1970

An Evaluation of Three Techniques for the Quantitative Sampling of Marsh Invertebrates

John T. Falkenbury
Central Washington University

34

An Evaluation of Three Techniques for the Quantitative Sampling of Marsh Invertebrates

---

A Thesis

Presented to

the Graduate Faculty

Central Washington State College

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

John T. Falkenbury

August, 1970

APPROVED FOR THE GRADUATE FACULTY

_____

Jared Verner, COMMITTEE CHAIRMAN

_____

Stanford D. Smith

_____

Curt A. Wiberg

ACKNOWLEDGEMENTS

My sincere appreciation is extended to Drs. Jared Verner, S.D. Smith and Mr. C. Wiberg for their encouragement, inspiration, critical suggestions and support. My thanks are also given to Mr. L.C. Darlington, Connie Hutchison, and fellow graduate students who assisted in data processing, and to my former wife, V.C. Falkenbury, for editing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

An important aspect of avian ecology is the criterion used by birds to assess and select territories. It is assumed by some, that food availability is of utmost importance in these selections, and Gibb (1956, 1960), Root (1967), and Wiens (1969) have made detailed analyses of avian exploitation of food sources in intertidal and terrestrial habitats. With the exception of limited attempts by Horak (1970), Kale (1965) and Orians and Horn (1969), no studies regarding the differences in food availability of territories established by marsh birds have been made. The following paper reports a portion of research being done to assess invertebrate abundance and biomass in marshes in relation to bird utilization and mating success. Data from studies by Kale (1965), Orians and Horn (1969), Verner (1964, 1965), Verner and Engelsen (1970), and Verner and Willson (1966) based on avian mating success indicate certain territories are better than others and they have implied a need for studies of this type. To assess territory quality on the basis of food availability, accurate quantitative sampling techniques useful in marsh habitats are needed.

Extensive comparisons of terrestrial invertebrate sampling techniques and methods have been made by Lewis and Taylor (1968), Macfadyen (1962), Menhinick (1963), and Southwood (1968). Pearson and Kramer (1969) compared two methods for collecting drift organisms in streams, and Needham and Usinger (1956) evaluated the effectiveness of a surber sampler in Prosser Creek, California. Cook and Horn (1968), Falkenbury and Verner (1970), Horak (1970), Judd (1953, 1957, 1960, and

1964), Kale (1965), Lewis and Taylor (1968), Orians (unpub.), and Southwood (1968) have attempted to quantitatively sample the standing crop of invertebrates in dense marshes using various techniques. Most of their methods met with varying success depending on the exact habitat and organisms being sampled, but few of the methods were compared to evaluate their reliability as accurate sampling devices. Marsh habitats have not been sampled to a greater extent because of the difficulties in devising adequate sampling methods.

According to Menhinick (1963) there are three fundamentally different procedures for estimating population density: (1) mark and recapture, (2) total counts from a limited area, and (3) removal trapping. Removal trapping was used throughout this study for estimating marsh invertebrate density. The mark and recapture method was unfeasible because of the size of the organisms being sampled and the lack of good methods for marking aquatic invertebrates. Brusven (pers. comm.) has been successful in marking stonefly naiads for distribution work in Idaho streams, but the mark lasts only a short time and may attract predators. I have tried using a 2 cubic meter tenting device similar to those described by Kale (1965), Menhinick (1963) and Southwood (1968) to obtain total counts of invertebrates from a limited area of marsh, but problems of fumigation, collection of fallen specimens from the water surface, and the bulk of the device precluded its effectiveness in this study.

The present study was designed to develop, compare, and evaluate three methods for quantitatively sampling the invertebrate standing crop on the water surface of dense cattail (Typha latifolia) marshes at 19 sites around the periphery of Caliche Lake in Grant County, Washington.

An additional aspect of this study was to determine the variability among the sites relative to the abundance and biomass of the invertebrate organisms collected. The methods resulted from three summers of experimentation with various sampling techniques, both original and previously known. Methods that appeared to offer the best assessment of surface invertebrate abundance in marsh habitats were chosen for evaluation of their effectiveness as quantitative sampling devices.

STUDY AREA

Caliche Lake is an eight-year-old pothole lake that resulted from the elevated water table created by the Columbia Basin Reclamation Project. It is located in the sagebrush (Artemisia tridentata) and bunchgrass (Agropyron spicatum) zone of the Columbia River Basin approximately 4 miles southwest of George, Grant County, Washington, along Interstate Highway 90.

Temperatures in this area range from -7° C (mean minimum) in January to 33.5° C (mean maximum) in July (Franklin and Dyrness, 1969). The snow is often 20 to 30 cm deep and some portions of the lake freeze to a depth of 8 cm. Strong winds are frequent in summer and rainfall is 29 mm or less during the months of June, July and August (Franklin and Dyrness, 1969).

The entire lake, including its marshes, is 1450 m in length and lies in a nearly north-south direction. The lake is divided lengthwise into three sections arbitrarily designated I, II, and III (Fig. 1). The center section (II) is set apart from the northern section (I) by an earth-fill dam. A small stream at the west end of the dam connects the two sections. The southern section (III) of the lake is removed from section II by 325 m of extensive cattail marsh. These two areas are connected by a small stream.

The peripheral marsh of section II served as the study area. This section was approximately 590 m in length with an open water area of 5.4 hectares. Cattail dominated the periphery of the lake; some areas of cattail measured 24 m from the shore to the open water while

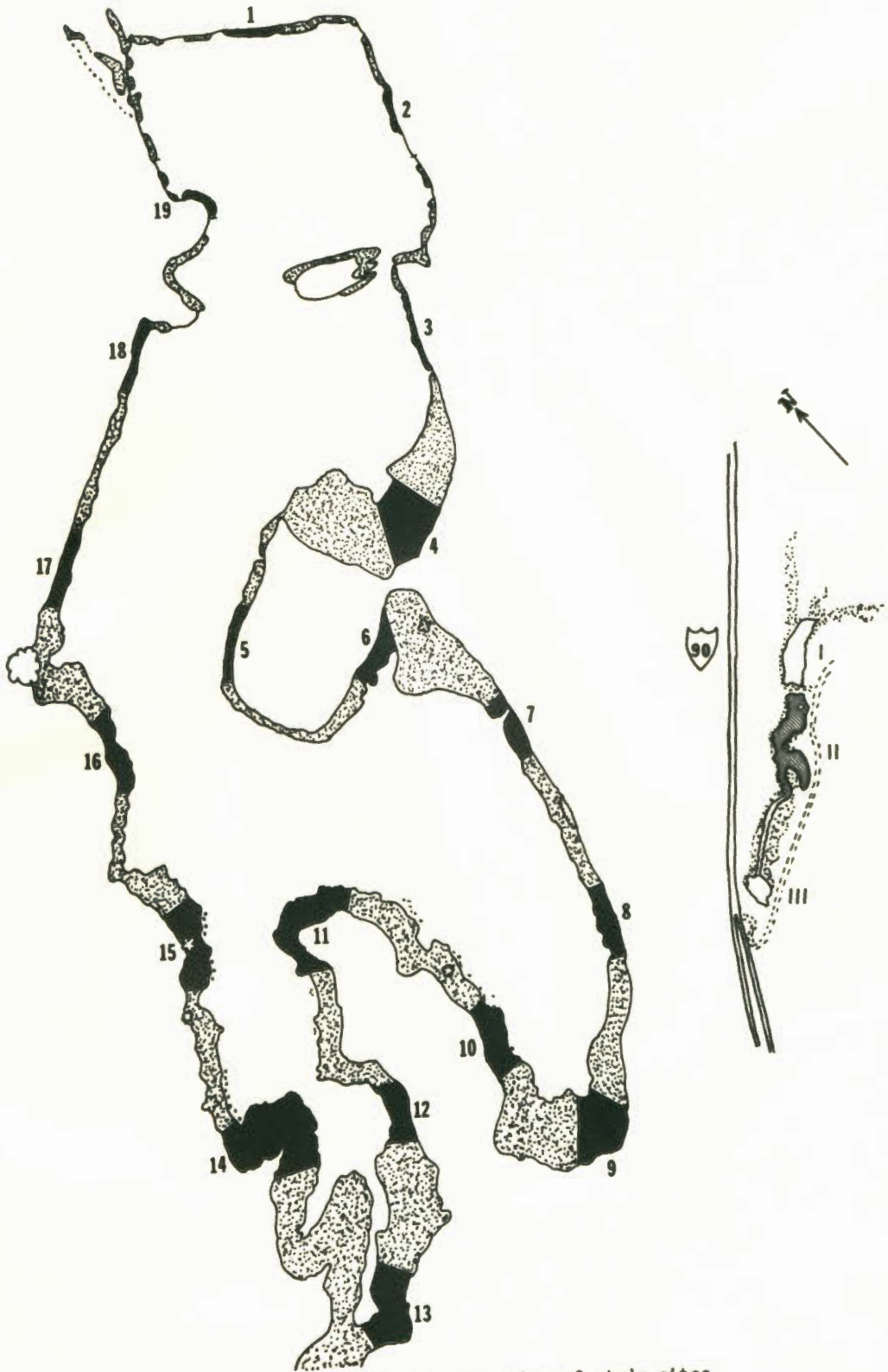


Fig. 1 Caliche Lake II. Location of study sites.

other areas were sparsley vegetated or barren of any emergent vegetation. The average width (shore to open waters) of cattail stands in the study area was 7.7 m. New Typha growth was not apparent until 1 April 1969; prior to this, all standing vegetation was dead and left standing from previous years. By 24 April 1969, some new growth had reached a height of 0.9 m. Several willows (Salix sp.) dotted the study area, and a single stand of bulrush (Scirpus sp.) occupied a 15 m portion of marsh on the west side of the study area.

On 1 April 1969 the average water depth for the marsh was 21 cm but this had decreased to 19 cm by 25 June 1969. An increase of 1 cm was noted on 9 July 1969, and this level remained constant for the duration of the study.

METHODS

Field work was begun on 16 April 1969 and completed 17 July 1969; a total of 14 weeks. Collecting was done three days each week while the remaining four days were used to sort, identify and count specimens.

Nineteen study sites were established around the peripheral marsh of Caliche Lake (II), each 30 m in length measured along the shoreline (Fig. 1). Each site was separated from neighboring sites by a distance of 60 m. The average width of these sites was determined by averaging several transects run from the shore to the last stand of vegetation on the open water side of the site. The area of each site was estimated by multiplying the average width by the average of the inside and outside lengths of each site.

Site facing directions, relative to the open water, were determined with a Leupold "sportsman" compass. Water depths were taken along the open water periphery of each site at the beginning of the study, and any variation that occurred during the study was noted on a yardstick sunk into a depth of 9 inches along the open water edge of site #4.

Twenty light intensity readings were taken in each site once during the study, on 4 and 5 July 1969, between the hours of 0900 and 1300 PST. This time was chosen because the sun was near its zenith between these hours. These readings were taken randomly (see Southwood, 1968) with a General Electric Type DW-68 photographic light meter aimed in a northerly direction, six inches above the water surface.

Meterological parameters of cloud cover, wind direction, wind velocity, and precipitation based on my judgement were noted five times each collecting day between the hours of 0900 and 1800 PST. Air temperature was recorded on an automatic recording thermometer placed adjacent to site #7 on the east side of the lake during a 60 hour period each week.

The floating debris cover in each site was approximated by using the microplot technique outlined by Daubenmire (1968) for terrestrial plant cover analysis. The floating debris consisted mainly of dead leaves and stalks of cattail deposited on the water surface from previous years. Twenty microplots were located randomly in each site at the beginning of the study. The method of randomness followed that outlined by Southwood (1968).

COLLECTING METHODS

Emergence Traps (ET)

One emergence trap constructed from hog fencing and fiberglass screening according to the technique described by Cook and Horn (1968) was approximately centered along the open water edge of each of the 19 study sites. Each trap was placed over cattail stems standing from previous years, clipped to a height of 12 inches above the water surface. As new growth occurred beneath each trap, it was clipped back to this height. Stalk counts were made beneath each trap at the beginning and end of the study.

All traps were emptied of captured specimens two consecutive

days per week,[1] between the hours of 1600 and 1900 PST in a clockwise direction around the lake beginning with site #1. All specimens with the exception of the Nematocera (Diptera) were preserved in 80% ethyl alcohol and labeled as to trap site, date, time of collection, and weather conditions. Water temperatures were recorded at each trap site at the time the trap was emptied. All Nematocera present in the traps were counted and arbitrarily classed according to size, based on the following scale:

small:	0 - 4 mm	total length
medium:	4 - 8 mm	total length
large:	8 + mm	total length

Floating Debris (FD)

Pieces of floating debris were collected along one randomly selected transect (see above) in each of the 19 study sites once each week for the duration of the study. The collecting period lasted approximately four hours, between the hours of 0830 and 1230 PST. The initial starting site was randomly chosen at the beginning of the study and the following week a site ten sites from the initial starting site was chosen as the starting site. Each week the next higher numbered site was chosen, and these sites were alternated between opposite sides of the lake each week. For example:

Week 1 - site #4	Week 2 - site #14
Week 3 - site #5	Week 4 - site #15
Week 5 - site #6	Week 6 - site #16

The initial starting direction was clockwise and this direction was

---

[1]Traps were collected only 1 day on weeks 9 and 13 because high winds swamped several traps. The weights taken these weeks were doubled (x2) in all biomass calculations to account for loss of 1 day's collection.

reversed every other week. This system varied the time of collection at each site over the four-hour collecting period.

Ten pieces of floating cattail leaves and/or stems were picked from the water surface along each random transect beginning at the shore and continuing to the open water side of each site. Each of these pieces was chosen as randomly as possible along the transect, though some selectivity was necessarily involved. The length of each piece of floating debris was approximately ten cm and longer pieces were clipped with scissors to approximately this length.

Each piece of vegetation was placed in a freezer jar containing 80% ethyl alcohol for further analysis in the laboratory. Undoubtedly some specimens were lost by this method, but presumably the losses were approximately the same for each site. Each jar was labeled according to site number, date, and time of collection.

Water temperatures were taken with a standard centigrade thermometer at a depth of 4 cm at the first and last collection sites and at several other sites as well. These readings were taken halfway between the shore and the open water.

All contents of each collecting jar were poured into a white-bottomed dissecting tray and all organisms were carefully picked out and kept for identification and counting. The vegetation was then split along a horizontal plane to extract any specimens lodged in the mesophyll. Specimens were identified to family using standard keys. All specimens of a given taxon were counted and the length of each was recorded. All specimens were saved for weighing at the completion of the study.

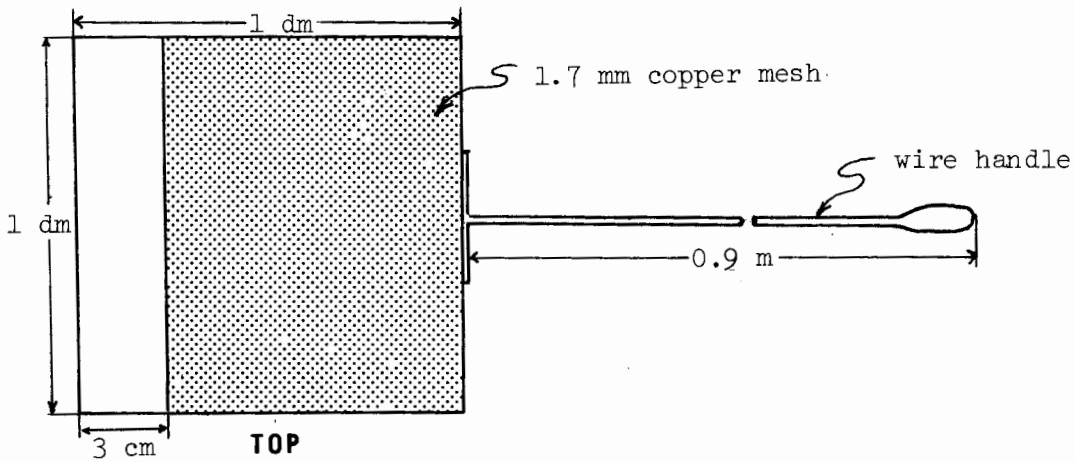
The area of each piece of floating debris was calculated. These

areas were summed for each study site to obtain a total area for the collected floating debris. From these figures an estimate of the total population of any single family could be made for any given site on any collecting day because the total floating debris coverage in each site had been estimated.

Open Water (OW)

A modified tea strainer 1 dm^2 was used to sample the small patches of open water between bits of floating debris. This strainer was designed in such a way that, with practice, the collector could sample an open water area of 1 dm^2 to a depth of 1 cm. The strainer was constructed from a 3 cm wide strip of 16 ga galvanized sheet metal bent into a three-sided square with 1.7 mm mesh copper screening attached to the lower edge as a bottom for the strainer. Another 3 cm galvanized strip was attached horizontally across the front on the bottom of the scoop for additional strength. When completed, the strainer resembled a household dustpan with a screen bottom (Fig. 2). A wire handle 0.9 m in length was attached to the scoop and this was bent in such a way that the collector could hold the scoop at his side while standing almost upright and the scoop bottom would be parallel to the water surface.

Ten scoop samples were made in each site each week along a randomly selected transect extending from the shore to the open water edge. The route scheme for moving around the lake and the procedure for choosing transects was similar to that described above for floating debris samples. Each scoop sample was placed in a plastic dissecting tray, care being taken to ensure that all organisms were removed from



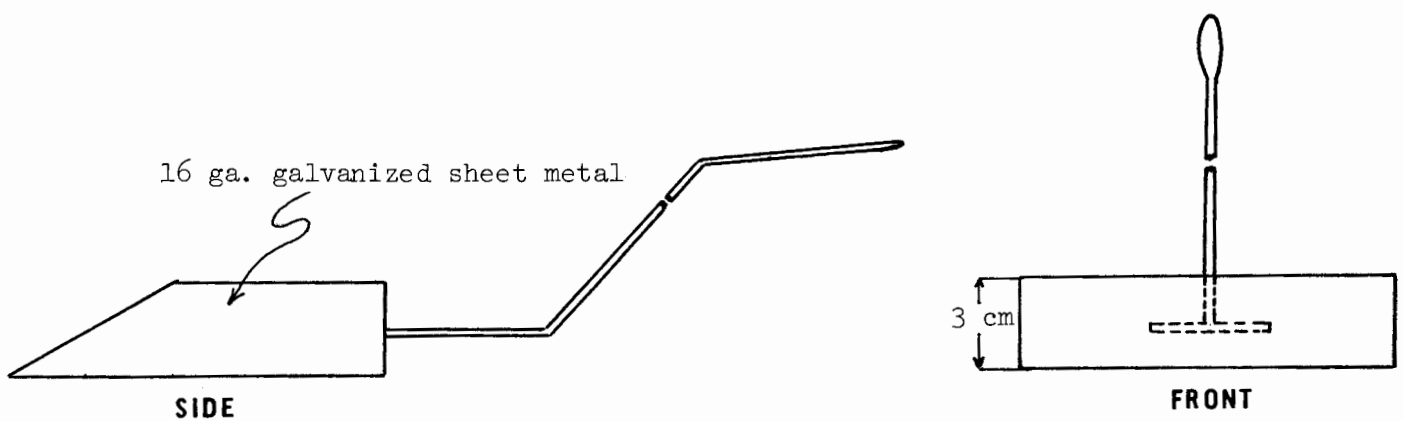


Fig. 2 Detail of open water sampler.

the scoop before the next sample was taken. All specimens were placed in 80% ethyl alcohol. Any specimens less than 2 mm in any dimension were discarded because they could slip through the screen bottom of the sampler, thus affecting accurate counts.

A one-minute pause was taken between scoops to allow the water surface to settle and any disturbed organisms to stabilize their activities. Care was taken to avoid shadows on the water surface. Samples were taken between the hours of 0800 and 1300 on the day following the floating debris samples. Specimens were later identified to family, measured for length, and placed in fresh 80% ethyl alcohol for weighing at a later time.

Weighing

Approximately 1265 weighings were made on a Mettler Analytical balance #B-5 with an optical accuracy of 0.05 mg and a weighing accuracy of ± 0.0001 mg, based on ten weighings of the same object. These weighings were conducted at the completion of the field work to determine the biomass of the specimens collected with each technique at the various sites. The following procedure was used for all weighings:

Excess ethyl alcohol was decanted and vials of specimens were placed in a Labline drying oven set at 100° C for no less than 24 hours. This time length was determined by taking the largest single sample and weighing it at eight-hour intervals until no further weight loss was noted. The specimens were discarded at the completion of the weighing as rehydration was not feasible. All weights were recorded in mg/cm^2 of sample surface.

Nematocera noted in the emergence traps were not collected and

could not be weighed. The approximate weights of these were determined by drying and weighing several individuals from each size category to obtain an average weight for individuals within a specific category. This average weight was applied to all specimens counted in the emergence traps.

To account for the possibility of snail shells biasing the final comparisons of techniques based on biomass (Needham and Needham, 1962) all samples were weighed with and without snails over 6 mm in length. All subsequent statistical calculations were made once with snails included and once without them. Adult Gyrinidae, Gerridae, Notonectidae, Corixidae, Dytiscidae, and Hydrophilidae were taken only sporadically in the OW samples because of their elusive behavior, therefore, these families were discarded from the weighed samples.

Data Analyses

The Spearman Rank Correlation was used to test the relationships among the three sampling methods. Two comparisons were made: (1) Correlations were determined with sites ranked according to the biomass taken each week at each site by each technique. (2) Correlations were determined with the collecting weeks ranked according to the biomass taken at each site each week for each technique. The Spearman test is robust (Owen, pers. comm.) consequently, $P \leq 0.10$ was chosen as indicating a significant correlation.

As a simple, though crude, means of determining whether or not different sites vary significantly in captured biomass, statistics have been applied on the assumption that sites of equal biomass yield should produce samples in excess of one another about an equal number of times.

For example, if Sites 1 and 2 were equivalent, we would expect the sample at Site 1 to exceed that at Site 2 in approximately 7 of 14 cases. Ideally, they should yield equal biomasses every time sampled, but the vagaries of sampling make this unlikely. The probability of Site 1 randomly exceeding Site 2 on 10 of 14 occasions is calculated by the expression:

$$\frac{14!}{10!\ 4!}\left(\tfrac{1}{2}\right)^{14} = 0.061$$

By the same formula, the probability of Site 2 randomly exceeding Site 1 on 11 of 14 occasions is only 0.002. Hence, it has been possible to examine the various site pairs to determine in which instances the biomass at one exceeded that at the other at least 11 of 14 times; yields at these sites are considered to be significantly different.

RESULTS

Numbers of Specimens

Tables 1, 2, 3, and 4 show the total number of specimens collected at each site, by family or higher taxon, for each technique over the 14-week collecting period. With all techniques employed, most specimens, both adult and immature insects plus other invertebrates, were taken from Site 18, while the fewest were collected from Site 9. Between the three techniques, the FD method consistently yielded the greatest numbers of specimens. In terms of specimens taken by each sampling technique, the FD method gave the highest immature (I) insect yield in Site 16 while Site 5 yielded the most adult (A) insects. The fewest immature insects taken by the FD method were taken at Site 9 and the fewest adult insects were collected at Site 8. The most invertebrates other than insects were collected at Site 2 and the least number were taken at Site 12. The greatest number of insects (I and A) plus other invertebrates were collected at Site 2 and the least were taken in Site 12. The ET data show Site 6 to have yielded the greatest number of emerging insects and Site 3 produced the lowest number. By the OW technique, most immature and adult insects were taken from Site 9 while the lowest immature insect yield was taken in Site 2 and the least number of adult insects were taken in Sites 6, 8, 10, and 17; none were taken in Sites 1, 2, 3, 4, 11, 16, 18, and 19. The greatest number of invertebrates other than insects were taken in Site 1 and the lowest yield was taken in Site 9. The highest yield of insects (I and A) plus other invertebrates was taken from Site 1 and the lowest from

Table 1

Total numbers of specimens (teneral and adult) by taxon taken at each site by ET method (n=26)

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total	Mean
Aeshnidae	5	16	6	-	4	4	4	8	-	-	2	1	-	-	-	3	2	6	2	63	3.31
Coenagrionidae	190	223	74	147	136	146	226	276	67	166	188	112	49	212	231	379	249	186	213	3470	182.63
Lestidae	-	-	-	-	-	-	-	-	1	3	2	6	-	2	6	2	-	1	-	23	1.21
Baetidae	15	14	38	141	57	90	87	62	63	175	98	96	82	69	95	66	90	91	24	1453	76.47
Caenidae	-	-	-	-	-	-	1	2	-	-	6	1	-	-	-	-	-	-	-	10	0.52
Leptoceridae	-	-	-	-	-	-	3	6	1	4	2	5	1	4	9	-	1	-	1	37	1.94
Limnephilidae	1	-	-	-	-	-	-	-	-	-	-	1	-	-	1	2	1	-	1	7	0.36
Unid. Trichoptera	-	-	1	-	1	-	-	2	-	1	-	1	1	4	8	4	1	-	-	24	1.26
Unid. Nematocera	128	192	177	368	409	909	374	476	265	797	604	515	695	578	670	548	674	500	128	9007	474.05
Tabanidae	-	1	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	4	0.21
Empididae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	0.10
Dolichopodidae	-	1	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	4	0.21
Syrphidae	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	0.10
Otitidae	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	0.10
Sciomyzidae	-	2	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	4	0.21
Sphaeroceridae	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	0.05
Ephydridae	53	54	30	63	48	41	21	40	25	27	25	23	13	28	39	40	55	35	23	683	35.94
Anthomyiidae	-	-	-	-	-	1	-	2	1	-	2	-	-	2	1	-	2	1	1	13	0.68
Muscidae	1	-	-	1	1	-	1	1	2	1	-	-	-	1	1	-	1	-	-	11	0.57
Unid. Diptera	-	-	-	1	-	-	-	-	2	-	-	3	1	1	-	-	-	1	1	10	0.52
Unid. Hymenoptera	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	3	0.15
Total Emergent Insects	393	503	326	723	658	1193	717	878	429	1175	931	764	842	902	1061	1094	1076	821	397	14833	780.57

Table 2

Total numbers of specimens by taxon taken at each site by OW method (n=14)
A = adult I = immature

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total	Mean
Aeshnidae	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	0.05
Unid. Anisoptera(I)	-	1	-	-	-	-	1	1	-	-	1	1	-	-	-	-	-	1	1	7	0.36
Coenagrionidae(I)	2	1	-	1	1	5	1	-	4	-	1	-	2	1	-	3	1	3	3	29	1.52
Lestidae(I)	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	2	0.10
Unid. Zygoptera(I)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	0.05
Baetidae(I)	4	5	13	7	18	26	18	2	14	7	12	15	-	10	10	7	6	4	12	190	10.00
Dixidae(I)	1	-	-	2	-	-	-	1	-	1	1	-	-	-	1	2	-	-	-	9	0.47
Culicidae(I)	-	-	-	1	1	14	1	-	46	-	-	-	-	2	-	-	-	3	-	68	3.57
Ceratopogonidae(I)	-	1	-	2	-	3	2	2	-	-	2	-	1	1	-	-	-	-	1	15	0.78
Chironomidae(I)	67	27	43	63	29	30	45	45	17	15	23	8	7	21	20	55	61	62	39	677	35.63
Unid. Diptera(I)	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	0.05
Corixidae(I)	1	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	3	0.15
Notonectidae(I)	6	2	1	1	2	5	5	10	-	7	11	10	5	4	4	6	2	3	13	97	5.10
Gerridae(I)	3	2	-	2	7	4	2	12	4	16	10	14	17	12	6	13	3	2	9	138	7.26
Veliidae (A)	-	-	-	-	2	1	3	1	25	1	-	3	4	5	18	-	1	-	-	64	3.36
" (I)	-	1	1	2	2	1	-	12	40	11	10	39	23	15	20	15	1	3	10	206	10.84
Unid. Gerroidea(I)	-	-	-	-	-	-	-	2	6	-	-	1	-	4	9	2	1	1	-	26	1.36
Mesoveliidae(I)	1	5	4	2	6	2	-	2	-	1	2	3	1	-	2	1	9	6	12	59	3.10
Hebridae(A)	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	0.05
Unid. Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	3	0.15
Hydrophilidae(I)	4	-	5	3	-	1	5	7	4	3	2	-	-	1	1	1	-	3	1	41	2.15
Helodidae(I)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	0.05

Table 2 (Continued)

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total	Mean
Unid. Coleoptera(I)	-	-	-	3	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	6	0.31
Unid. Insecta(I)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	2	0.10
Insect Totals (A)	0	0	0	0	2	1	4	1	25	1	0	3	4	5	18	0	1	0	0	65	
(I)	89	45	67	89	66	92	80	99	137	62	76	93	56	73	75	106	84	91	102	1582	
Total Insects	89	45	67	89	68	93	84	100	162	63	76	96	60	78	93	106	85	91	102	1647	86.68
Planariidae (Tricladida)	3	4	5	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	2	16	0.84
Daphnidae (Cladocera)	40	9	15	13	38	84	64	39	3	28	17	31	29	16	30	9	32	13	4	514	27.05
Ostracoda	42	11	3	3	7	2	2	-	-	-	3	2	1	4	8	8	10	13	86	205	10.78
Talitridae (Amphipoda)	36	7	59	12	17	25	19	13	3	13	30	10	5	8	12	23	15	53	26	386	20.31
Acarina	2	-	-	-	-	-	2	-	1	-	-	-	-	-	1	-	-	-	1	7	0.36
Araneida	2	2	1	-	1	-	1	2	-	-	-	-	3	-	1	2	-	-	1	16	0.84
Physidae	129	30	75	16	44	65	11	11	13	15	9	6	8	14	22	52	58	28	45	651	34.26
Lymnaeidae	4	-	-	-	1	9	11	6	12	24	1	1	1	-	1	4	2	-	3	80	4.21
Planorbidae	-	-	-	1	-	-	-	-	-	2	2	-	2	-	-	1	-	-	-	8	0.42
Unid. Gastropoda	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.10
Unid. Egg Masses	5	3	4	1	1	2	-	3	5	-	3	-	1	-	-	4	2	3	4	41	2.15
Unidentified	4	-	-	-	3	-	9	-	-	-	-	-	1	-	-	-	-	-	-	17	0.89
Inverts other than insects	268	66	162	46	112	189	119	74	37	82	65	50	52	42	75	103	119	110	172	1943	102.26
Total other inverts and Insects	357	111	229	135	180	282	203	174	199	145	141	146	112	120	168	209	204	201	274	3590	188.94

Table 3

Total numbers of specimens by taxon taken at each site by FD method (n=14)
A = adult I = immature

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total	Mean
Aeshnidae (I)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	0.10
Unid. Anisoptera(I)	4	3	-	4	3	1	2	1	1	3	4	3	1	3	4	4	3	2	5	51	2.68
Coenagrionidae(I)	15	16	11	10	9	9	12	5	4	6	3	11	14	4	8	12	9	9	17	184	9.68
Lestidae (I)	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.05
Baetidae (I)	2	-	2	1	-	2	-	-	-	1	1	1	3	2	2	-	4	1	11	33	1.73
Tipulidae (I)	-	-	-	-	-	-	-	-	5	1	-	-	1	-	-	-	-	-	-	7	0.36
Dixidae (I)	-	2	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	3	8	0.42
Culicidae (I)	-	-	-	1	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	5	0.26
Ceratopogonidae(I)	21	29	14	61	15	63	23	13	45	24	18	24	45	51	27	17	37	32	31	590	31.05
Chironomidae (I)	406	397	427	595	770	685	618	559	335	519	587	543	349	575	499	756	681	748	427	10476	551.36
Stratiomyidae (I)	-	-	-	2	-	3	-	-	-	-	-	1	-	-	-	-	-	-	-	6	0.31
Dolochopodidae (I)	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	0.05
Unid. Diptera (I)	5	1	-	-	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-	9	0.47
Corixidae (I)	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	0.10
Gernidae (I)	-	-	-	-	-	-	-	1	-	-	-	-	2	2	1	-	-	-	-	6	0.31
Veliidae (I)	-	-	-	-	-	-	1	1	2	-	-	1	3	2	2	-	1	-	-	13	0.68
Unid. Gerroidea(I)	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	0.10
Mesoveliidae (I)	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	3	0.15
Hebridae (A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0.05
Haliplidae (A)	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.10
" (I)	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	4	0.21
Dytiscidae (A)	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	4	0.21
" (I)	-	-	-	-	-	2	-	1	1	1	1	-	-	1	-	-	-	2	1	10	0.52

Table 3 (Continued)

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total	Mean
Hydrophilidae (A)	9	3	9	2	13	4	4	2	11	5	3	5	6	11	4	12	10	8	8	129	6.78
" (I)	64	68	75	69	70	102	81	68	76	66	80	63	73	85	77	106	65	84	36	1408	74.10
Unid. Coleoptera(A)	1	-	-	1	-	-	-	-	-	-	1	-	2	-	-	-	2	1	1	9	0.47
" (I)	-	-	1	-	-	-	-	-	1	-	-	-	-	-	3	-	1	-	-	6	0.31
Unid. Insecta (I)	-	-	-	1	4	-	-	1	2	-	-	2	-	1	1	-	-	-	-	12	0.63
Insect Totals (A)	10	4	9	4	14	5	4	2	11	5	4	5	8	12	5	12	12	9	10	145	7.63
(I)	518	517	533	745	872	869	737	651	474	622	697	649	492	726	625	896	801	881	533	12838	675.68
Total Insects	528	521	542	749	886	874	741	653	485	627	701	654	500	738	630	908	813	890	543	12983	683.31
Hydra	-	1	-	-	1	-	-	-	-	-	-	-	1	-	-	-	1	3	1	8	0.42
Planeriidae (Tricladida	319	273	124	41	82	4	1	5	4	1	19	35	83	27	17	73	132	136	135	1511	79.52
Nematoda	12	-	-	3	5	10	5	1	36	3	6	20	-	5	3	2	6	16	-	133	7.00
Hirudinea	-	-	-	3	-	4	-	3	22	3	-	-	2	-	2	-	-	-	1	40	2.10
Daphnidae (Cladocera)	1	1	-	3	2	7	6	4	1	2	6	1	1	2	1	1	4	-	-	43	2.26
Ostracoda	421	270	87	80	77	61	-	-	11	4	40	32	60	31	41	87	104	366	252	2024	106.52
Cyclopidae (Copepoda)	-	11	-	9	10	17	9	10	16	25	7	12	8	2	10	13	13	21	11	204	10.73
Telitridae (Amphipoda)	349	769	362	744	599	507	379	605	232	320	436	178	247	354	484	384	411	710	515	8585	451.84
Acarina	1	1	-	1	-	-	2	5	6	3	-	-	-	3	-	-	1	-	-	23	1.21
Araneida	2	2	-	2	1	1	-	3	2	-	2	6	-	3	2	1	-	1	1	29	1.52
Physidae	1427	1541	599	352	410	258	101	93	133	135	161	109	293	191	171	471	822	1053	530	8850	465.78
Lymnaeidae	3	1	-	2	4	37	210	117	75	202	24	10	5	5	8	19	6	4	-	732	38.52
Planorbidae	-	-	-	9	1	6	3	7	8	13	2	9	53	28	4	3	1	2	-	149	7.84
Unid. Egg Masses	92	53	86	65	68	66	38	51	76	50	38	39	82	41	38	50	65	30	113	1141	60.05
Unidentified	1	-	-	-	-	-	1	-	-	-	-	1	1	1	-	-	-	-	-	5	0.26
Inverts other than Insects Totals	2628	2923	1258	1314	1260	978	755	904	622	761	741	452	836	693	781	1104	1566	2341	1559	23476	1235.57
Grand Total (FD) other inverts and Insects (I & A)	3156	3444	1800	2063	2146	1852	1496	1557	1107	1388	1442	1106	1336	1431	1411	2012	2379	3231	2102	36459	1918.89

Table 4

Total specimens taken by each technique at each site
A = adult I = immature

Technique	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Emergence Traps	393	503	326	723	658	1193	717	878	429	1175	931	764	842	902	1061	1044	1076	821	397	14833
Floating Debris																				
(insects) A	10	4	9	4	14	5	4	2	11	5	4	5	8	12	5	12	12	9	10	145
I	518	517	533	745	872	869	737	651	474	622	697	649	492	726	625	896	801	881	533	12838
Total Insects	528	521	542	749	886	874	741	653	485	627	701	654	500	738	630	908	813	890	543	12983
Inverts other than insects	2628	2923	1258	1314	1260	978	755	904	622	761	741	452	836	693	781	1104	1566	2341	1559	23476
Total insects and other inverts	3156	3444	1800	2063	2146	1852	1496	1557	1107	1388	1442	1106	1336	1431	1411	2012	2379	3231	2102	36459
Open Water																				
(insects) A	-	-	-	-	2	1	4	1	25	1	-	3	4	5	18	-	1	-	-	65
I	89	45	67	89	66	92	80	99	137	62	76	93	56	73	75	106	84	91	102	1582
Total Insects	89	45	67	89	68	93	84	100	162	63	76	96	60	78	93	106	85	91	102	1647
Inverts other than insects	268	66	162	46	112	189	119	74	37	82	65	50	52	42	75	103	119	110	172	1943
Total insects and other inverts	357	111	229	135	180	282	203	174	199	145	141	146	112	120	168	209	204	201	274	3590
Grand Total	3906	4058	2355	2921	2984	3327	2416	2609	1735	2708	2514	2016	2290	2453	2640	3265	3659	4253	2773	54882

Site 2 by the OW method.

Biomass

Tables 5, 6, 7, 8 and 9 show the biomass (mg/m^2 OW, FD, and $mg/2m^2$ ET sample surface) of each sample taken weekly, by site, and totals by week and site taken by each of the sampling methods.

The greatest biomass was taken by the FD method. The ET method was next in biomass yield, while the OW technique showed the lowest biomass taken by the three methods.

For each technique, the maximum weight yield occurred either on the 9th or the 10th week, except FD without snails, which had its highest weight yield during week 14. The lowest biomass for each technique centered around weeks 1 and 2 except the FD series, with and without snails, which showed their lowest points during week 3.

Over the 14-week collecting period, Site 2 ranked first in biomass taken by the FD method with and without snails. Site 1 ranked first for OW technique with snails and Site 7 ranked first without snails. Site 16 was first in biomass yield for the emergence traps.

The lowest yield for the FD method, both with and without snails, was taken in Site 12. Site 2 was lowest for OW technique both with and without snails, while lowest yield for the emergence traps was taken at Site 13.

Data totals from Tables 5, 6, 7, 8 and 9 are graphically represented in Figures 3 and 4.

Correlations

Of a total of 114 calculated correlations (Table 10) among the various techniques at each site, based on ranks of the 14 weekly biomass

Table 5

Biomass (mg/2m^2 sample surface) taken weekly by ET method

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Total
1	21	26	40	52	41	34	168	402	366	848	145	96	124	121	2484
2	32	50	55	767	64	60	175	377	605	746	353	180	452	107	4023
3	18	29	32	25	35	68	24	187	132	433	43	76	548	173	1823
4	72	54	76	38	201	124	134	156	312	160	88	167	200	145	1927
5	57	29	74	25	67	96	61	137	639	360	175	184	165	95	2164
6	52	60	145	137	129	239	47	265	395	201	190	219	159	108	2346
7	16	30	33	174	26	118	111	566	316	515	56	256	175	505	2897
8	4	9	96	95	66	186	109	388	982	655	343	362	237	417	3949
9	16	113	83	73	31	89	194	111	22	92	23	23	52	8	930
10	70	106	97	149	209	118	139	331	817	224	45	175	122	218	2820
11	22	56	124	144	88	115	68	289	612	377	118	159	270	123	2565
12	67	51	75	36	91	42	42	125	88	143	183	140	129	135	1347
13	35	71	45	33	228	60	30	92	76	46	16	18	000	3	753
14	44	64	117	42	147	95	50	414	326	431	80	84	214	136	2244
15	37	146	52	59	179	107	123	470	509	457	86	105	63	233	2626
16	29	86	99	94	117	153	181	442	626	921	388	190	489	234	4049
17	65	86	22	54	89	168	69	439	705	450	26	227	354	260	3014
18	22	98	41	155	91	113	72	288	487	323	211	302	365	425	2993
19	29	40	11	22	35	80	54	178	555	792	116	71	93	33	2109
Total	708	1204	1317	2174	1934	2065	1851	5657	8570	8174	2685	3034	4211	3479	

Table 6

Biomass (mg/m^2 sample surface) taken weekly by OW method, w/o snails 6mm+

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Total
1	89	4	7	47	45	126	69	111	108	47	89	22	6	50	820
2	26	6	14	00	37	7	25	21	3	15	3	21	7	50	235
3	31	2	1	121	38	35	10	45	121	4	78	7	31	21	545
4	115	4	6	28	95	50	8	30	54	12	12	6	5	14	439
5	40	1	27	32	9	40	7	24	20	68	27	16	8	8	327
6	49	6	12	30	8	37	32	141	121	109	61	25	20	56	707
7	68	5	43	58	6	46	8	24	42	28	96	11	60	119	614
8	14	7	6	32	14	26	19	13	27	15	46	39	3	2	263
9	5	4	5	28	4	84	28	37	65	186	13	10	2	37	508
10	8	3	4	9	7	17	71	32	48	48	85	19	1	1	353
11	4	00	13	36	24	88	19	11	51	11	5	32	6	7	307
12	16	130	20	255	35	78	7	2	5	17	17	22	5	29	638
13	12	11	3	50	20	37	2	2	22	12	3	27	1	72	274
14	14	6	6	10	22	16	9	8	140	16	14	6	19	12	298
15	42	19	5	31	4	48	8	4	3	76	14	6	16	15	291
16	19	2	17	9	28	14	105	155	91	101	44	15	26	44	670
17	21	2	11	8	16	14	11	53	53	74	20	34	5	9	331
18	42	2	12	16	79	21	9	21	290	52	24	13	5	15	601
19	24	24	109	68	224	48	27	21	76	41	26	12	70	47	817
Total	639	238	321	868	715	832	474	755	1340	932	677	343	296	608	

Table 7

Biomass (mg/m^2 sample surface) taken weekly by OW method w/snails 6mm+

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Total
1	89	4	7	47	45	594	69	111	301	47	89	22	6	50	1481
2	26	6	14	00	37	7	25	21	3	15	3	21	7	50	235
3	31	2	1	121	38	133	10	45	121	290	357	7	31	21	1208
4	115	4	6	28	95	50	8	30	54	12	12	6	5	14	439
5	40	1	27	32	9	40	7	24	20	68	27	16	8	8	327
6	49	6	12	30	8	37	32	141	121	251	61	25	20	56	849
7	68	5	43	58	6	46	8	24	42	28	96	11	60	119	614
8	14	7	6	1167	14	26	19	13	27	15	221	39	3	2	1573
9	5	4	5	28	4	84	28	37	65	371	13	10	2	256	912
10	8	3	4	839	7	17	71	32	48	85	19	29	1	119	1282
11	4	00	13	36	24	88	19	11	51	11	5	32	6	7	307
12	16	130	20	255	35	78	7	2	5	17	17	22	5	29	638
13	12	11	3	50	20	37	2	2	22	12	3	27	1	634	836
14	14	6	6	10	22	16	9	8	140	16	14	6	19	12	298
15	42	19	5	31	4	48	8	4	3	76	14	6	16	15	291
16	19	2	17	9	28	14	105	155	91	101	44	15	26	44	670
17	21	2	11	8	16	14	11	53	53	74	20	34	5	9	331
18	42	2	12	16	79	21	9	21	290	52	24	13	5	15	601
19	24	24	109	68	224	48	27	21	76	41	26	12	70	47	817
Total	639	238	321	2833	715	1398	474	755	1533	1582	1065	353	296	1507	

Table 8

Biomass (mg/m^2 sample surface) taken weekly by FD method w/o snails 6mm+

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Total
1	4,000	900	2,000	3,100	1,500	3,400	8,000	7,900	3,000	2,600	10,800	1,500	2,500	7,800	59,000
2	2,200	9,000	1,000	1,500	3,800	3,200	4,800	3,600	4,100	4,500	9,100	6,800	10,600	7,400	71,600
3	2,100	500	1,500	1,000	800	1,400	2,300	1,800	2,900	3,600	7,200	2,400	4,500	3,400	35,400
4	900	400	2,900	1,200	4,600	2,300	2,600	2,900	2,400	1,700	1,000	3,200	2,600	1,700	30,400
5	3,000	1,300	100	1,200	2,300	1,800	1,800	2,400	4,100	3,400	3,800	4,200	5,700	5,300	40,400
6	1,900	3,400	1,100	3,500	2,500	2,900	1,800	4,200	6,200	1,100	3,200	2,200	2,300	3,900	40,200
7	1,700	300	900	2,000	1,400	1,700	1,200	1,400	2,900	2,200	2,100	4,400	2,000	6,700	30,900
8	600	5,800	1,300	2,500	3,600	1,600	2,600	1,000	2,700	1,400	1,300	2,000	3,600	3,200	33,200
9	1,100	1,200	800	1,200	1,700	1,000	4,100	2,200	2,500	2,700	1,800	1,500	500	1,200	23,500
10	500	1,000	1,500	1,400	2,900	2,100	1,700	3,200	2,000	2,100	2,800	1,000	2,600	2,400	27,200
11	1,100	1,400	400	2,500	700	2,100	800	2,100	2,000	2,500	1,000	2,200	3,100	2,100	24,000
12	200	1,800	900	500	800	1,300	2,700	900	2,100	900	900	1,300	1,700	1,500	17,500
13	1,100	500	2,100	700	2,700	1,400	2,900	2,400	1,400	2,300	700	2,000	2,200	4,100	26,500
14	1,400	300	1,600	1,300	2,300	2,500	2,000	600	3,300	1,500	1,700	1,300	1,500	1,800	23,100
15	1,200	1,500	600	1,800	3,300	1,500	1,400	1,100	2,200	1,800	300	2,300	2,200	2,400	23,600
16	2,100	600	1,100	3,300	1,700	2,300	700	2,400	1,500	3,900	1,000	3,200	2,100	2,400	28,300
17	1,200	200	1,400	3,400	1,900	3,500	3,700	1,100	4,300	4,300	2,900	1,900	2,300	3,300	35,400
18	1,800	1,800	4,100	1,800	3,200	1,700	4,000	1,800	4,400	4,600	3,800	3,700	3,900	6,400	47,000
19	1,900	1,900	3,500	2,800	15,100	4,100	4,100	1,800	2,300	1,200	2,100	3,500	2,100	2,600	49,000
	30,000	33,800	28,800	36,700	56,800	41,800	53,200	44,800	56,300	48,300	57,500	50,600	58,000	69,600	Total

Table 9

Biomass (mg/m^2 sample surface) taken weekly by FD method w/snails 6mm+

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Total
1	4,000	900	2,000	3,100	1,500	4,800	11,400	7,900	4,700	2,600	10,800	3,000	2,500	10,200	65,800
2	2,200	9,000	1,000	1,500	3,800	4,500	6,400	3,600	5,900	4,500	9,100	6,800	10,600	7,400	76,300
3	2,100	800	1,500	1,000	800	1,400	2,300	1,800	6,300	7,100	7,200	2,400	4,500	4,600	53,800
4	900	9,700	2,900	1,200	4,600	2,300	2,600	3,800	2,400	1,700	1,000	3,200	2,600	1,700	40,600
5	6,400	1,300	100	1,200	2,300	1,800	3,300	2,400	5,700	3,400	5,800	4,200	5,700	5,300	48,900
6	1,900	5,000	2,700	3,500	2,500	2,900	2,700	7,300	6,200	1,100	4,200	4,100	4,400	11,200	59,700
7	1,700	700	900	2,000	1,400	1,700	2,400	1,400	2,900	2,200	2,100	6,000	3,200	10,100	38,700
8	600	5,800	1,300	2,500	3,600	1,600	2,600	1,000	2,700	1,400	1,300	2,000	12,300	6,500	45,200
9	1,100	1,200	800	1,200	1,700	1,000	4,100	2,200	5,600	3,300	1,800	1,500	1,900	1,200	28,600
10	500	1,000	1,500	1,400	2,900	2,100	1,700	5,600	2,000	2,100	2,800	2,400	2,600	3,300	31,900
11	1,100	1,400	400	2,500	700	2,100	800	2,100	2,000	2,500	1,000	2,200	3,100	2,100	24,000
12	200	1,800	900	500	800	1,300	2,700	2,300	2,100	900	900	1,300	2,800	1,500	20,000
13	1,100	500	2,100	6,400	2,700	1,400	2,900	2,400	1,400	2,300	700	2,700	2,200	4,100	32,900
14	1,400	300	1,600	1,300	2,300	2,500	2,000	600	3,300	1,500	1,700	1,300	1,500	1,800	23,100
15	10,700	1,500	600	1,800	3,300	3,100	1,400	1,100	2,200	1,800	300	2,300	2,200	4,900	37,200
16	2,100	600	1,100	3,300	1,700	2,300	700	2,400	2,800	3,900	1,000	3,200	2,100	2,400	29,600
17	1,200	200	1,400	3,400	1,900	3,500	3,700	1,100	4,300	4,300	3,800	1,900	2,300	3,300	36,300
18	1,800	1,800	4,100	1,800	3,200	1,700	4,000	1,800	10,500	9,800	3,800	3,700	3.900	6,400	58,300
19	1,900	1,900	3,500	2,800	15,100	7,600	9,100	1,800	2,300	5,000	2,100	3,500	2,100	2,600	61,300
	42,900	45,400	30,400	42,400	56,800	49,600	66,800	52,600	75,300	61,400	61,400	57,700	72,500	90,600	Total

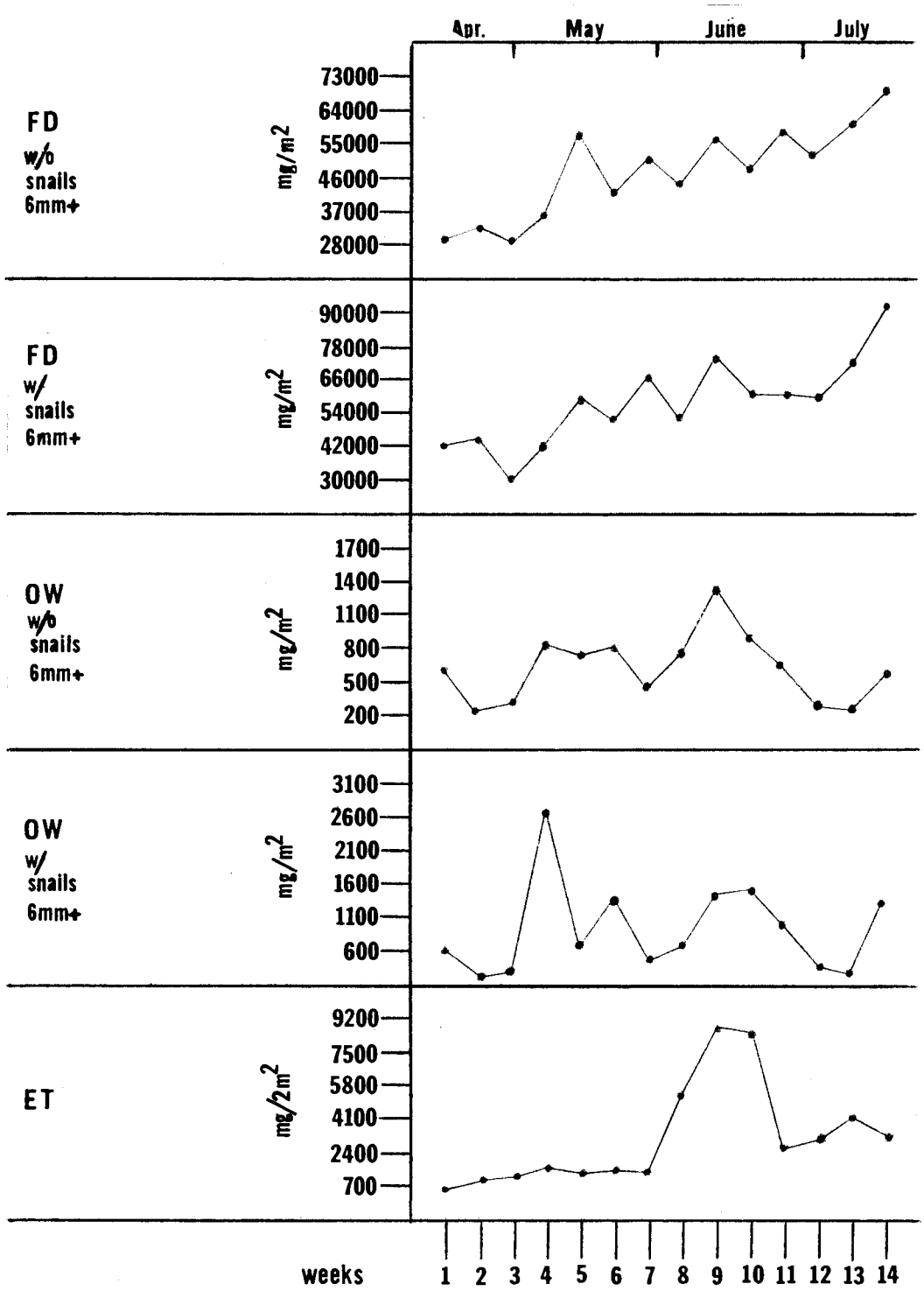


Fig. 3 Total biomass (mg/m^2, FD and OW; mg/$2m^2$, ET sample surface) taken at the 19 study sites by each technique each week.

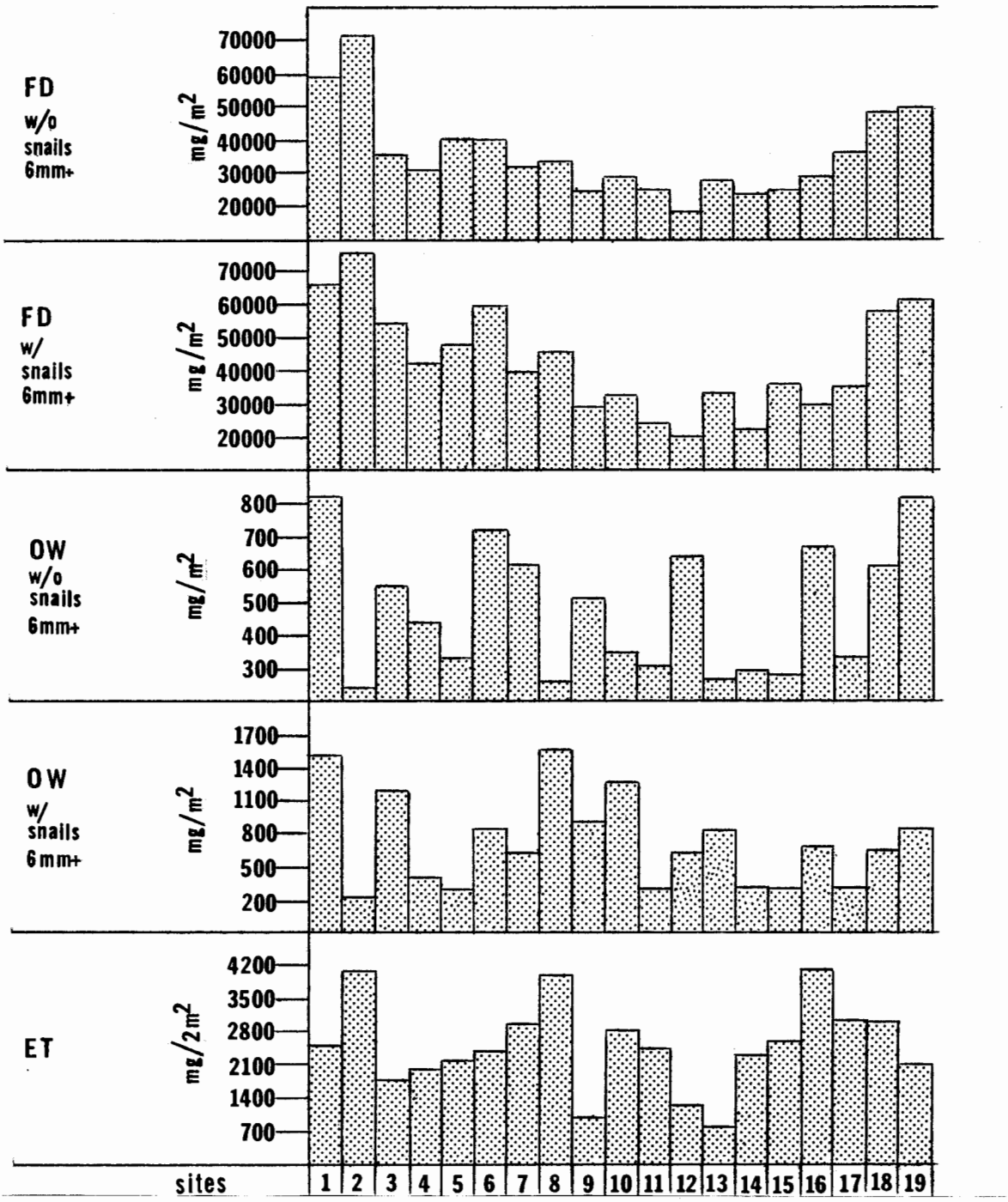


Fig. 4 Total biomass (mg/m^2, FD and OW; $mg/2m^2$, ET) taken during the 14 week collecting period at each site by each technique.

Table 10

Spearman Rank Correlation Coefficients of: FD vs ET, FD vs OW, ET vs OW in each case with and without snails 6 mm or more in length. Values are for each site ranked by weekly biomass totals. (R = 0.388, P = 0.10*; R = 0.462, P = 0.05**; R = 0.549, P = 0.02***; R = 0.608, P = 0.01****.)

Site	FD vs ET		FD vs OW		ET vs OW	
	w/	w/o	w/	w/o	w/	w/o
1	.420*	.377	.768****	.760****	.266	.271
2	.366	.438*	.105	.122	.420*	-.420
3	.466**	.561***	.366	.046	.274	.028
4	.297	.652****	-.357	.002	.141	.141
5	.479**	.725****	.029	-.315	.184	.184
6	.294	.322	.127	.344	.469**	.499**
7	.532**	.580***	.374	.500**	.064	.064
8	.057	-.063	-.295	-.261	.087	.136
9	.162	.218	.237	.504**	.014	.087
10	.441*	.349	.136	.215	.561***	.596***
11	.584***	.584***	.114	.114	.340	.340
12	.068	.182	-.486	-.383	-.328	-.328
13	-.212	-.701	.315	-.107	.048	.048
14	.225	.225	.648	.648****	.449*	.449**
15	-.024	.347	.204	-.087	-.339	-.339
16	.425*	.425*	.104	.104	.692****	.692****
17	.240	.319	.287	.269	.436*	.436*
18	.488**	.480**	.128	.058	.151	.151
19	-.136	-.421	.487**	.465**	-.205	-.205

captures, only 34 were significant at least at the 0.10 level. Only 25 were significant at least at the 0.05 level, 13 at the 0.02 level and 7 at the 0.01 level.

Sixteen significant correlations were found in the FD versus ET series, with (8) and without snails (8). At least one significant correlation was shown at 10 of the 19 sites. In the FD vs OW correlations, only seven were significant and at least one significant correlation was shown at five of the 19 sites. Eleven significant correlations were calculated in the ET vs OW series, and only six of 19 sites showed at least one significant correlation.

Of a total of 84 correlations calculated (Table 11) among the various techniques for each week, based on ranks of the total biomass captured at each of the 19 sites, only 8 were significant at least at the 0.10 level, and only one was significant at least at the 0.05 level. At least one significant correlation was obtained for only one week in the FD vs ET series, for three weeks in the FD vs OW series, and for two weeks in the ET vs OW series.

Site Differences

Comparisons of weekly biomass takes at the various sites according to the statistical procedure outlined above, indicate that many sites differ significantly (Table 12). For example, by the ET method, Site 2 > Site 1, 2 > 3, 6 > 12, 16 > 19, etc. By the FD method without snails 6mm+, Site 1 > Site 3, 5 > 12, 14 > 3, 19 > 15, etc. By the FD method with snails 6mm+, Site 1 > Site 10, 2 > 3, 18 > 11, etc. By the OW method without snails 6mm+, Site 1 > Site 3, 6 > 2, 19 > 17, etc. By the OW method with snails 6mm+, Site 1 > Site 4, 3 > 11, 19 > 4, etc.

Table 11

Spearman Rank Correlation Coefficients of: FD vs ET, FD vs OW, ET vs OW in each case with and without snails 6 mm or more in length. Values are for each week ranked according to biomass totals for each site. (R = 0.457, P = 0.10*; R = 0.545, P = 0.05**; R = 0.646, P = 0.02***; R = 0.716, P = 0.01****.)

Week	FD vs ET		FD vs OW		ET vs OW	
	w/	w/o	w/	w/o	w/	w/o
1	-.191	-.070	.539**	.508*	.073	.073
2	-.022	.117	.325	-.079	.201	.201
3	-.201	-.326	-.173	-.232	-.090	-.090
4	.190	.388	-.132	-.270	-.244	-.503*
5	.284	.284	.208	.208	-.115	-.115
6	.096	.208	-.222	-.240	-.349	-.271
7	.054	-.016	.046	.004	.512*	.512*
8	-.355	-.213	.422	.533*	.183	.183
9	-.175	.076	.128	.168	-.056	-.221
10	.346	.211	.293	.065	.022	.007
11	.116	.155	.446	.457*	.219	.205
12	.343	.337	-.106	-.299	.359	.359
13	.452	.489*	.016	-.092	.294	.294
14	.178	.073	.290	.305	-.256	-.203

Table 12

Sites showing significant differences ($P \geq 0.002$) in biomass (mg/m^2 sample surface) taken by each technique (see text).

ET		FD w/o snails		FD w/ snails		OW w/o snails	OW w/ snails
2 > 1	15 > 3	1 > 3	16 > 12	1 > 3	16 > 12	1 > 3	1 > 4
2 > 3	15 > 9	1 > 7	17 > 9	1 > 7	17 > 12	1 > 4	1 > 5
2 > 7	15 > 13	1 > 10	17 > 12	1 > 8	18 > 9	1 > 5	1 > 9
2 > 13	15 > 14	1 > 11	18 > 4	1 > 10	18 > 10	1 > 8	1 > 11
2 > 19	16 > 1	1 > 12	18 > 8	1 > 11	18 > 11	1 > 9	1 > 14
4 > 12	16 > 2	1 > 13	18 > 9	1 > 12	18 > 12	1 > 10	1 > 15
4 > 13	16 > 3	1 > 14	18 > 10	1 > 13	18 > 13	1 > 11	1 > 17
5 > 13	16 > 4	1 > 15	18 > 11	1 > 14	18 > 14	1 > 14	1 > 18
5 > 19	16 > 5	2 > 3	18 > 12	1 > 15	18 > 17	1 > 15	3 > 5
6 > 3	16 > 9	2 > 4	18 > 13	1 > 17	19 > 9	1 > 17	3 > 11
6 > 9	16 > 11	2 > 5	18 > 14	2 > 3	19 > 11	6 > 2	3 > 14
6 > 12	16 > 12	2 > 7	18 > 15	2 > 5	19 > 12	6 > 4	3 > 15
6 > 13	16 > 13	2 > 8	18 > 17	2 > 7	19 > 14	6 > 9	6 > 2
6 > 19	16 > 14	2 > 9	19 > 11	2 > 8	19 > 15	6 > 10	6 > 4
7 > 3	16 > 19	2 > 10	19 > 12	2 > 9		6 > 14	6 > 9
8 > 3		2 > 11	19 > 14	2 > 10		6 > 15	6 > 14
8 > 5		2 > 12	19 > 15	2 > 11		7 > 13	6 > 15
8 > 9		2 > 13		2 > 12		16 > 11	6 > 17
8 > 12		2 > 14		2 > 13		18 > 14	6 > 18
8 > 13		2 > 15		2 > 14		19 > 4	16 > 11
9 > 13		2 > 16		2 > 15		19 > 8	18 > 14
10 > 3		3 > 12		2 > 16		19 > 11	19 > 4
10 > 9		3 > 15		2 > 17		19 > 13	19 > 8
10 > 12		4 > 12		4 > 12		19 > 14	19 > 11
10 > 13		5 > 9		5 > 9		19 > 15	19 > 13
10 > 19		5 > 12		5 > 12		19 > 17	19 > 14
11 > 3		6 > 7		6 > 7			19 > 15
11 > 9		6 > 9		6 > 9			19 > 17
11 > 13		6 > 11		6 > 10			
11 > 19		6 > 12		6 > 11			
12 > 13		6 > 14		6 > 12			
14 > 3		6 > 15		6 > 14			
14 > 9		7 > 12		6 > 16			
14 > 12		8 > 12		6 > 17			
14 > 13		13 > 12		8 > 12			

DISCUSSION

The sampling of insect populations to establish estimates of their abundance, either relatively or absolutely, has yet to be accomplished satisfactorily. Many factors affect the accuracy of such attempts, and some of these show no promise of easy solution. For example, different insect species vary in their ease of capture: (1) because they occupy different places in the same habitat, (2) because they differ in avoidance reactions to trapping, (3) because they have different circadian rhythms, or (4) because the periods of peak abundance are not the same for all species. Techniques that work well for sampling adult dipterans in the marsh do not sample forms that burrow in cattail stalks, yet the latter may be an important food source for some marsh birds.

Kale (1965), Menhinick (1963) and Southwood (1968) have shown that different collectors bias their samples in different ways. The use of self-collecting devices may eliminate subjective bias, but introduce instrumental bias.

Sample size is undoubtedly critical. In the present study, even though a minimum of 60 hours per week were invested during the period of field work, it is likely that too few samples were taken, especially with emergence traps. Note, for example, that Needham and Usinger (1956) suggest a minimum of 194 Surber ft^2 bottom samples for assessing stream dwelling organisms in a single riffle to produce accurate figures of wet weights at the 95% confidence level.

G. H. Orians (pers. comm.) has evidence that the harvesting of odonate larvae by "rough fish" substantially reduces their abundance. Sheldon Ralston of the Washington State Game Department (pers. comm.) reported that waterfowl production at Winchester Wasteway, Grant County, Washington nearly doubled following poisoning of "scrap fish." The harvesting of insects by vertebrates in areas of highest insect density might significantly lower that density below what could be found elsewhere. One might then erroneously conclude that what in reality was one of the most productive sites sampled was one of the least productive.

Perhaps of greatest concern to ecologists attempting to assess insect populations should be the fact that they are not sampling productivity; they are sampling standing crop. Before that standing crop can be evaluated in its role in the ecology of predators, the turnover rate of each component species must be known. Insect species A, for example, may comprise twice the biomass of insect species B in a sample, but B may have three times the turnover rate and so in fact be 1.5 times as important as an energy source for predators.

From the above considerations, the only safe conclusion regarding samples obtained in the present study is that their accuracy as indicators of marsh insect standing crop cannot be confidently assessed.

Emergence Traps

While the emergence trap technique is probably the most effective technique yet available for sampling insects emerging from an aquatic habitat, several possible factors could bias results. Light intensity beneath the traps is altered and may either depress or enhance the catch. The number of emerging stalks of marsh vegetation

included in the traps may affect emergence although D. R. Paulson (pers. comm.) believes this to be of minor importance if at least several stalks are available.

Disturbance of the benthos created by walking to the traps can be minimized by using the same path each time or by approaching the traps by boat (see Judd, 1953).

Floating Debris

The collection of floating debris from the water surface promises to be an accurate method for estimating absolute abundance of that component of the invertebrate populations because the total amount of floating debris can be assessed quantitatively and the specimen yield from a small sample is of such magnitude that accurate weighings can be made. This technique is subject to bias resulting from the observer's subjectively choosing samples. This kind of subjective bias should not go unnoticed since birds probably subjectively forage in these habitats. Little experience is required to permit selection of those pieces of floating vegetation most likely to provide high yields. To test this, I made 10 collections each comprising 10 pieces of floating debris, predicting before each collection whether the yield would be high or low. In most instances 10 predictions of 10 were correct. The poorest score was 7 correct out of 10.

It is certain some organisms were lost when collections were made because their behavior is such that they drop from the debris the moment it is disturbed. These losses are assumed to be the same for all collections.

Open Water

Of the three collecting methods, the open water technique was most cumbersome and was probably the least accurate. The volume of water sampled was not known and specimens were easily "sloshed" from the scoop while samples were being taken. Accidental contact with emergent vegetation sometimes resulted in the loss of the sample or a portion of it. The technique was time consuming and bias was easily introduced by the collector because the sampling areas among the floating mat were necessarily subjectively chosen. Tea strainers or other gadgets would probably not prove more successful since all of these must contact the water surface before collections are made and accurate volumes of water being sampled will not be known. Finally, there is no way to assess the role of the screen's approach to and contact with the water surface in causing immediate escape reactions in many but not necessarily all species.

Variations in Site Biomass

Data from 1064 surface samples taken by the three techniques clearly show significant variation in biomass of invertebrates taken at the various sites around Caliche Lake. These variations can probably be judged to be real, since comparisons are made within each technique, and any observer bias, etc. should thus affect the compared samples in similar ways.

An important consideration emerging from these comparisons is that the different sampling methods do not all rank the 19 sites in the same order of standing crop abundance. One could argue that all levels in a trophic system should provide the same relative index to a site's

primary productivity. If this is true, then we might expect all three sampling procedures employed here to produce equivalent rankings of the sites and to yield significant correlations by the Spearman test. The fact that most Spearman correlations were not statistically significant, even at the 0.10 level indicates that these collecting procedures may be infrequently sampling the same trophic systems.

On the other hand, the same trophic systems may be involved. Differences in turnover rates among the organisms sampled by each procedure could lead to an absence of correlation in standing crop. Further, differential predation, for example by fishes, on the different organisms sampled could also destroy an otherwise valid correlation.

The demonstration of variation in insect abundance from point to point around the periphery of a continuous water body is of singular importance to ecologists. It points to a possible explanation for differential use of the lake margin by insect predators, as discussed below.

Insect Sampling and Avian Ecology

Stenger (1958) pointed to a correlation between the size of Ovenbird (Seiurus aurocapillus) territories and the density of invertebrates in leaf litter, where the birds forage. Verner (1964), Verner and Engelsen (1970), and Verner and Willson (1966) argue that some polygamous male marsh birds may have greater success attracting mates because their territories provide more insects for feeding young. Indeed many students of avian ecology are more or less explicit about the importance of insect abundance in the discrimination of potential breeding sites by birds (eg. see Lack, 1954, 1966; Orians, 1961; Orians

and Horn, 1969; Root, 1967). These opinions seem based primarily on intuition but also to some extent on studies of avian time and energy budgets, which are not necessarily entirely accurate assessments of avian territory quality. There is a critical need here for accurate means of assessing absolute quantities of insect biomass per unit time as they relate to problems of avian territory quality and modes of territory assessment by birds.

Attention must be given to the following source of error: (1) Birds alter their foraging strategy in response to changes in insect abundance (Kale, 1965; Lack, 1954, 1966; Orians, 1961; Orians and Horn, 1969; Root, 1967). No sampling technique can precisely mimic the foraging efficacy of any bird species, let alone vary its strategy in response to fluctuations in insect abundance. (2) The most abundant insects sampled may not be the most available to a given bird species. (3) Avian predation lowers the abundance of the very species one needs to assess, so they are less common where the birds forage, yet their abundance is unaffected where the birds do not forage. (4) Birds learn quickly to feed on insects captured in certain kinds of traps, thus lowering the apparent catch. I have observed this while using emergence screens to assess odonate abundance at Turnbull National Wildlife Refuge. Red-winged Blackbirds learned to watch the screens for emerging naiads and to pluck them from the screen before they emerged as adults. Falkenbury and Verner (1970) also report avian exploitation of their sticky traps.

Finally, all the various difficulties of estimating insect abundance discussed earlier, particularly the sampling of standing crop without a knowledge of turnover rate, must be overcome. Until this has

been accomplished, all claims to evidence of invertebrate abundance as a correlate of predator use can only be given conditional acceptance.

LITERATURE CITED

Cook, Paul P. and Henry S. Horn. 1968. A Sturdy Trap for Sampling Emergent Odonata. Ann. of the Entomol. Soc. of Amer. 61(6): 1506-1507.

Daubenmire, Rexford. 1968. Plant Communities. Harper and Row, Pub., New York. 300 p.

Falkenbury, John T. and Jared Verner. 1970. A Trapping Technique for Sampling Insects in Dense Vegetation. The Amer. Midland Natur. 83(2): 627-629.

Franklin, J. F. and C. T. Dyrness. 1969. Vegetation of Oregon and Washington. U.S. Dept. of Agr. Forest Serv. Res. Pap. PNW-80. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 216 p.

Gibb, J. 1956. Food, Feeding Habits and Territory of the Rock Pipit Anthus spinoletta. Ibis 98: 506-530.

_____. 1960. Populations of Tits and Goldcrests and Their Food Supply in Pine Plantations. Ibis 102: 163-208.

Horak, G. J. 1970. A Comparative Study of the Foods of the Sora and Virginia Rail. The Wilson Bull. 82(2): 206-213.

Judd, W. W. 1953. A Study of the Population of Insects Emerging as Adults from the Dundas Marsh, Hamilton, Ontario, During 1948. The Amer. Midland Natur. 49(3): 801-824.

_____. 1957. A Study of the Population of Emerging and Littoral Insects Trapped as Adults from Tributary Waters of the Thames River at London, Ontario. The Amer. Midland Natur. 58(2): 394-412.

_____. 1960. A Study of the Population of Insects Emerging as Adults from South Walker Pond at London, Ontario. The Amer. Midland Natur. 63(1): 194-210.

_____. 1964. A Study of the Population of Insects Emerging as Adults from Saunders Pond at London, Ontario. The Amer. Midland Natur. 71(2): 402-414.

Kale, Herbert W. II. 1965. Ecology and Bioenergetics of the Long-billed Marsh Wren Telmatodytes palustris griseus (Brewster) in Georgia Salt Marshes. Nuttall Ornithological Club, Cambridge, Mass. 142 pp.

Lack, David. 1954. The Natural Regulation of Animal Numbers. Oxford Univ. Press, Oxford. 343 p.

_____. 1966. Population Studies of Birds. Clarendon Press, Oxford. 341 p.

Lewis, T. and L. R. Taylor. 1967. Introduction to Experimental Ecology. Academic Press Inc., New York. 401 p.

Macfadyen, A. 1962. Soil Arthropod Sampling in Advances in Ecological Research, Vol. I. J. B. Cragg (ed.). 1962. Academic Press, New York. 203 p.

Menhinick, Edward F. 1963. Estimation of Insect Population Density in Herbaceous Vegetation with Emphasis on Removal Sweeping. Ecology 44(3): 617-621.

Needham, James G. and Paul R. Needham. 1962. A Guide to the Study of Freshwater Biology. Holden-Day, Inc., San Francisco. 107 p.

Needham, Paul R. and Robert L. Usinger. 1956. Variability in the Macrofauna of a Single Riffle in Prosser Creek, California, as Indicated by the Surber Sampler. Hilgardia 24(14): 383-409.

Orians, Gordon H. 1961. The Ecology of Blackbird (Agelaius) Social Systems. Ecol. Monogr. 31: 285-312.

_____ and Henry S. Horn. 1969. Overlap of Foods of Four Species of Blackbirds in the Potholes of Central Washington. Ecology 50(5): 930-937.

Pearson, William D. and Robert H. Kramer. 1969. A Drift Sampler Driven by a Waterwheel. Limnol. and Oceanog. 14(3): 462-465.

Root, Richard B. 1967. The Niche Exploitation Pattern of the Blue-gray Gnatcatcher. Ecol. Monog. 37: 317-350.

Southwood, T. R. E. 1966. Ecological Methods with Particular Reference to the Study of Insect Populations. Methuen and Co. Ltd., London. 437 p.

Stenger, Judith. 1958. Food Habits and Available Food of Ovenbirds in Relation to Territory Size. The Auk 75(3): 335-346.

Verner, Jared. 1964. Evolution of Polygamy in the Long-billed Marsh Wren. Evolution 18(2): 252-261.

_____. 1965. Breeding Biology of the Long-billed Marsh Wren. The Condor 67(1): 6-30.

_____ and Gay H. Engelsen. 1970. Territories, Multiple Nest Building, and Polygyny in the Long-billed Marsh Wren. The Auk 87(3): 557-567.

Verner, Jared and Mary F. Willson. 1966. The Influence of Habitats on Mating Systems of North American Passerine Birds. Ecology 47(1): 143-147.

Wiens, John A. 1969. An Approach to the Study of Ecological Relationships Among Grassland Birds. Ornithological Monog. 8: 93 p.