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COMPARISON OF DRY ICE-BAITED CDC AND NJ LIGHT TRAPS FOR MEASURING MOSQUITO ABUNDANCE IN CALIFORNIA

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Abstract

Mosquito catch in NJ light traps has been declining in recent years, compromising the sensitivity of the California mosquito monitoring program. CDC traps operated without light and augmented with dry ice have been considered for replacement or augmentation. To provide information on comparative sensitivity and ability to measure abundance over time and space, catch of mosquitoes in NJ light traps were compared to catch in CDC traps operated concurrently at 8 sites within the Coachella Valley, Kern, San Joaquin County and Sacramento-Yolo Mosquito and Vector Control Districts. CDC traps always collected more female mosquitoes than NJ traps; however, differences in sensitivity varied markedly over time and space precluding the calculation of a universal conversion factor. Regressions of the catch of female *Culex tarsalis* in CDC traps as a function of catch in NJ traps within districts indicated that the slopes varied markedly, again precluding the derivation of a universal function. We conclude that mosquito control districts that switch surveillance from NJ to CDC traps should operate both traps concurrently at several sites to derive regression functions to convert historical relative abundance data from NJLTs to equivalent counts in CDC traps for analysis.

Key words: Surveillance, NJ light traps, CDC traps, *Culex tarsalis*

Introduction

Measurement of mosquito abundance throughout the state of California currently relies on the enumeration of phototactic species collected by New Jersey or American light traps (NJLTs) (Mulhern 1942). Recently, the magnitude of change in the catch of these species over time and space in NJLTs has decreased (Wegbreit and Reisen 2000), resulting in population measurements that may be insufficient for surveillance and control decisions. This decrease in catch may be attributed to 1) increased competing background illumination due to urbanization and enhanced security lighting, 2) decreased mosquito abundance due to improved abatement and water management, and/or 3) failure to adequately sample non-phototactic mosquitoes such as *Culex quinquefasciatus* which have become the focus of control in urban areas. CDC style traps (Sudia and Chamberlain 1962) operated without light and augmented with dry ice (CDCTs) at fixed locations on a systematic schedule have been recommended to augment or replace NJLTs to enhance the sensitivity of the statewide population monitoring program (Reisen et al. 1999). Such a strategy was adopted previously by the Kern MVCD (Mosquito and Vector Control District) (Meyer 1991) and has produced temporal data with patterns different from concurrently operated NJLTs (Wegbreit and Reisen 2000).

Before trap replacement can be finalized, comparative studies were necessary to quantify differences in trap sensitivity for a variety of vector and pest species and to provide methods of converting NJLT to CDCT counts so that historical data can be used prospectively to detect significant fluctuations in abundance. Conversion ratios have been recommended for *Culex tarsalis* females collected in urban, suburban and rural environments in several mosquito control districts (Milby et al. 1978). Recently regression analyses attempted to compare catch size over time and space (Reisen et al. 1999).

The overall purpose of the current research was to extend these previous studies and to determine if NJLTs and CDCTs provide comparable measurements of mosquito population size, emphasizing *Cx. tarsalis*, the primary vector of western equine encephalomyelitis and St. Louis encephalitis viruses in California. Analyses then focused on developing regression models to estimate CDCT counts from NJ light trap counts and thereby provide an historical data to identify significant deviations in future mosquito surveillance data using CDCTs.

Materials and Methods

A NJLT and a CDCT [baited with 1-2 kg of dry ice and operated without light or rain shield] were paired at 8 locations each within the Coachella Valley, Kern, San Joaquin County, and Sacramento-Yolo Mosquito and Vector Control Districts situated in the Coachella, San Joaquin and Sacramento valleys of California. Paired traps were situated within 25-50 m of each other and were operated concurrently once per week for 16-21 weeks during the summer of 2000. Catch was enumerated by species and sex.

Trap counts were transformed by ln[y+1] to normalize the distribution and control the variance prior to least squares analyses (Reisen and Lothrop 1999). Trap sensitivity was evaluated by comparing transformed mean catch per trap-night for each species/sex using a multivariate ANOVA with trap type and site as the main effects and weeks as a repeated measure (Hintze1998). Comparisons of catch size over time and space were done by correlation and then regression analyses using untransformed and transformed counts.

Results.

Sensitivity. In the current paper, we assumed that catch size measures trap sensitivity. CDCTs always collected more females of all species than NJLTs, except for *An. freeborni* that were collected equally well by both traps (Table 1). *Cx. tarsalis* and *An. freeborni* males always were collected more abundantly in NJLTs than CDCTs. These results agreed well with previous studies in California (Milby et al. 1978; Meyer et al. 1984; Reisen et al. 1999), and indicated that males detected the 25 watt lamp in the NJLT above background competing illumination.

Comparability. Correlations among trap types over time and space within each district were calculated for untransformed and transformed counts, and the highest significant r values shown in Table 1. Catch in paired traps was correlated significantly ($P<0.01$) over time and space for 12 of 14 groups of females, but only for 2 of 7 groups of males. Frequent agreement in these female population measurements was encouraging and surpassed results reported previously (Reisen et al. 1999). However, in the multivariate ANOVAs for each species and sex within each district, the trap type x site interaction and the site main effect terms always were highly significant ($P<0.001$), indicating that the difference in trap catch varied significantly among the 8 trap sites within each district. Similar spatial effects were observed during previous studies comparing NJLTs and CDCTs (Reisen et al. 1999) and different types of CDC traps (Reisen et al. 2000).

Variability. Data on female *Cx. tarsalis* from each of the 4 districts were analyzed in detail to delineate more clearly the range of variability in population measurements by NJLTs and CDCTs. In multivariate ANOVAs on data from each district, the trap type x site interaction terms were always highly significant ($P<0.001$), indicating that catch size measured by the two traps changed spatially in a disproportional manner (Fig. 1). Generally, the magnitude in the difference between the catch in NJLTs and CDCTs increased as a function of population size (Fig. 2), indicating that the NJLTs were less sensitive to population change than the CDCTs. Variability in these data precluded the calculation of a universal ratio to convert counts between trap types.

Mean counts of *Cx. tarsalis* females over all sites per week differed significantly as a function of time ($P<0.001$) in all, but the Kern District where the time effect was not significant ($P>0.10$). There was no significant time x trap interaction in the ANOVAs, although the magnitude of change over time in CDCTs always exceeded NJLTs (Fig. 3). Counts in CDCTs then were regressed as a function of counts in NJ light traps within each of the four districts (Table 2). Regressions were done using both untransformed [linear fit, data proportional] and ln [y+1] – ln [x+1] transformed [curvilinear or power function fit, data disproportional] data, and the goodness of fit expressed by the coefficient of determination, R^2. Functions with the best fit are shown in Table 2. The relationship between trap counts was linear in the Coachella Valley and Kern MVCDs and curvilinear in the San Joaquin County and Sac-Yolo MVCDs, indicating that the functional relationship as well as the slope of the regression between trap counts differed markedly among districts.

Discussion

The comparative features of CDCTs and NJLTs for sampling mosquitoes are summarized in Table 4, emphasizing surveillance for the arbovirus vector, *Cx. tarsalis*. In agreement with previous studies, CDCTs operated without light and baited with dry ice always collected as many or more female mosquitoes than NJLTs, even when these larger traps were configured with the light off and augmented with dry ice (Reisen et al. 2001). Therefore, we recommend that mosquito surveillance programs replace or supplement NJLTs with systematically operated CDCTs to enhance sampling sensitivity for females of most mosquito species. In California, *An. freeborni* and *Ps. columbiae* were collected well by both traps and may be an exception to this generalization.

No single sampling system is perfect. Using only CDCTs, data on *Cx. tarsalis* and *An. freeborni* males would be lost, and these data could be useful in locating poorly controlled or newly created larval habitats. In addition, because CDC traps probably would be operated once every week or every 2 weeks, inclement weather and/or other aberrant factors on the night of trap operation would have a greater impact on CDCT than NJLT data, because NJLTs typically are operated continuously during the surveillance season.

The cost of operating CDCTs **per night** is somewhat greater than NJLTs, because of battery and dry ice costs and labor and transportation for deployment and retrieval. However, if driving distances are comparable and the extra time required for processing NJLT samples is considered, then the overall cost for operating CDCTs is comparable to NJLTs (R. Takahashi, unpublished), but the enhanced sensitivity of CDCTs results in a better measure of changes in population size. Processing time for NJLTs must include the tedious job of sorting mosquitoes from the other insects. Because specimens in NJ light traps may be up to 1 week old when processed, specimens may be hard to identify because they frequently are broken and badly rubbed. In contrast, mosquitoes collected by CDCTs are alive, easy to identify and suitable for other purposes such as insecticide bioassays. Specimens collected by CDCTs used for measuring mosquito abundance also could provide females for virus monitoring, thereby providing a systematic framework for regional arbovirus surveillance. NJLT specimens also can be tested for virus using RT-PCR (L.D. Kramer, unpublished); however, the mosquitoes must be <5 days old, dry and in pool sizes <25.

Comparing current measurements of population size to historical data is useful in determining if populations are significantly high or low and is one of the primary factors used to forecast the relative risk of encephalitis virus transmission (Eldridge1987). Switching trapping methods in California from NJLTs to CDCTs will interrupt the historical continuum of data collected by most districts for >30 years and thereby compromise the interpretation of catch size. However, increasing urbanization and security lighting already have confounded this continuum by progressively decreasing NJLT sensitivity (Reeves and Milby 1989; Wegbreit and Reisen 2000). The use of historical data trends after switching trap methods will require regional statistical analyses to relate catch in CDCTs and NJLTs operated concurrently at varying habitats over time within each district. Our attempts to provide universal conversion ratios were thwarted by significant interaction between trap types and sites that varied as curvilinear function of mosquito population size. Regression analyses also failed to provide a universal functional relationship between trap types. Although both trap types generally measured similar trends in female abundance as indicated by correlation analyses and the lack of interaction between trap types and time, regression functions between trap types varied markedly among the 4 districts studied; the relationship was linear in 2 districts and curvilinear in 2 other districts.

Transition from NJLTs to CDCTs will enhance population measurement and provide improved data for making control decisions and projecting the risk of encephalitis transmission. However, additional comparisons and statistical analyses at the local level will be necessary to convert historical NJLT data to detect fluctuations in abundance levels measured by CDC traps.

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Table 1. Sensitivity of CDC and NJ light traps for sampling Mosquitoes in California, 2000.

		Mean per trap-night[1]		Correlation[2]	
Species - sex	District	CDC	NJLT	r	Trans.
Oc. melanimon F	Sac-Yolo	0.34*	0.22	0.72	T
Ae. vexans F	Coachella	1.33*	0.11	0.52	T
An. freeborni F	Sac-Yolo	0.55	0.49	0.68	T
An. freeborni M	Sac-Yolo	0.00	0.26*	0.01	ns
Cx. erythrothorax F	Coachella	0.14*	0.01	0.38	T
Cx. pipiens F	Sac-Yolo	0.98*	0.62	0.67	N
Cx. pipiens F	San Joaquin	1.82*	0.64	0.61	T
Cx. pipiens M	San Joaquin	0.47*	0.00	-0.07	ns
Cx. quinquefasciatus F	Coachella	4.58*	0.34	0.82	N
Cx. quinquefasciatus F	Kern	1.71*	0.16	-0.09	ns
Cx. quinquefasciatus M	Coachella	0.23	0.21	0.68	N
Cx. quinquefasciatus M	Kern	0.07	0.24*	0.02	ns
Cx. tarsalis F	Coachella	5.09*	0.84	0.74	N
Cx. tarsalis F	Kern	1.00*	0.26	0.59	N
Cx. tarsalis F	Sac-Yolo	2.17*	1.33	0.72	T
Cx. tarsalis F	San Joaquin	0.88*	0.49	0.58	T
Cx. tarsalis M	Coachella	0.03	0.47*	0.24	ns
Cx. tarsalis M	Kern	0.02	0.29*	0.02	ns
Cx. tarsalis M	Sac-Yolo	0.00	0.59*	0.44	N
Ps. columbiae F	Coachella	4.32*	1.58	0.78	N

[1] Data transformed by ln[y+1] and analyzed by 3 way ANOVA blocked by time and space. Back transformed means followed by * were significantly greater ($P<0.05$); rest not different ($P>0.05$)

[2] Product moment correlation between traps in time and space, significantly highest correlation using N [not transformed] or T [both axes transformed by ln(y+1)] ($P<0.05$); ns, not significant $P>0.05$

Table 2. Summary of regression analysis for *Cx. tarsalis* females; Number per CDC trap as a function of NJ light trap

MVC District	Transformation	Regression[1] Intercept	Slope	R^2
Coachella Valley	None	4.12	13.54	0.54
Kern	None	1.49	7.84	0.35
San Joaquin	Ln-Ln	0.17	0.37	0.33
Sac-Yolo	Ln-Ln	0.55	1.21	0.52

[1] Function based on highest R^2 value; data either not transformed or transformed by ln(y+1) and ln(x+1). All slopes >0 (P<0.01).

Table 3. Comparative features of CDCT and NJLT.

	Feature	CDCT	NJLT
1	Sensitivity - females	High	Low
2	Sensitivity - males	None	Moderate
3	Impact of weather	High	Low
4	Processing time	Fast	Slow
5	Virus surveillance	Yes	No
6	Cost of operation	High	Low
7	Historical data duration	Short	Long

Figure captions

Figure 1. Interaction between trap sites and trap types depicted by the mean number of *Cx. tarsalis* females collected per trap-night per site during 2000 transformed by ln [y+1] and plotted as a function of trap type for each of 8 sites within the (A) Coachella Valley, (B) Kern, (C) San Joaquin and (D) Sacramento-Yolo MVCDs.

Figure 2. Decrease in NJLT sensitivity as a function of population size depicted by the difference in the mean number of *Cx. tarsalis* females collected per CDCT-night minus NJLT-night plotted as a function of the mean number of females per trap-night [transformed by ln(y+1)] for each of 32 sites within 4 MVCDs in California.

Figure 3. Mean number of female *Cx. tarsalis* in CDCTs and NJLTs transformed by ln[y+1] and plotted as a function of time in experiment weeks during 2000 for the (A) Coachella Valley, (B) Kern, (C) San Joaquin and (D) Sacramento-Yolo MVCDs.

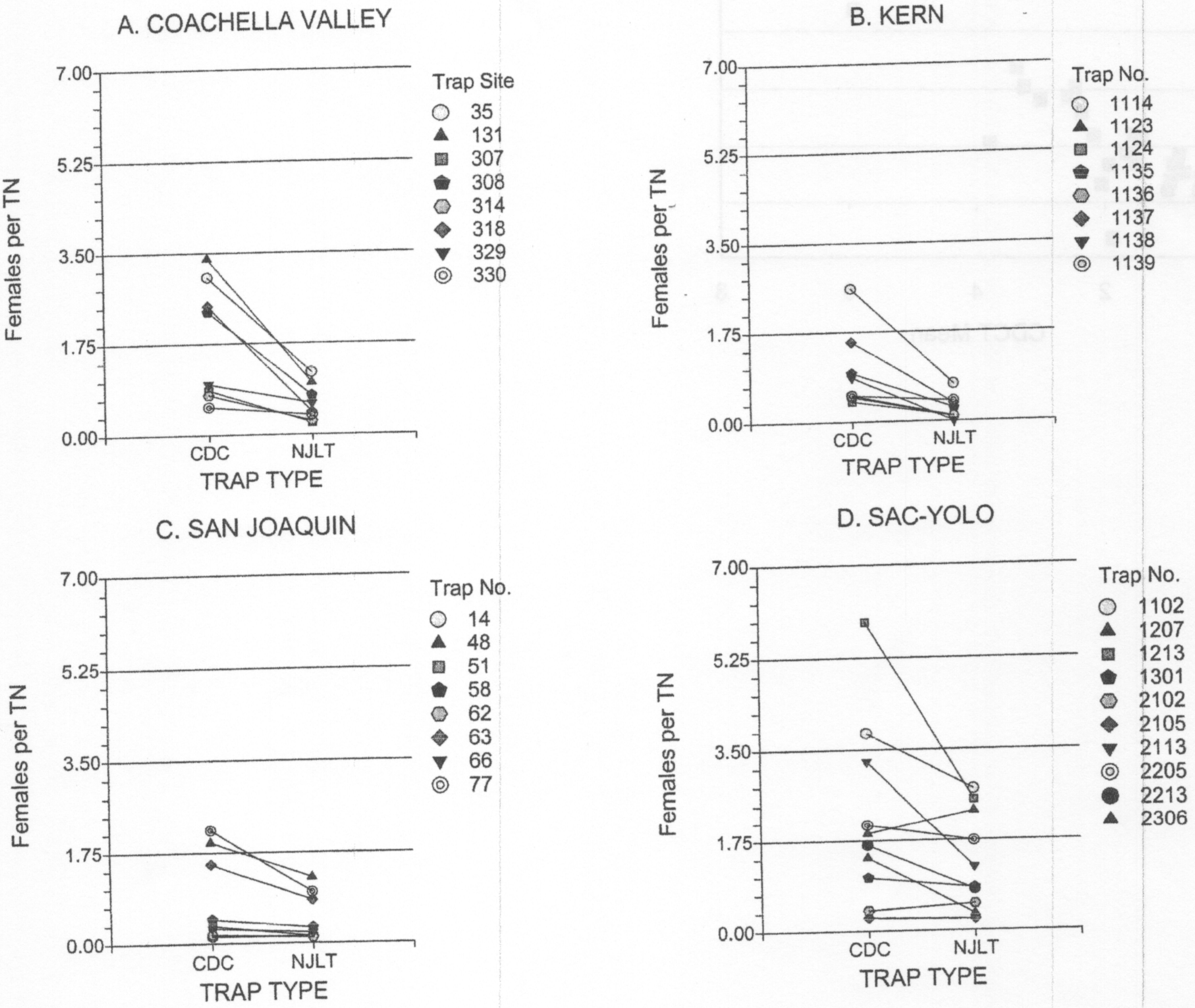

A. COACHELLA VALLEY
Females per TN
7.00
5.25
3.50
1.75
0.00
CDC
NJLT
TRAP TYPE
Trap Site
○ 35
▲ 131
▨ 307
⬟ 308
⬡ 314
◆ 318
▼ 329
◎ 330
B. KERN
Females per TN
7.00
5.25
3.50
1.75
0.00
CDC
NJLT
TRAP TYPE
Trap No.
○ 1114
▲ 1123
▨ 1124
⬟ 1135
⬡ 1136
◆ 1137
▼ 1138
◎ 1139
C. SAN JOAQUIN
Females per TN
7.00
5.25
3.50
1.75
0.00
CDC
NJLT
TRAP TYPE
Trap No.
○ 14
▲ 48
▨ 51
⬟ 58
⬡ 62
◆ 63
▼ 66
◎ 77
D. SAC-YOLO
Females per TN
7.00
5.25
3.50
1.75
0.00
CDC
NJLT
TRAP TYPE
Trap No.
○ 1102
▲ 1207
▨ 1213
⬟ 1301
⬡ 2102
◆ 2105
▼ 2113
◎ 2205
● 2213
▲ 2306

Fig. 1

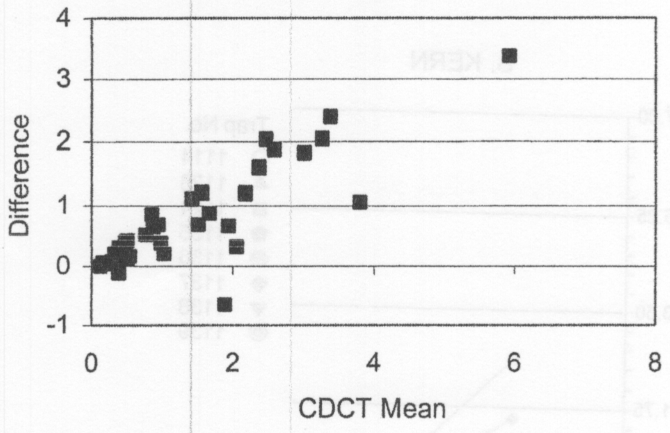
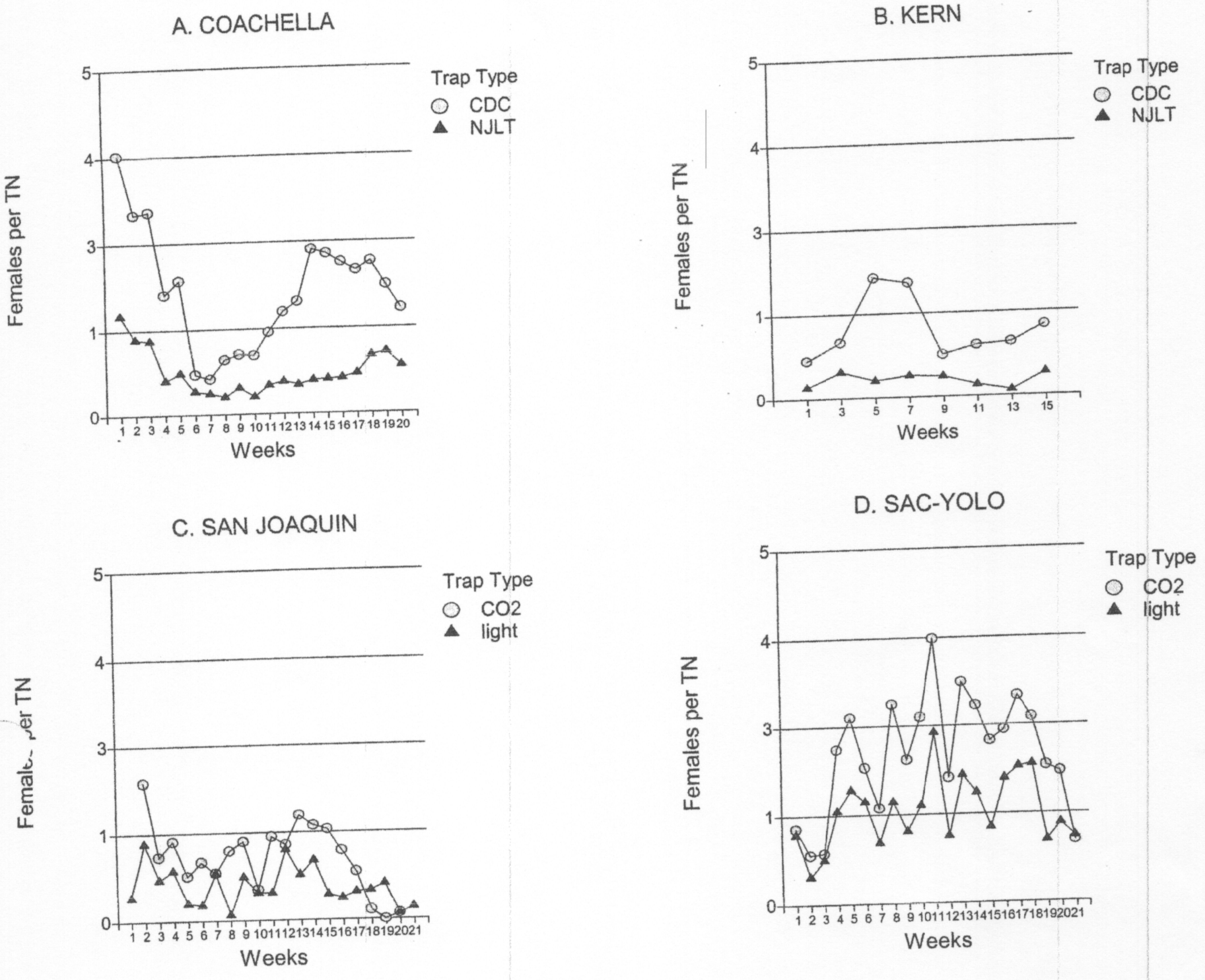


Fig. 2



A. COACHELLA

B. KERN

C. SAN JOAQUIN

D. SAC-YOLO

Fig. 3