COMPARISON OF DRY ICE BAITED LIGHT TRAPS WITH HUMAN BAIT COLLECTIONS FOR SURVEILLANCE OF MOSQUITOES IN NORTHERN QUEENSLAND, AUSTRALIA

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ABSTRACT. Adult mosquitoes were collected from April 1984 to September 1985, at 3 sites at or adjacent to the Ross River Dam, north Queensland. The numbers attracted to dry ice baited encephalitis virus surveillance (EVS) light traps and to human bait were similar. Both methods sampled 18 taxa and ranked the abundances of *Culex annulirostris, Anopheles annulipes s.l., Aedes vigilax, Mansonia uniformis* and *Ma. septempunctata* similarly at each locality. Significant correlations between the 2 methods were found for all 5 of the dominant species, but were stronger for *Ae. vigilax, Ma. uniformis* and *Ma. septempunctata* than for *Cx. annulirostris* or *An. annulipes*. Human bait attracted more *Cx. annulirostris, Ae. vigilax* and *Ma. uniformis* than the EVS traps. The relative effectiveness of the 2 methods varied significantly with time for *Cx. annulirostris* and *An. annulipes*, but both methods revealed similar long term population trends. These data suggest that EVS surveillance may be better suited for sampling *Ae. vigilax*, and human bait (or alternatively animal bait) or a combination of both methods would be more appropriate for sampling *Cx. annulirostris* at the dam.

INTRODUCTION

Human bait catches (HBC) have been reported as the standard and most useful method for collecting host-seeking anthropophilic mosquitoes (Service 1976). However, collectors may risk infection with vector-borne pathogens. Such collections can be used to estimate mosquito pest and disease transmission potential, monitor temporal changes in relative population size and assess the effectiveness of control operations, especially for container breeding *Aedes* in dengue surveillance programs (Goettel et al. 1980). As a tool for surveillance, HBC is limited by differences in collector attractiveness, diligence and ability to catch all species landing. The procedure is labor intensive and often restricted to a short period.

Dry ice supplemented light traps capture a greater number of mosquito individuals and species as compared with human bait, New Jersey light trap and other collection methods used in North America (Newhouse et al. 1966, Acuff 1976, Slaff et al. 1983) and in Australia (Russell 1985). Both Slaff et al. (1983) and Parsons et al. (1974) concluded that dry ice supplemented light traps provided an accurate assessment of mosquito pest problems by reflecting landing counts. Although Acuff (1976) recorded discrepant proportions of *Ae. vexans* (Meigen) and *Ae. trivittatus* (Coq.) in dry ice supplemented CDC light traps vs. 10-min landing rate counts on human bait, he concluded that both supplemented and non-supplemented light traps gave representative samples of mosquito populations.

Our study evaluated the reliability and effectiveness of the dry ice supplemented encephalitis virus surveillance trap (EVS) in comparison with human biting catches for monitoring mosquitoes at the Ross River Dam near Townsville in northern Australia. Five mosquito species—*Culex annulirostris* Skuse, *Anopheles annulipes* Walker, *Mansonia uniformis* Theobald, *Ma. septempunctata* Theobald and *Aedes vigilax* (Skuse)—were selected for evaluation on the basis of one or more criteria: 1) previous records of breeding in the impoundment (Rae 1990, Barker-Hudson et al. 1986), 2) their abundance and pest status to humans, and 3) their potential as vectors (Kay and Standfast 1987).

MATERIALS AND METHODS

Study site description: The Ross River Dam (stage 1) is situated on the outskirts of the twin cities of Townsville and Thuringowa (19°25′S, 146°45′E) in northern Queensland. The dam is approximately 10 km inland from coastal saltmarsh and was constructed in 1973 to augment the water supplies of the 2 cities and for flood mitigation. Further details are given in Kay et al. (1990).

Trap regimen and placement: Mosquitoes were sampled with dry ice baited encephalitis virus surveillance (EVS) light traps (Rohe and Fall 1979) and by human bait collections (HBC), for 2 consecutive nights each month from April 1984 to September 1985.

The EVS traps differed from the original design in that they employed a photosensitive

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Table 1. Mosquitoes captured by dry ice baited EVS traps and human bait collection (HBC) in the Ross River Dam catchment from April 1984 to September 1985.

	Big Bay		Oak Valley		Stanley	
	EVS	HBC	EVS	HBC	EVS	HBC
Ae. alboscutellatus	0	0	0	0	0	1
Ae. alternans	0	0	2	0	0	1
Ae. elchoensis	3	8	2	1	0	1
Ae. kochi	1	0	1	0	3	0
Ae. lineatopennis	0	0	0	1	0	4
Ae. normanensis	3	11	5	36	30	46
Ae. notoscriptus	0	1	22	8	6	9
Ae. vigilax	176	178	67	153	253	535
Ae. vittiger	0	3	5	24	4	25
Ad. catasticta	3	0	109	1	17	0
An. amictus	18	49	7	25	42	33
An. annulipes	3,093	1,738	280	414	126	73
An. bancroftii	47	29	7	0	1	0
An. meraukensis	35	31	2	40	17	20
Cq. nr *crassipes*	20	3	26	0	3	0
Cx. annulirostris	479	756	703	1,307	133	372
Cx. bitaeniorhynchus	5	0	2	0	0	0
Cx. quinquefasciatus	0	0	1	0	1	0
Ma. uniformis	649	948	10	11	1	3
Ma. septempunctata	121	78	10	18	3	3
Ur. nivipes	0	0	0	1	0	0
No. collected	4,653	3,833	1,261	2,040	640	1,126
No. of collections	36	35	36	35	35	35

switch which turned the traps on at dusk and off at dawn. A self-closing gate was incorporated to prevent the escape of trapped mosquitoes from the collection bags. Each trap was operated by 6 rechargeable nickel cadmium "D" size batteries.

The EVS traps were suspended approximately 1 m above ground level. Pairs of EVS and HBC sites were established 30 m apart at each of 3 locations; near the existing water margin of the dam (Big Bay), approximately 2 km from the dam (Oak Valley) and approximately 4 km from the dam (Stanley). The collection sites were dominated by paper-bark trees (*Melaleuca* spp.) at Big Bay, eucalypt woodland at Oak Valley and the introduced chinee apple shrub (*Ziziphus mauritania*)) at Stanley. The density of vegetation varied from lush during the wet summer months, to more open during winter and spring as vegetation either dried out or was burnt off.

Human bait collections were undertaken for 1 h, with the last 50 min in darkness, and were initiated when the EVS traps were self-activated by failing light. One collector employed an aspirator and flashlight with a red filter to capture mosquitoes landing on his clothing and exposed arms and legs. Aspirated mosquitoes were periodically transferred into a holding container. No mosquitoes arrived at the human baits before the EVS traps began operation. The EVS traps operated throughout the night, and mosquitoes gathered were collected within 2 h after sunrise.

Statistical treatment: All counts were transformed to log (y + 1) to stabilize the variance. Regressions were used to examine the capacity of the EVS trap method to predict human biting rates. Fixed factor analyses of variance, using location, sampling time and trap type were used to look for temporal and spatial variation in the relative effectiveness of the 2 collection methods. These methods were used to examine total species counts and for each of the 5 dominant species separately. In the analyses of variance, we were looking for interaction effects involving trap type: that is, for any indications that the relative effectiveness of the 2 trapping methods differed between locations or between monthly sampling periods. The existence of interactions of this kind compromises the reliability of the EVS trap as an index of the abundance of mosquitoes that impact on human populations.

RESULTS

The 2 trapping methods sampled similar numbers of mosquitoes (Table 1). The EVS trapping collected an average of 61.3 per trap night, and HBC, 66.7 per hour of collection effort. Both methods sampled 18 species and gave the same rank order of abundance for the 5 numerically dominant species (*Ae. vigilax*, *An. annulipes*, *Cx.*

annulirostris, Ma. uniformis and *Ma. septempunctata*) at each site. There were several less abundant species that were sampled predominantly by the EVS trap. These were species either for which humans are not a preferred host (*Aedeomyia catasticta* Knab, *Coquillettidia sp.* near *crassipes* Van der Wulp, *Cx. bitaeniorhynchus* Giles), or species unlikely to breed in the dam and sampled in numbers too low for meaningful comparisons between trapping methods (e.g., *Ae. kochi* Dönitz, *Cx. quinquefasciatus* Say).

A regression of human bait catch per trap-night on EVS catch per trap-night for all species combined showed a significant relationship, but it was evident from Fig. 1 that overall biting rates in any single sampling period would be predicted only very imprecisely from the concurrent EVS catch.

Culex annulirostris: Analysis of variance results (Table 2) demonstrated that location, sampling time and trap type all affected the number of *Cx. annulirostris* captured (human bait caught significantly more individuals than the EVS trap). There was a significant time*trap interaction: i.e., the relative effectiveness of the 2 trapping methods was not constant throughout the study.

This interaction arose because several peaks in abundance shown by the human bait catch (notably in February 1985 and June 1985) were not detected by the EVS trap (Fig. 2). Consequently, the correlation between the 2 methods was relatively weak (Fig. 1).

Aedes vigilax: *Aedes vigilax* showed a strong correlation between sampling methods (Fig. 1), but with one major outlying point, again in February 1985 (Fig. 2). Sampling time had a much greater effect on abundance than either location or trap type (Table 2). There also was a location*time interaction, due to a major September peak in abundance at Big Bay (detected by both trapping methods) which did not occur at either of the other 2 sites (Fig. 2). Human bait collections did not show consistently higher catches than the EVS traps.

Anopheles annulipes: As with *Cx. annulirostris*, the correlation between the 2 sampling methods was significant but relatively weak (Fig. 1). There were several interactions involving trap type (Table 2), indicating that the relative effectiveness of the 2 trapping methods varied unpredictably with both time and place. We suggest that this is mainly due to the relatively low numbers of *An. annulipes* collected per comparison at Oak Valley and Stanley (Fig. 3). At Big Bay, where *An. annulipes* abundance was higher, the temporal pattern was similar for both trapping methods.

Mansonia *species: Mansonia septempunctata* and *Ma. uniformis* were collected early in the study in substantial numbers only at Big Bay. The data available for comparison of sampling methods were therefore quite limited. However, the correlation between EVS catch and human bait catch (Fig. 1) is strong for both species. In addition, both sampling methods reflected similar abundance patterns over time (Fig. 3). Catches of *Ma. uniformis* were higher from human bait than from EVS traps. For *Ma. septempunctata* there was no significant difference in the numbers caught by either method.

DISCUSSION

This is the first long-term study carried out in Australia designed to compare the relative usefulness of CO_2 supplemented EVS traps with human bait collections for: 1) indicating general seasonal patterns of abundance, 2) identifying short-term pest problems, and 3) arbovirus surveillance and predicting epidemics of arthropod-borne disease. In urban California, this third goal seems to have been achieved for Western equine encephalomyelitis and St. Louis encephalitis incidence using the relatively inefficient New Jersey light trap (Olson et al. 1979).

Our data over 18 months in the Ross River Dam environs near Townsville clearly demonstrate correlations (range of r values 0.61–0.92) between the numbers of adult mosquitoes collected by EVS trap and by human bait collection. The correlation was better for *Ae. vigilax, Ma. uniformis* and *Ma. septempunctata* than for either *Cx. annulirostris* or *An. annulipes*, or for the total catch. The lower correlation for *Cx. annulirostris* is not unexpected as Standfast (1965) has demonstrated that substantial numbers attracted to light traps are engaged in nonspecific flight rather than biting activity. Hence the EVS trap, which uses light as well as CO_2, may be sampling a different fraction of the total population than human bait collections.

Both methods recorded 18 taxa (with 3 differences in minor species collected) and successfully ranked the 5 dominant taxa in order of abundance (Table 1) at all 3 study sites (Table 2). *Anopheles annulipes, Ma. uniformis* and *Ma. septempunctata* were collected in greatest numbers at Big Bay whereas most *Cx. annulirostris* and *Ae. vigilax* were taken at Oak Valley and Stanley, respectively.

Trapping method had a significant impact on catches of *Cx. annulirostris, Ae. vigilax* and *Ma. uniformis*. Overall, HBC collected more host-seeking females than EVS traps operated concurrently. There were no significant differences for *An. annulipes* and *Ma. septempunctata*. Hu-

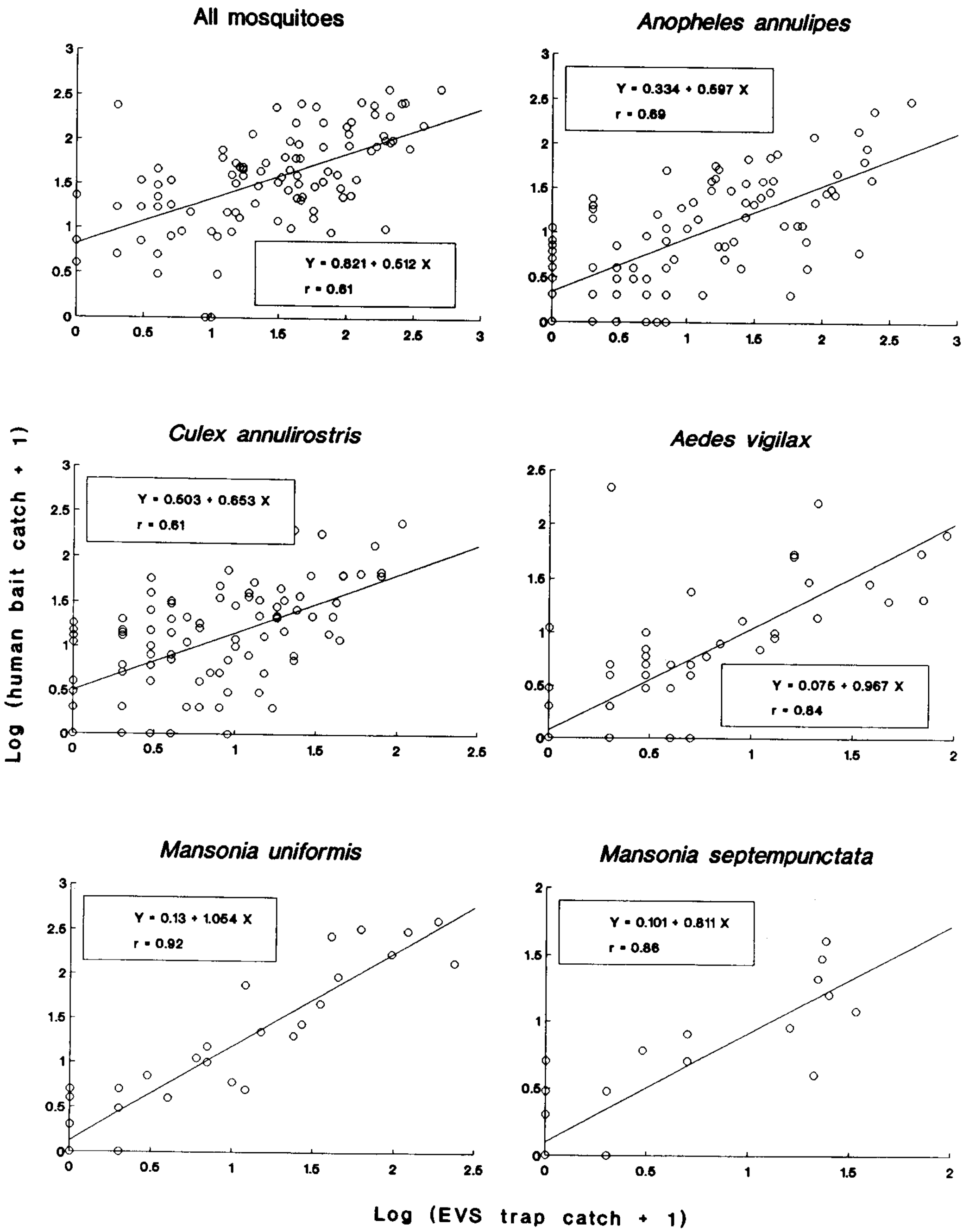

Fig. 1. Relationship of mosquito catches using human bait (HBC) to concurrent catches using a CO_2-baited light trap (EVS), for the total catch and for numbers of the 5 dominant species.

man bait catches have the advantages of direct measurement of man-mosquito contact, being completed in an hour and easily sorted. However, their labor intensiveness, even if over a short time, and the safety aspect are drawbacks. In view of substantial arbovirus, particularly Ross River virus activity around the dam (Kay et al. 1990), it would be prudent to utilize antibody positive collectors or a trap design that prevents engorgement. Alternatively, as *Cx. an-*

Table 2. Factors significantly affecting the capture rate of the dominant mosquito species in trap collections. (Residual degrees of freedom 35 for *Mansonia* species and 104 in all other cases.)

Species	* Location	Time	Trap	Location × time	Time × trap
Cx. annulirostris	b**	b	b	b	a
Ae. vigilax	a	b	a	b	NS
An. annulipes	b	b	b	b	b
Ma. uniformis	b	b	NS	NS	NS
Ma. septempunctata	b	b	NS	NS	NS
Total mosquitoes	b	b	b	b	NS

* Degrees of freedom: Location (2), time (17), trap (1), location × time (34), trap × time (17).
** P, a = <0.05; b = <0.01; NS = not significant.

nulirostris is the primary target for surveillance in the Ross River Dam area, animal baits (or traps) could be used. In host preference studies at Charleville and Kowanyama, Queensland, bovine, porcine and canine baits were shown to be significantly better attractants than man (Kay et al. 1979). Furthermore, animal baited traps conveyed similar population trends to human bait collections when tested by correlation coefficient or by rank correlation (Kay 1979). This would ensure human safety and result in larger samples for arbovirus processing.

In northern Australia, human bait collections were superior to light traps for *Cx. annulirostris* (Standfast and Barrow 1968) and Standfast (1965) suggested that the gravid and blood fed females were undersampled in light traps. In southern Australia, significantly more *Cx. annulirostris* were collected by dry ice-baited EVS trap than by unbaited EVS, CDC light trap, small animal baited EVS or by resting box; these were found to accurately represent the parous component (Russell 1985). Although our study has demonstrated the relative usefulness of the dry ice supplemented baited EVS trap compared with human bait collections with respect to quantity, we have yet to evaluate trap-specific age structure. However, we do not think that our results will be different from those of Russell (1985).

Although our baited EVS traps were comparable to HBC in terms of numbers collected and with respect to broad trends, the regression analysis (Fig. 1) and significant time*trap interactions (Table 2) suggest they may be less useful for monitoring short-term changes in abundance. The use of EVS traps occasionally failed to detect periods of high biting activity of *Cx. annulirostris*, and the third order interaction for *An. annulipes* also suggested some sampling inconsistencies. There are several possible reasons for these discrepancies, including variation in the mechanical efficiency of the EVS traps themselves (or of the human collectors), the attractiveness of the trap light with respect to moon phase (the outlying February and June data did not, however, correspond to full moon), residential lights, weather or the age composition of the mosquito population available for sampling.

The seasonal nature of the dominant mosquito taxa in this study is well recognized (Standfast and Barrow 1968, Russell and Whelan 1986), and interactions of locality with time and trap were predictable. The pronounced wet season (January–March) and prolonged dry season greatly influence environmental changes. During the dry season, the shoreline of the lake recedes, many emergent grasses and aquatic plants are stranded and die, temporary pools disappear, and foliage cover becomes thinner. The predominant flora may react differently in different localities, and this too may affect the range of attraction of both light and dry ice used in the EVS traps.

These sampling inconsistencies for *Cx. annulirostris* mean that EVS traps will not invariably detect high levels of human impact for this species, and consequently that they are probably not sufficiently sensitive to use as a trigger for the implementation of control measures against this species. Even for *Cx. annulirostris*, however, EVS trapping adequately monitors general seasonal trends and reliably identifies geographic variation in impact. In contrast, EVS trapping does appear to be a sensitive indicator of the impact of *Ae. vigilax*, another Australian species whose importance as a vector warrants its surveillance and control. Where sensitive monitoring for *Cx. annulirostris* is critical to short-term decision making, we would suggest the addition of animal baited traps.

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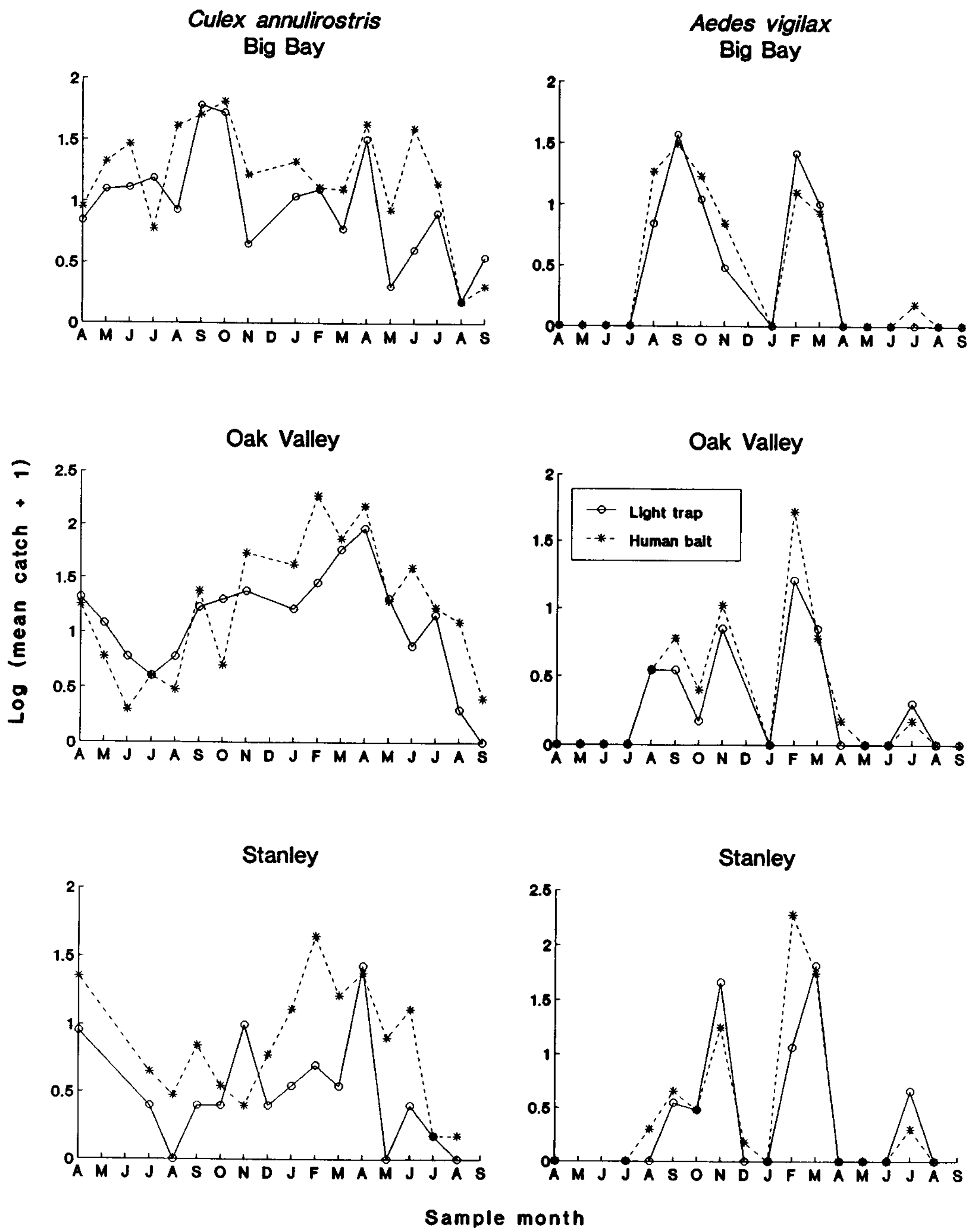

Fig. 2. Average nightly catches during each month by each trapping method at each site for *Culex annulirostris* and *Aedes vigilax*.

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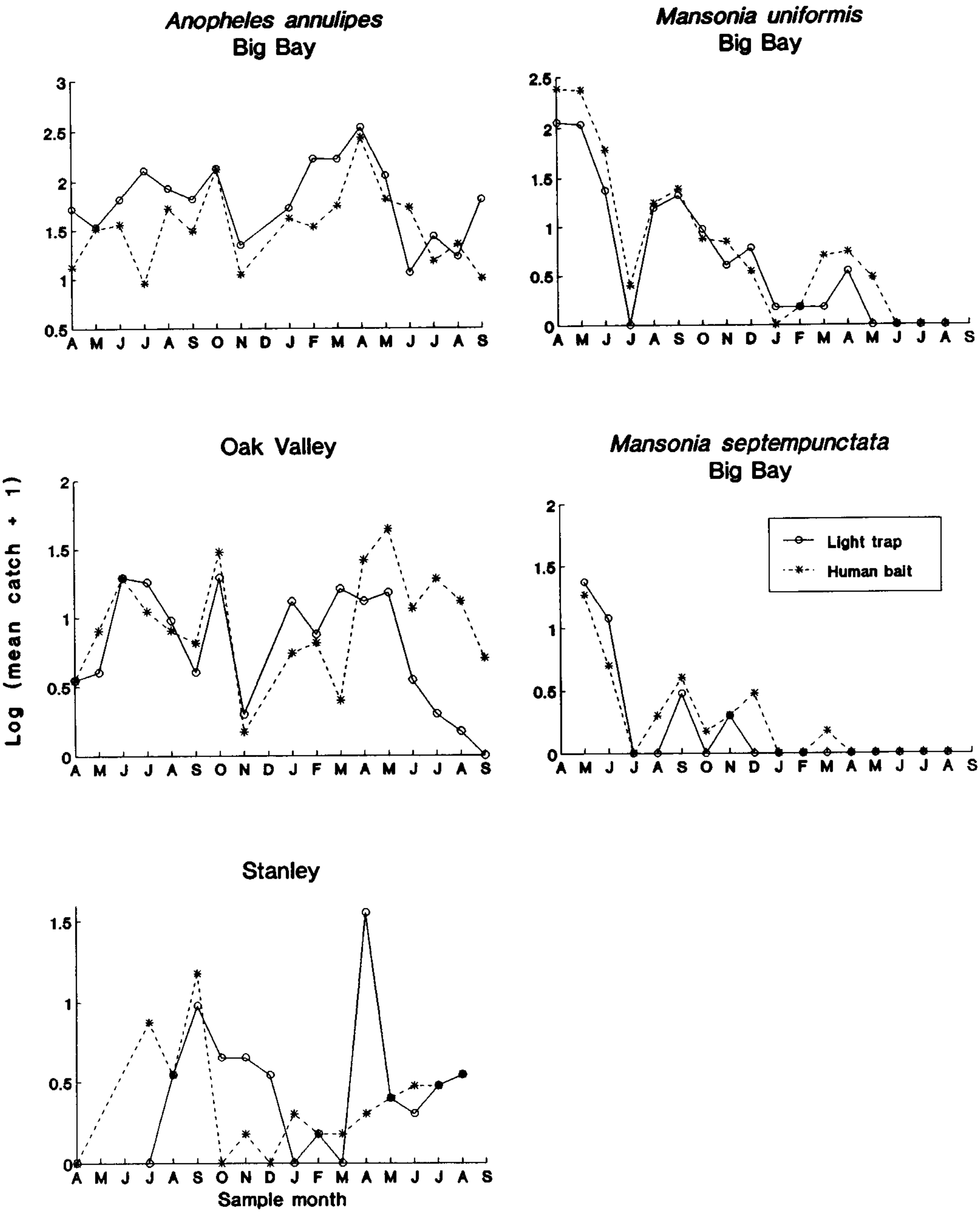

Fig. 3. Average nightly catches during each month by each trapping method at each site for *Anopheles annulipes* and at the Big Bay site for *Mansonia uniformis* and *Ma. septempunctata*.

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