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Trap color and placement affects estimates of insect family-level abundance and diversity in a Nebraska salt marsh

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Abstract

Sampling programs to establish baseline ecosystem information (e.g., species abundance and diversity) often fail to consider the potential influence of sampling techniques on results. Research on sampling economically important insects has demonstrated the possible influences of trap color and trap placement on results, but few data have been collected from natural environments. Consequently, we examined the effects of color (yellow and blue) and placement (exposed and shaded by plants) of sticky traps on insect captures and diversity estimates from a Nebraska inland salt marsh community. We identified 1913 specimens from 67 insect families collected during five trapping dates in July 1996. More Cicindelidae were collected on exposed traps, and more Staphylinidae, Dolichopodidae, Cicadellidae, and Thripidae were collected on shaded traps. More Dolichopodidae were collected on yellow traps, while more Syrphidae and Thripidae were collected on blue. Shannon and alpha diversity measures were significantly higher for shaded traps than exposed traps, but were not affected by trap color. Our results highlight the importance of characterizing sampling techniques when establishing diversity estimates. These data provide the first complete accounting of community-level insect response to colored sticky traps and provide new information for color preference of non-economic insect species.

Introduction

In most ecological and entomological studies censusing of individuals is impractical, so samples are collected to provide estimates of population densities. With this goal, sampling methods are selected which provide the greatest efficiency and accuracy for a given species or life stage of a species (Southwood, 1978; Pedigo & Buntin, 1994). When sampling is directed at characterizing diversity, the change in objective requires corresponding changes in sampling methods. Measuring insect occurrence, for the purpose of establishing species range or species diversity, is a form of extensive sampling in which relative estimates (counts in association with a sampling technique rather than unit land area) are determined (Southwood, 1978; Pedigo & Buntin, 1994). We find little in the large sampling literature that directly addresses sampling issues in establishing relative estimates.

The ideal sampling technique to measure species diversity would be equally effective for all species in a habitat, all active life stages, and at all population densities. No sampling technique can meet these requirements. Broadly, two sampling approaches are possible: interception and attraction. Interception techniques, such as insecticidal fogging, sweep netting, Malaise and pitfall traps, have the advantage of capturing all individuals moving across their barrier. The efficiency of these techniques depends on such issues as placement, physical environment, retention of captures, and the degree to which species in the habitat are moving. Attraction traps, such as sticky traps, light traps, and baited traps, have many of the limitations of interception traps, and vary in their attractiveness among species.

As part of our ongoing research, we have been examining interspecific relationships between two co-occurring salt marsh tiger beetle species (*Cicindela*

togata LaFerte and *C. circumpicta* LaFerte). Previous work has shown that some tiger beetle communities are prey-base limited (Pearson, 1988). Because the salt marsh is a harsh environment (particularly in mid-summer when these species are active as adults [Willis, 1967]), prey abundance and diversity might influence interspecific relationships of *C. togata* and *C. circumpicta*. Consequently, we examined insect diversity and abundance on two salt flats occupied by *C. togata* and *C. circumpicta* at dates and times when these tiger beetle species are foraging. Although this narrow objective explains our choice of sampling methods, timing and habitat, questions of insect sampling and measurement of diversity at the family-level are issues of broader ecological interest.

In this study, we sampled the insect fauna of an eastern Nebraska salt marsh using sticky traps. We investigated this area because relatively little is known about the insect fauna (Spomer & Higley, 1994), and because the salt concentrations restrict plant growth allowing for simultaneous sampling of vegetated and barren areas. Also, eastern Nebraska salt marshes are the most threatened habitats in the state and are home to the threatened Salt Creek tiger beetle, *Cicindela nevadica lincolniana* Casey (Spomer & Higley, 1994), as well as other salt marsh tiger beetle species (Spomer et al., 1997). We chose to use sticky traps for sampling because many small insects are resident in salt marsh habitats and are diurnally active. However, factors influencing sticky trap attractiveness for diversity estimates are not known despite the common use of sticky traps to sample insect populations for ecological studies (Southwood, 1978) and in monitoring for the purposes of pest management (Pedigo & Buntin, 1994). Sticky traps may either passively intercept insects or attract the insects with allelochemicals (like pheromones), shapes, and colors.

We tested the effects of trap color, trap placement, and number of sampling periods on insect captures. We then used indices of species diversity to examine trap color and placement differences. These data provide the first complete account of community-level insect response to colored sticky traps and provide new information for color preference of non-economic insect species.

Materials and methods

Our studies were conducted on two salt flats within the Arbor Lake Wildlife Management Area (Lancaster Co., NE), an area of protected eastern Nebraska salt marsh. The eastern Nebraska salt marshes were formed from the percolation of ground waters through salt-rich Dakota sandstone followed by their evaporation on the surface. The high concentration of salt restricts plant life to halophytes like salt grass, *Distichlis spicata* (L.) Greene, and saltwort, *Salicornia rubra* A. Nels. These halophytes grow sparsely around the edges of the salt flat and are gradually replaced by non-saline restricted species like brome grass as the distance from the salt deposits increase. Although water is seasonally abundant during the summer months, the substrate becomes arid and surfaces of bare soil may exceed 60 °C (Willis, 1967). The soil in the shade of plants is about 10 °C cooler (W. Hoback, pers. obs.).

Samples were collected on five dates from two separate salt flats during July 1996 (2, 9, 19, 23, and 29 July). The combination of dates and salt flats were sampling replicates. By sampling only in July, we targeted primarily summer species while avoiding senescent spring and newly emerging fall species. This was necessary because comparison of diversity indices assume that all species in the community are represented in the sample (Pielou, 1975).

Our basic sampling unit was either a blue or yellow sticky trap card (7.7 × 12.8 cm) (Gempler's, Mt. Horeb, WI). We selected these colors because blue traps are typically used to monitor Thysanoptera and yellow traps are used to monitor pest Homoptera and Diptera in agricultural settings. All traps were placed horizontally on the surface of the salt flat in areas without plants (exposed condition) or beneath salt grass and other salt adapted plants (shaded condition) growing on the salt flat. Traps were placed at least 2 m apart.

On each sampling date, ten traps of each color (20 total) were randomly placed in exposed or shaded locations. The traps were placed with four of each color exposed and shaded on the smaller salt flat and six of each color exposed and shaded on the larger salt flat. Different trap locations within the confines of the salt flat were selected for each sampling period. The traps were placed in the morning (between 0900 and 1000) and collected after approximately 7 h. This timing corresponds to our observed periods of peak foraging by *C. togata* and *C. circumpicta* (W. Hoback, pers. obs.). At the time of collection, the traps were covered with cellophane wrap and brought to the laboratory where they were refrigerated until analysis. The surveys were repeated on the five dates for a total of 50 traps in each the exposed and the shaded

condition. Placement and retrieval of traps required approximately one hour of labor per sampling date.

Trapped insects were identified to family. The unidentified specimens (2% of trapped individuals) were either immatures or were destroyed during sampling. Laboratory sorting and identification required approximately 15 person hours for all sticky traps from a particular date.

For each taxon for each date, we tested for differences in number of insects trapped using SAS's General Linear Model Least Significant Differences test and ANOVA ($P = 0.05$) (SAS Institute, 1989). We detected no significant differences between insect families collected on the two salt flats, and obtained too few data to analyze each trap separately. Consequently, we combined all traps of each condition (color or placement) for each sampling date ($N = 10$ per date; 50 traps total). We calculated family-level Simpson's, Margelef's, Shannon-Wiener, and alpha diversity indices for each trap condition (Magurran, 1988) and made comparisons using *t*-tests ($P = 0.05$). To test for differences in taxon response over the entire study, we used chi-squared goodness of fit tests to compare between trap conditions with the null hypothesis of no preference. Because we captured few individuals in some families, we limited our analyses to families where capture totals exceeded 20 individuals.

Results and discussion

Trap color and placement. We collected and identified 1913 insects comprising 67 families from ten insect orders (Table 1). Numerically, we collected more insects in the shade ($n = 1154$ or 60%; $df = 1$; $P < 0.01$) and more on yellow traps ($n = 1178$ or 62%; $df = 1$; $P < 0.01$).

Trap color and placement had significant effects on the capture of individuals in three insect orders. More Coleoptera ($n = 393$ or 88%; $F = 31.72$; $df = 1$; $P < 0.01$) were collected on exposed traps than on shaded traps, but Coleoptera showed no preference for trap color. In contrast, more Diptera (605 or 74%) were collected in the shade than on the exposed traps ($F = 27.38$; $df = 1$; $P < 0.01$), and Diptera showed a strong preference for yellow traps ($n = 572$ or 75%; $F = 24.05$; $df = 1$; $P < 0.01$). More Thysanoptera were collected in the shade than on the exposed traps ($n = 104$ or 78%; $F = 4.95$; $df = 1$; $P = 0.037$) but showed no trap color preference.

Mean numbers of families collected per trapping date did show differences. Across all sampling dates, more families ($F = 12.41$; $df = 1$; $P = 0.039$) of insects were collected from traps placed in the shade of plants (29.8 ± 2.5) than on exposed traps (20.0 ± 1.3), and more ($F = 6.06$; $df = 1$; $P < 0.01$) families were collected on yellow traps (28.0 ± 1.8) than on blue traps (21.8 ± 1.8). Eight of 67 families showed significant trap preferences by sampling date (Table 1). Of the families showing preferences, only the Cicindelidae were collected more often on the exposed areas of the salt flat ($F = 144.4$; $df = 1$; $P < 0.01$). More Staphylinidae ($F = 7.83$; $df = 1$; $P = 0.047$), Dolichopodidae ($F = 6.17$; $df = 1$; $P = 0.030$), Cicadellidae ($F = 6.45$; $df = 1$; $P = 0.033$) and Thripidae ($F = 11.57$; $df = 1$; $P = 0.021$) were collected from shaded traps than from exposed traps. Three families showed trap color preference. The Dolichopodidae ($F = 6.80$; $df = 1$; $P = 0.024$) preferred yellow traps, while the Syrphidae ($F = 11.72$; $df = 1$; $P = 0.014$) and Thripidae ($F = 5.13$; $df = 1$; $P = 0.047$) preferred blue traps.

When all sampling was combined (50 traps for 35 h in each condition), nine families showed significant trap preference (chi-squared test; $df = 1$; $P < 0.05$) in response to trap placement. Both Cicindelidae and Poduridae were collected more frequently in the sun while Sminthuridae, Dolichopodidae, Syrphidae, Trixoscelidae, Cicadellidae, Acrididae, and Thripidae were more frequently collected from shaded traps (Table 1). Only three families showed significant preference (chi-squared test; $df = 1$; $P < 0.05$) for trap color. Poduridae and Dolichopodidae were collected more frequently on yellow traps, and Thripidae were collected more frequently on blue traps.

Color preferences by economically important insects have previously been demonstrated (Southwood, 1978; Prokopy & Owens, 1983) and are summarized in Table 2 (based on Bioabstract and Agricola searches with additional searches of all literature cited).

Most insects that have been examined prefer yellow traps (Prokopy & Owens, 1983); however (perhaps because of small numbers of individuals trapped in our study), we found only a small percentage of families which showed a statistical preference for color (4%). For some families, no detectable preference resulted from relatively low numbers; for other families such as the Cicindelidae and Poduridae, color preferences may not exist because such preferences may not be biologically significant to these species.

Table 1. Family-level insect response to sticky trap color or placement in the Arbor Lake Wildlife Management Area (Lancaster Co, NE). Numbers represent the sum of all individuals collected from 100 traps placed in each condition over five sampling dates in July 1996 and do not reflect interactions between conditions. Preference ($P < 0.05$) for trap condition was tested for all families whose total captures exceeded 20 individuals using Chi-squared goodness of fit

Order	Family	Sun		Shade	Yellow		Blue
Coleoptera	Cicindelidae	384	*	32	224		192
	Cleridae	1		0	0		1
	Curculionidae	1		1	1		1
	Mordellidae	1		0	0		1
	Staphylinidae	6	*	21	15		12
Collembola	Poduridae	31	*	2	25	*	8
	Sminthuridae	37	*	120	67		90
Diptera	Agromyzidae	1		2	0		3
	Anthomyzidae	2		0	2		0
	Asilidae	1		0	0		1
	Bombyliidae	0		1	1		0
	Cecidomyiidae	2	*	10	6		6
	Ceratopogonidae	0		1	1		0
	Chloropidae	40		46	38		48
	Culicidae	1		4	3		2
	Dolichopodidae	61	*	412	421	*	52
	Drosophilidae	0		1	0		1
	Empididae	1		6	5		2
	Lauxaniidae	0		2	2		0
	Lonchaeidae	1		0	1		0
	Micropezidae	1		3	3		1
	Muscidae	24		16	26		14
	Mycetophilidae	1		8	3		6
	Otitidae	0		1	1		0
	Phoridae	0		2	1		1
	Pipunculidae	0		2	2		0
	Rhagionidae	0		1	1		0
	Sarcophagidae	1		4	2		3
	Scatopsilidae	2		0	1		1
	Scenopinidae	0		1	1		0
	Sepsidae	10		24	24		10
	Simuliidae	0		1	0		1
	Stratiomyidae	1		1	0		2
	Syrphidae	5	*	21	14		12
	Tabanidae	0		1	0		1
	Tachinidae	2		1	2		1
	Trixoscelidae	4	*	33	11		26
Hemiptera	Miridae	0		2	1		1
	Pentatomidae	0		1	1		0
	Piesmatidae	2		1	3		0
Homoptera	Aleyrodidae	0		1	1		0
	Aphididae	9		10	18		1
	Cicadellidae	19	*	83	62		40
	Psyllidae	1		13	13	*	1

Table 1. Continued.

Order	Family	Sun	Shade	Yellow	Blue
Hymenoptera	Andrenidae	37	45	33	49
	Apidae	10	11	12	9
	Argidae	0	1	1	0
	Braconidae	5	13	12	6
	Chalcididae	3	5	6	2
	Eulophidae	0	12	9	3
	Eurytomidae	0	2	1	1
	Formicidae	2	2	1	3
	Ichneumonidae	0	1	1	0
	Mymaridae	6	10	8	8
	Perilampidae	1	0	0	1
	Pteromalidae	0	3	3	0
	Scelionidae	3	2	3	2
	Sphecidae	2	8	7	3
	Tenthredinidae	0	1	1	0
	Tiphiidae	2	6	7	1
	Trichogrammatidae	2	2	3	1
	Vespidae	1	3	4	1
Lepidoptera	Hesperiidae	0	3	1	2
Odonata	Coenagrionidae	0	4	2	2
Orthoptera	Acrididae	2 *	23	15	10
	Tettigoniidae	0	1	1	0
Thysanoptera	Thripidae	30 *	104	44 *	90
Totals:					
Families	44	61	58	50	
Individuals	759	1154	1178	735	
Margalef's index	6.48	8.51	8.06	7.42	
Shannon index	2.13	2.68	2.66	2.69	
Simpson Index	3.64	3.16	5.70	8.80	
Alpha index	10.16	13.72	12.79	12.13	

*$P < 0.05$.

Color preferences may change during the insect's lifetime. For example, Jenkins & Roques (1993) showed different trap responses between pre-reproductive and reproductive adult anthomyiids. The pre-reproductive flies were attracted to yellow traps presumably while in search of nectar sources, but reproductive flies were attracted to purple traps that may resemble host leaves for oviposition. Similarily, Kring (1970) showed that tephritid flies are attracted to yellow squares prior to maturation and red spheres during oviposition.

We found that trap color and placement influenced the number and composition of insects captured in this study. Of these two, trap placement had the greatest effect on numbers of individuals and numbers of families. Shaded traps caught approximately 33% more insect families per trapping date than exposed traps. This is expected for the Nebraska salt marsh environment because the surface temperatures of the exposed salt flats can exceed 60 °C (W. Hoback, pers. obs.) – a lethal temperature for most insects (Hadley, 1994). Blue traps were less effective than yellow traps for collecting the majority of families. Also, yellow traps consistently caught approximately 20% more insect families than blue traps suggesting that in most ecological studies using sticky traps to collect insects, yellow should be used. We could not discern any differences regarding the influence of trap color

Table 1. Insect families that demonstrate sticky trap color preference. This table was compiled from literature searches. In all studies, the insects were given choices between at least two sticky trap colors and showed significant ($P < 0.05$) preference. In some instances where an insect family has been extensively studied for color preference (e.g., Homoptera), only the first report of color preference for an insect family is included unless subsequent studies differed

Order	Family	Color	Reference
Coleoptera	Chrysomelidae	Yellow, Green**	Dominick, 1976
	Coccinellidae	Yellow	Dowell & Cherry, 1981
	Curculionidae	Yellow, Green, White**	Cross et al., 1976
	Scarabaeidae	Yellow	Fleming et al., 1940
	Scolytidae	Red	Entwistle, 1963
Diptera	Agromyzidae	Yellow	Tryon et al. 1980; Ferro & Suchak, 1980
	Anthomyiidae	Yellow*, Purple	Jenkins & Roques, 1993
	Ceratopogonidae	Black	Hill, 1947
	Chloropidae	Blue	Mayer, 1961
	Dolichopodidae	Yellow	Present study
	Psyllidae	Yellow	Wilde, 1962
	Syrphidae	Blue	Present study
	Tephritidae	Yellow, Orange	Kring, 1970; Greany et al., 1977
Homoptera	Aleyrodidae	Yellow	Bellows et al., 1988
	Aphididae	Yellow	Broadbent, 1948
	Cicadellidae	Orange, Yellow, Red***	Capinera & Walmsley, 1978
	Pseudococcidae	Green	Heng-Moss et al., 1997
Hymenoptera	Aphelinidae	Yellow	Samways, 1986
	Braconidae	Yellow	Neuenschwander, 1982
	Encyrtidae	Yellow	Samways, 1986
	Eulophidae	Green, Yellow**	Redak & Bethke, 1995
	Mymaridae	Yellow	Neuenschwander, 1982
Thysanoptera	Thripidae	Blue	Gillespie & Vernon, 1990; Present study

*Yellow pre-reproductive, Purple for reproductives.
**No differences in response between colors.
***Species level differences in color preference.

and placement between predacious and herbivorous groups, but we did not have a large number of predacious families for comparison. In this study, thrips and syrphids preferred blue; their presence would have been underestimated had blue not been tested.

Our results suggest that the eastern Nebraska salt marsh inhabiting tiger beetles have a diverse but potentially limited prey base (Table 1). The tiger beetles *C. togata* and *C. circumpicta* accounted for about 22% of the total insects collected in this study and competition for prey might be intense because tiger beetle foraging is limited to the areas sampled in this study. Of the insects captured in this study, most from Table 1 could be killed and eaten by adult tiger beetles which are known to forage on a wide range of arthropod prey (Willis, 1967; Pearson, 1988). Exceptions may include the very small insects such as collembolans, thrips, and minute hymenopterans. Other insects that are probably not eaten by adult tiger beetles include large odonates and sphecids. The acridids captured by the sticky traps were early instars which we have observed being eaten by tiger beetles.

Diversity differs with trap parameters. Critical considerations in diversity estimates include the number of sampling periods and trap effectiveness (Southwood, 1978). To establish the number of sampling periods, we plotted cumulative number of families collected by date to quantify the number of trapping dates necessary to ensure collecting >95% of the families (Figure 1). For the exposed and shaded traps and for the yellow-colored traps, the curves approached an asymptote after four collecting dates, with between 3

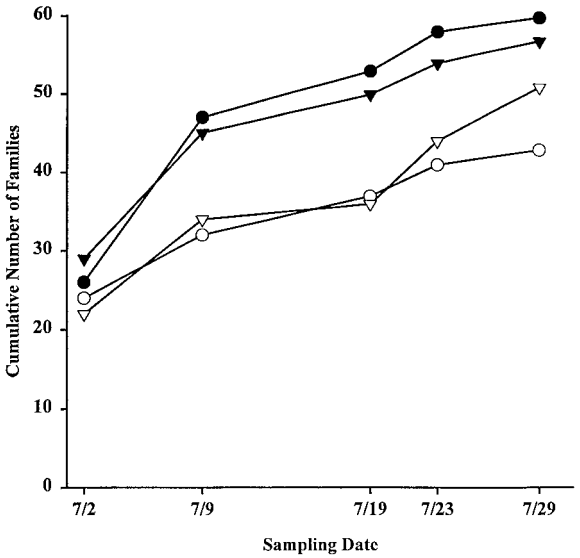

Figure 1. Cumulative number of novel insect families collected over time in July 1996. Filled circles represent shaded traps, open circles represent exposed traps. Filled triangles represent yellow traps and open triangles represent blue traps.

and 5% of the total families added on the last date. The blue traps had a variable response, with nearly 20% of the total families added on the last day.

For the purposes of insect monitoring and control, sticky traps are used to collect a few specific target organisms. Thus, color preferences have been tested for only a few insect families (Table 2). Additionally, the majority of these tests have been conducted within greenhouses or field monocultures. For diversity assessment in ecological studies, the influences of sticky trap color and placement are presently unknown. Having established differences in insect response to trap color and placement, we examined the influence of these trap parameters on diversity estimates. Our examination focused on characterizing differences in trapping parameters and on using an index to describe insect diversity in the salt marsh study habitat.

Traps with higher levels of taxonomic diversity were considered more successful. Measures of diversity have two components, variety and abundance. We used captures by family to calculate the Margalef index as a measure of family richness – an estimate that combines the number of families and the number of individuals in an area (Magurran, 1988). Margalef's diversity estimates were highest for shaded traps (8.51) compared to exposed traps (6.48) and were very similar between trap colors (8.06 for yellow; 7.42 for blue). Although not robust, the speed and ease of calculation of the Margalef's index makes it useful to assay possible trap and placement effects prior to a full investigation of diversity.

We chose the Shannon index (Shannon-Wiener method) to estimate diversity as a function of proportional abundance because of its wide use and because it lets researchers statistically compare diversity estimates from studies with different trapping methods (Hutcheson, 1970; Magurran, 1988). Shannon indices of family-level diversity were significantly higher ($t = 2.64$; df $= 1356$; $P < 0.01$) on the shaded traps (2.68) than on the exposed traps (2.13). The Shannon–Wiener estimates of diversity were similar ($P > 0.25$) between blue traps (2.66) and yellow traps (2.69). The Shannon index assumes that individuals are randomly sampled from an infinitely large population (Pielou, 1975) and that all species are represented in the sample (Peet, 1974).

Although continuing to be widely used, the Shannon index has been criticized by May (1975), Goodman (1975), and others for lacking biological meaning and for over-emphasizing rare organisms. For comparison, we calculated Simpson indices which measure species dominance. The Simpson index measures dominance by dividing one by the probability of two individuals drawn at random belonging to two different species. Thus, for the Simpson index larger numbers indicate lower diversity because the sample is dominated by fewer species and because single captures are excluded from analysis (Magurran, 1988). The largest Simpson index value was 8.8 on blue traps; yellow traps produced a value of 5.7. The Dolichopodidae (the most abundant family) showed a strong preference for yellow traps, while the Thripidae and Syrphidae preferred blue traps. The exposed and shaded traps produced similar Simpson values (3.64 and 3.16, respectively), reflecting more similarity in trap response and more instances of multiple captures of specific insect families (Table 1).

Taylor (1978) favored the use of the alpha (log series) index when species follow a log-normal distribution because it has high discriminatory power and is only weakly influenced by sample size. As with the Shannon index, the alpha indices were higher for shaded traps (13.72) compared to exposed traps (10.16) but did not differ between yellow (12.79) and blue (12.13) traps.

We found that trap placement had a significant effect on insect diversity estimates while trap color had less effect. Higher diversity in the shade can probably be explained by the harshness of the environment,

which forces insects to seek favorable microclimates on hot days, and by the greater resources available from the plants. The differences between trap colors as indicated by calculated indices is a somewhat more surprising result because we collected almost 40% more insects from 20% more families on yellow traps than on blue traps. A contributing factor for the similar diversity estimates for both Shannon and alpha diversity indices was the distribution of captures from the rarer families. A single capture or a few insects of nine families were only collected on blue traps, and 15 families were only collected on yellow traps. In contrast, calculated Simpson indices suggested less diversity than other indices, probably because captures from rarer families have less influence on the Simpson index than others (Magurran, 1988).

The use of family-level diversity for quantification of trapping protocol. Ideally, any estimate of diversity should examine organisms at the species level, as any estimate of diversity at a taxonomically higher level will be unable to explain the relationship between species or population size and range. By not identifying species, the trophic relationship of a community is not defined nor can the diversity estimates based on family be compared to those based on other taxa. However, in the absence of taxonomic keys or expertise, the examination of a community for the purpose of estimating diversity can be accomplished by the use of family level identifications. With insects, family-level identification may be a reasonable option for diversity estimates that seek to incorporate all data from a given trapping method. Notable exceptions to this general rule may include sampling aquatic habitats where fewer species exist and sampling uniform terrestrial environments, such as monocultures or caves.

Sticky traps may have been ineffective for sampling all families within the salt marsh community. Some larger and stronger insects probably escaped the traps as evidenced by a few traps with scales from lepidopteran wings. In addition, we have observed a number of insects on the salt flat (notably Mutillidae, some species of Asilidae, and dragonflies) that were not captured by the sticky traps. In the future, small-scale absolute sampling should be used to calibrate trap efficiency and to determine if the pattern of rare families is an artifact of sampling technique or is biologically meaningful.

A final sampling issue that must be tested in the future is the assumption that all members of an insect family will show a similar response to trap color and condition. At present, few studies have examined multiple species primarily because the majority of tests have targeted a particular insect pest. Tests involving trap response by multiple species within a family have produced mixed results. For example, Dowell & Cherry (1981) found five of six coccinellid species were captured most often on yellow traps while Walker (1974) found that the thrips, *Frankliniella fusca* Hinds, and *F. tritici* Fitch were attracted to yellow and white, and Vernon & Gillespie (1990) found *F. occidentalis* (Pergande) was most attracted to blue. Thus, it is possible that few families in our study showed trap color preference because of differences at lower taxonomic levels. For this to be true, within families total captures from multiple species must be similar and have opposing trap color preferences.

Despite its limitations, the use of family-level diversity estimates has many advantages over conventional species diversity studies. First, family-level identification of all organisms is more quickly achieved than species-level determinations. Second, the rapid asymptote of the family accumulation curves (Figure 1) demonstrates that more than 95% of trap-susceptible families will be collected in a short sampling period (3–4 dates). Third, with the assumption that many families have multiple responding species, the Shannon and alpha diversity indices provide conservative estimates of species abundance. Fourth, the use of families to measure diversity avoids problems associated with the identification of cryptic, sister, or sibling species. The calculation of family-level diversity is an excellent method for initial surveys.

Although Peet (1974) suggested the use of different levels of hierarchic classification, and Ricklefs & Schluter (1993) again mentioned this possibility, with the exception of Labandeira & Sepkoski (1993) who used family-level diversity of fossilized insects, we could find no precedence for family-level diversity measures for terrestrial arthropods. This is surprising because family-level identification is relatively easy and allows large samples to be sorted and identified in a relatively short time. In addition, maximal data per sample can be attained because nearly all captured specimens can be identified to family.

Measuring diversity at taxonomic levels above the species is an issue of considerable controversy and strongly held opinions among biologists, especially among aquatic ecologists. Rosenberg & Resh (1993) summarize this debate. We agree with those who argue that species-level measurements are the most

biologically meaningful. However, with extraordinarily diverse groups, like insects, we are sympathetic to the view that measuring diversity for taxa above the species level is preferable to making no estimates.

Given the potential benefits and drawbacks, what does the family-level data tell us about insect response to sticky traps in the salt marsh community? First, the use of families facilitated classification of a robust array of insects. This is especially encouraging for explaining the co-occurrence of the tiger beetles given that the summertime salt marsh conditions are extreme (high temperatures, few plants, and little water). As expected for such an area, we caught greater numbers and greater diversity in the shade (a spatial refuge). This result led to a much greater Margelef's number, an estimate that can be used to place traps in the most favorable conditions for diversity in later studies. For the purposes of estimating total diversity in this salt marsh environment, the Shannon index and the alpha log series index produced identical results (highest diversity in the shade, no difference between colors) and, more importantly, either could be used at the family level to produce a baseline diversity estimate in approximately 55 person-hours. Such efficiency is not currently available using any other method.

Some data from aquatic systems have demonstrated close agreement between family-level and species-level diversity estimates (Hughes, 1978). Further, in a comparative study, Furse et al. (1984) found that measuring diversity at higher taxonomic levels is a reasonable metric for monitoring ecosystem health despite the fact that species have more precise environmental requirements, an opinion supported in recent reviews (Metcalfe, 1989; Rosenberg & Resh, 1993). In the absence of direct comparisons between family and species-level estimates for terrestrial insects, we must recognize the meaning and limitations of family-level diversity estimates. To us, the key observation is that an absence of family-level differences *does not* imply an absence of species-level differences, but the occurrence of family-level differences *does* imply species-level diversity will also be different.

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