented the butterflies' escaping as they worked their way to either end of the trap, through hardware cloth valves and into holding cages. The central barrier was rectilinear and 3.7 m high. The roof ridge was made straight and the roof slope was reduced to 15°—making the eaves 3.4 m high. Although model #2 caught substantially higher proportions of migrants than model #1, most migrants were hesitant to fly through the 13 cm slots and would, instead, hover under the roof and eventually escape.

Model #3. During February 1984 I greatly improved access to the longitudinal duct, thereby converting model #2 to model #3. The width of the roof slots was increased more than threefold to 45 cm and a sharply sloping upper roof of ½ inch hardware cloth was interposed between the duct and each main roof (Fig. 1, left; Fig. 2). The hard-

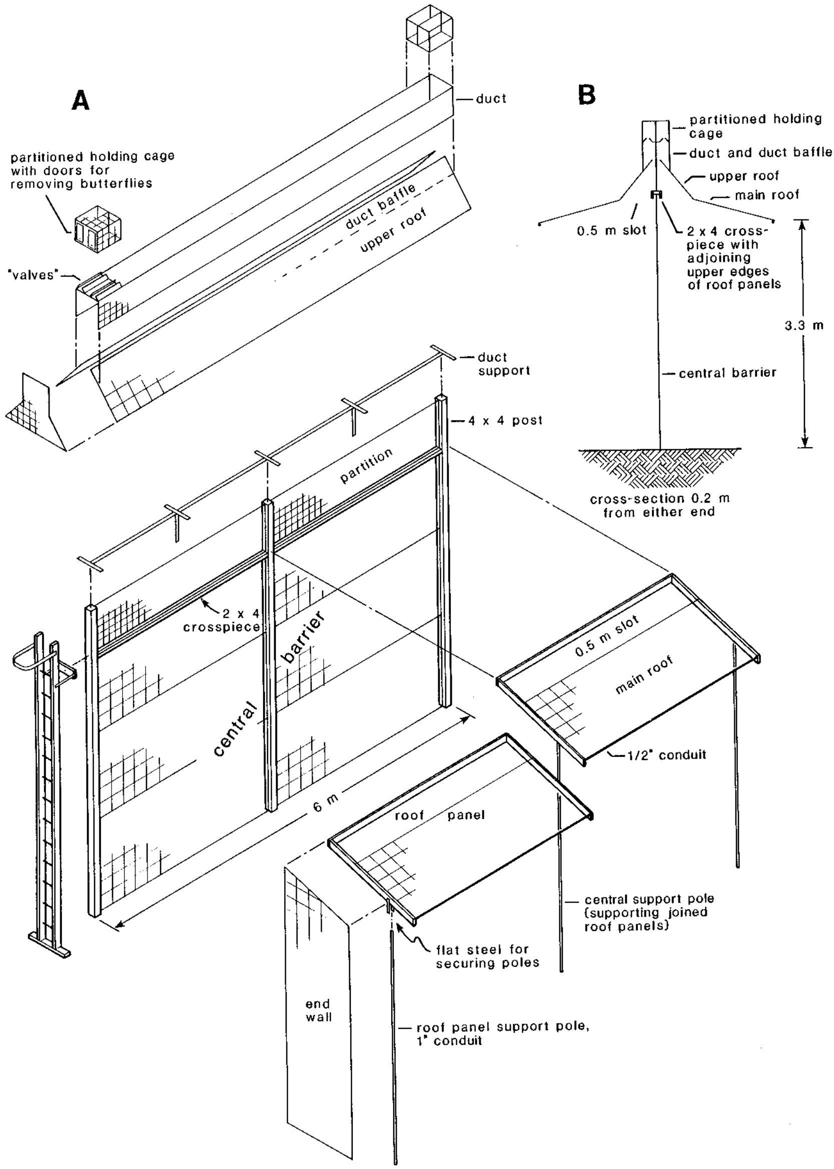

FIG. 2. Model #3 permanent flight trap: **A,** exploded diagram; **B,** cross section. (Drawings by S. A. Wineriter)

TABLE 1. Migration of four species of butterflies as revealed by 6 m, permanent flight traps at Gainesville, Florida, 1979–1984.

Trap Year	Net northward spring migration[a]				Net southward fall migration[b]			
	P. sen.	*A. van.*	*J. coenia*	*U. prot.*	*P. sen.*	*A. van.*	*J. coenia*	*U. prot.*
Model #1								
1979	0	1	185	0	157	22	2	13
1980	3	0	13	0	69	12	1	5
1981	2	0	44	0	263	26	6	1
1982	7	2	85	0	126	15	22	24
1983	2	0	4	0	54	7	−1	0
1984	1	1	27	0	92	10	−3	0
Model #2								
1983	—	—	—	—	86	157	21	55
Model #3								
1984	6	6	252	−1	548	326	62	531
Sum	21	10	610	−1	1395	575	110	629
Consistency[c]	96	92	96	33	91	94	72	99

[a] Number trapped on south side of barrier minus number trapped on north side of barrier (1 March to 22 May).
[b] Number trapped on north side of barrier minus number trapped on south side of barrier (1 Sep. to 30 Nov.).
[c] Percent of total trapped that were flying in the migratory direction (viz. southward in the fall, northward in spring).

ware cloth of the 50 cm upper roof extended as a baffle 25 cm into the duct, thereby impeding the escape of migrants from the duct (Fig. 2B). (Building a #3 trap is described in the appendix.)

THE CATCHES

At least seven species of butterflies migrate southward through Gainesville each fall: *Phoebis sennae* (L.), *Agraulis vanillae* (L.), *Junonia coenia* Hübner, *Urbanus proteus* (L.), *Panoquina ocola* (Edwards), *Lerema accius* (J. E. Smith), and *Eurema lisa* (Boisduval & LeConte) (Walker, 1978, 1980, 1985). Only the first four will be dealt with here, because they were captured in the largest numbers.

As reported previously (Walker, 1980), the direction of net movement of these species at Gainesville is down the peninsula in the fall and, for the first three species, toward Georgia in the spring (Table 1). Net numbers trapped flying northward in spring (1 March to 22 May) for the six years varied from −1 for *U. proteus* (viz., 1 northward, 2 southward) to 610 for *J. coenia*. Net numbers trapped flying southward in fall (1 Sep. to 30 Nov.) varied from 110 for *J. coenia* to 1395 for *P. sennae*. With the exception of *U. proteus* in spring and *P. coenia* in fall, more than 90% of migrants trapped were captured flying in the seasonally appropriate direction (Table 1).

Trapping efficiency of models #1 and 3 was studied during October 1984. During the five observation periods of 3 hours or more, model

TABLE 2. Absolute trapping efficiency of model #3 of a permanent trap for sampling migrating butterflies.

Date (1984)	Time (EDT)	*P. sennae* Capt./cand.[a]	*P. sennae* %	*A. vanillae* Capt./cand.	*A. vanillae* %	*U. proteus* Capt./cand.	*U. proteus* %
4 Oct.	1251–1551	16/25	64	6/11	55	15/25	60
5 Oct.	0917–1217	14/17	82	3/7	43	11/23	48
5 Oct.	1306–1606	8/12	67	0/6	0	9/19	47
11 Oct.	1238–1600	12/18	67	4/13	31	3/10	30
12 Oct.	1100–1400	8/24	33	5/15	33	3/7	43
All observations		58/96	60	18/52	35	41/84	49
95% C.I.[b]			49–70		22–50		38–60

[a] Number of migrants *captured* during observation period/number of *candidate* migrants (i.e., southward flying individuals that would have flown over the 6-m, ENE–WSW line at the base of the trap's central barrier had the trap not been in place).
[b] Based on binomial distribution.

#3 caught an average of 60% of candidate *P. sennae*, 35% of *A. vanilla*, and 49% of *U. proteus* (Table 2). Model #1 caught 13% of candidate *P. sennae* (13 of 98) but 0 of 44 *A. vanillae* and 0 of 55 *U. proteus*.

Because the traps sample adjacent 6 m cross sections of migrants, it is likely that season-long differences in their catches are due principally to differences in trapping efficiency and that differences in numbers of potential captives are minor or lacking. Confirming this conjecture is the fact that numbers of *P. sennae* and *A. vanillae* observed during 15+ hours of watching were 98 and 44 for model #1 and 96 and 52 for model #3. (Numbers of *U. proteus* were more discrepant for the two traps, 55 and 84, but these butterflies are relatively small, dark, and fast, making it likely that some escaped notice—which, in turn, makes it likely that 49% overestimates the proportion of this species trapped.) Table 3 compares catches of models #2 vs. 1 during fall of 1983 and catches of models #3 vs. 1 during all of 1984.

By using the absolute trapping efficiencies in Table 2 and the relative trapping efficiencies in Table 3, the numbers of fall migrants in Table 1 were converted to estimates of total fall migration across each ENE–WSW meter (Table 4). (All traps were oriented ENE–WSW—perpendicular to the axis of the Florida peninsula.)

DISCUSSION

Further improvements. The model #3 flight trap caught far higher proportions of the migrant butterflies that encountered it than did earlier polyester or hardware cloth traps (Table 3). However, its absolute efficiency was still less than 70% (Table 2). Two easy-to-make changes promise to improve its performance substantially. The first

TABLE 3. Relative trapping efficiency of models #1, 2, and 3 of a permanent trap for migrating butterflies.

Species of migrant	Model 2 vs. 1		Model 3 vs. 1		Model 3 vs. 2
	Numbers[a]	Ratio	Numbers[b]	Ratio	Ratio[c]
P. sennae	86 vs. 54	1.6	554 vs. 93	6.0	3.7
A. vanillae	157 vs. 7	22.4	332 vs. 11	30.2	1.3
J. coenia	21 vs. −1	—	314 vs. 24	13.1	?
U. proteus	55 vs. 0	—	530 vs. 0	—	?

[a] Net numbers of migrants caught by models 2 and 1 during fall 1983.
[b] Net numbers of migrants caught by models 3 and 1 during spring and fall 1984.
[c] Calculated by using model 1 as the standard.

change concerns the fact that some migrants refused to fly upward into the longitudinal duct. The refusal of some of these migrants probably resulted from their view of the sky being partially blocked by 6 m of 2×4 that supported the duct. A less sky-blocking support (e.g., a 3 × 3 cm steel angle) should be substituted. The second change concerns the fact that most of the migrants that escaped did so by flying around the end walls. (Specifically, 67 of the 115 escapees in Table 2 left the trap within 10 seconds by flying around the end wall.) The end walls could be extended to 2.4 m making lateral escape much less likely.

Uses. Permanent flight traps can monitor butterfly migrations continually, and they can provide information about migrations so sparse that they cannot be directly observed. The data in Tables 1 and 4 (and unpublished data on other species) illustrate these uses. Permanent flight traps also provide a convenient means of collecting large numbers of live migrants for studies of morphology, physiology, sex ratios, mating status, behavior, etc.

Traps with other uses. The great improvement in efficiency of the model #3 over the model #1, which copied the design features of the original polyester trap (Walker, 1978), suggests that a much improved, portable, polyester trap might be made by copying the design features

TABLE 4. Fall migration (net no. flying southward across each ENE–WSW meter) as estimated by permanent flight traps, Gainesville, Florida, 1979–1984. (Numbers captured are in Table 1; trapping efficiencies based on Tables 2 and 3. Estimates for 1983 and 1984 are from catches of models #2 and 3, respectively.)

Species	Year					
	1979	1980	1981	1982	1983	1984
P. sennae	262	115	438	210	88	152
A. vanillae	316	173	374	216	97	155
U. proteus	—	—	—	—	—	181

of the model #3 permanent trap. Furthermore, traps half as long should catch much larger numbers of migrants than did the original 6 m polyester traps. (A similar shortening is also an option for permanent traps and would reduce costs for materials ca. 30%.)

An important limitation for all flight traps yet used to study butterfly migration is that they distinguish migratory directions only crudely. This limitation could be overcome by constructing an octagonal trap having eight identical openings leading to eight holding cages, thereby separating migratory directions at 45° intervals rather than the 180° intervals of the present traps.

The permanent traps built thus far capture migrants alive and, therefore, require daily servicing. Traps could be run at remote locations, or at near locations with reduced service time, if the holding cages were modified to kill and preserve the migrants captured. For example, dichlorvos-impregnated plastic could be used to cause the captives to drop into containers of dilute formalin.

Finally, devices could be substituted for the holding cages that would automatically mark the butterflies with fluorescent pink paint and allow them to continue their migratory flights—to be caught, perhaps, by downstream traps. (If such devices seem far-fetched, see Wolf and Stimmann, 1972.)

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APPENDIX

This appendix describes the main steps in building a model #3 permanent flight trap. It omits details that can be improvised by anyone with experience in light construction. The present model #3 was built by modifying a model #2, but the following steps describe how to build one from scratch. Materials for one trap now cost ca. $500.

1. Central supports. Lay out a 6 m line perpendicular to the migratory direction. At each end and at the center of the line set a post (e.g., an 18′ treated 4×4) so that 4.4 m extends vertically from the ground. Connect the posts at 3.7 m with treated 2×4's (to which the main roof panels will be attached).

2. Superstructure. Prepare a support for the duct by attaching 3⁄16″ × 1″ × 0.4 m cross pcs. of flat steel at the ends and at 1.5 m intervals along one flat surface of a 6.0 m pc. of ⅛ × 1¼ × 1¼″ steel angle. Attach the steel angle, cross pcs. up, to the tops of the main posts. Affix a 0.7 m vertical support for the steel angle midway between each pair of main posts. Install two 3.0 × 0.7 m vertical partitions of ¼ inch hardware cloth, attaching the top edges to the steel angle, the ends to the posts, and the bottom edges to the 2×4 cross pcs. Make a three-sided square duct by bending lengthwise a 6.0 × 1.2 m pc. of ¼ inch hardware cloth at 0.4 and 0.8 m. Invert the duct over the duct support and attach a 6.0 × 0.75 m pc. of ½ inch hardware cloth to each lower edge of the duct in such a fashion that the lower 50 cm of width can become upper roof and the upper 25 cm of width can become duct baffle (Fig. 2).

3. Main roof panels. Build four roof panel frames of treated wood and steel tubing, each consisting of a 2 × 4 × 1.7 m (outer rafter; make 2.5 m if end wall is to be 2.4 m), a 1 × 4 (=2 × 9 cm) × 3.0 m (upper edge), a 1 × 4 × 1.7 m (inner rafter), and a 3.0 m pc. of ½″ electrical conduit (lower edge). Cut upper ends of rafters at 75°. Attach a 1.2 × 3.0 m pc. of ½ inch hardware cloth to each roof panel with one edge riveted to the conduit, leaving a 0.5 m slot between the hardware cloth and the upper edge of the panel frame. Attach each roof panel by its upper edge to one of the 2×4 cross pcs. Support the rafters at ca. 1.2 m with poles that position the eaves at 3.3 m. (Make poles of 2 pcs. of 1″ electrical conduit joined by driving them over opposite ends of a short pc. of ¾″ galv. pipe.) Bolt together the inner rafters of adjacent roof panels. Attach the lower edge of the secondary roof to the upper edge of the main roof.

4. Central barrier and ends. Attach the central barrier of three 6.0 × 1.2 m pcs. of ½ inch hardware cloth to the main support posts. Close the ends of the duct and the secondary roof with ¼″ hardware cloth. Make the end walls by attaching 1.2 m wide pcs. of ½″ hardware cloth to the end posts, the outer rafters of the roof panels, and the roof support poles. (If the end walls are to be 2.4 m wide, install another pole 1.2 m beyond each existing end-rafter support pole.)

5. Attachments. Construct two 4.4 m ladders using treated 2×4's as side pieces and 1″ electrical conduit as rungs. Install one ladder 0.3 m away from each end post. At the top of each ladder secure a safety loop of ⅛ × 1″ aluminum (to enable one to use both hands in servicing the trap). Make hardware cloth valves by appropriately cutting 15 × 30 cm areas on each side of each end of the top of the duct. Build two partitioned holding cages that will fit over the valves at either end of the duct. Make the doors to the chambers of the holding cages so that they will stay open as butterflies are removed. Install the holding cages—and wait for migrants.

ADDENDUM

During March 1985 the model #1 trap was razed and in its place an improved model #3 trap (i.e., a model #4 trap) was built using the directions given above—except that the main roof was made horizontal, thereby, simplifying construction and elevating the duct by 11 cm. The end walls extended 2.4 m from the central barrier. During the period 10 Apr to 29 May 1985, the net numbers of *J. coenia* trapped flying northward were 216 for the model #3 and 302 for the model #4 trap, translating into a 40% improvement in catch.

For the first time *Vanessa virginiensis* Drury was identified as a spring migrant, with 11 trapped flying northward and 2 flying southward (chi-square = 6.23; $P < 0.05$).