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RESEARCH MEMORANDUM

RM 72-11

DEVELOPMENT OF TECHNIQUES FOR ESTIMATING BIOMASS
OF DESERT INHABITING INVERTEBRATE ANIMALS

G.L. Bender, J. MacMahon
&
S. Szerlip

DESERT BIOME
U.S. INTERNATIONAL BIOLOGICAL PROGRAM
1971 PROGRESS REPORT

DEVELOPMENT OF TECHNIQUES FOR ESTIMATING BIOMASS
OF DESERT INHABITING INVERTEBRATE ANIMALS

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Sigurd Szerlip
Other Authors

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Tempe, Arizona

MAY 1972

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ABSTRACT

Sampling methods were tested and recommendations made for quantitative sampling of invertebrate animals on small to medium-sized shrubs, on large shrubs and trees, in the soil, in leaf litter, in the air, and on the surface of the soil. Sources for commercially-marketed sampling apparatus are indicated.
INTRODUCTION

Invertebrate animals make up a very important part of the biomass of a desert ecosystem. Any attempts to analyze such an ecosystem must account for the effects of this group of organisms. The development of techniques and methods for determining the numbers and biomass of invertebrates is essential for any detailed study of a desert ecosystem.

OBJECTIVES

The objectives of this study were to develop techniques and methods for estimating the numbers of desert-inhabiting invertebrate animals. The study concentrated on arthropods as important components of the invertebrate fauna. Other studies by other investigators are concerned with groups such as nematodes.

METHODS

In beginning the study certain priorities were established. The order of priority for the study was to investigate (1) invertebrates feeding or resting on selected plant species, (2) those living in the soil near selected plant species, (3) those flying over the study area, (4) those running on the ground in the study area, and (5) invertebrate predators. This report will take up each of these priorities in order and indicate the progress of the study and the recommendations for the methods to be used.

FINDINGS

Invertebrates resting or feeding on selected plant species.

This problem was the major focus of attention during the 1970 research year. Considerable field work was carried out at the Santa Rita Experiment Station on determining numbers of invertebrates on various plant species. A number of different techniques were tried, culminating in a specific recommendation for sampling low-growing plants up to 1 meter in height. The recommendation involved placing a standard plastic bubble over the plant and removing the invertebrates from the plant vegetation by means of a D-Vac Insect Suction Net. The details of the basis for the recommended sampling regime is given in the 1970 progress report.

Detailed instructions concerning the type of equipment recommended and the way in which it should be used were prepared and transmitted to all Validation Site Coordinators. This information is recorded on memoranda at the Biome head office collected into "Appendix B".

In addition, some preliminary work was carried out on sampling larger plants, such as trees and large shrubs. No specific recommendations were made on this problem and it was again considered during the 1971 sampling season.

Invertebrates living in the soil near selected plant species.

It is obvious to anyone collecting field data for studies of ecosystem functioning that the most elusive compartment is the soil and its component organisms. Not only is it difficult to see what goes on, but it is difficult to even estimate the numbers and kinds of organisms present from sample data. That this is the case is demonstrated by the plethora of recent "techniques" papers dealing with soil biota.
In general these various techniques make use of two fundamentally different principles, dynamic and mechanical. The dynamic methods are based on the response of living organisms to one or more factors such as heat, dryness, humidity, phototropisms, while in the mechanical methods the animal is passive and the extraction depends on the differences in the physical properties of the animal's body. Dynamic methods include Berlese and Tullgren funnel methods of extraction. Mechanical methods include sedimentation, differential wettability of the integument, and screening. The Salt and Hollick flotation method depends upon a combination of sedimentation of inorganic soil particles and differential wetting of the cuticle.

The history of the development of the two techniques is discussed by MacFadyan (1962). Many variations have been tried (Edwards and Fletcher, 1970) but the alternatives generally used are those from the original studies (Tullgren, 1918; Salt and Hollick, 1944). In this study the Tullgren Funnel method of extraction was compared with the Salt-Hollick Flotation method of extraction of organisms from desert soils. A series of samples of desert soils was taken and the organisms extracted by use of Tullgren Funnels and the Salt-Hollick Flotation method. The results were compared. In each succeeding set of samples the methods of sampling were refined, as were the methods of extraction in the light of the experience gained from previous sample sets.

In the first series of samples the area to be sampled was cleared of surface detritus and soil samples were taken with a one-inch diameter soil auger. Samples were taken under grass, *Larrea*, and *Acacia*, with the depth of the sample varying from 7.5-12.5 cm. Each sample was placed in a separate container for transportation to the laboratory. In the laboratory each sample was divided into two equal parts. One part was extracted by means of Tullgren funnels using a 25 watt bulb and extracting for 24 hours. The other part was extracted by a modification of the Salt-Hollick flotation method. The results are summarized in Table 1. Mites and Collembola were listed separately as they were the organisms present in largest numbers, while all others were grouped together under miscellaneous.

In every case the portion of the sample extracted by flotation yielded significantly higher numbers of organisms than the portion extracted by Tullgren funnels. In most cases the factor was more than 2 to 1 in favor of the flotation method. In three of the samples the residues of the Tullgren Funnel extractions were then processed using the flotation method. The flotation method yielded a total of 35 organisms as compared to the 24 organisms yielded by the Tullgren method. These 35 organisms were considered to be errors of the Tullgren method. A second series of 10 soil samples was taken under *Acacia*. The area to be sampled was cleared of detritus and 12.5 cm deep soil samples were taken with a 2.5 cm soil auger. The samples were placed in separate containers and taken to the laboratory where each was divided into two equal parts. One part was extracted by Tullgren funnels using a 25 watt bulb for 24 hours, while the second part was extracted by a modification of the Salt-Hollick flotation method. The results are summarized in Table 2.

The flotation method clearly yielded many more organisms than the Tullgren Funnel method. The total organisms extracted by flotation were nearly 10 times as numerous as those extracted by Tullgren methods. In three of the samples extracted by Tullgren methods the samples were extracted for 48 hours rather than 24 hours. This seemed to increase the numbers of organisms extracted from the samples.

A third series of soil samples were taken, this time under *Larrea divaricata*. The area to be sampled was cleared of surface detritus and 15 cm deep samples were taken with a 2.5 cm diameter soil auger. The samples were placed in separate containers and taken to the laboratory where each was divided into two equal parts. One part was extracted by Tullgren funnels while the second part was extracted by a modification of the Salt-Hollick flotation method. The residues from the Tullgren Funnels were extracted by the same flotation methods. Any organisms obtained from these residues were considered to be errors of the Tullgren funnel method. The results are summarized in Table 3.
Table 1. Soil samples extracted by flotation and Tullgren Funnels.

Soil Samples
Samples Extracted by Flotation

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>5 cm deep sample</th>
<th>7.5 cm deep sample</th>
<th>12.5 cm deep sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG01</td>
<td>50</td>
<td>12</td>
<td>117</td>
</tr>
<tr>
<td>SG02</td>
<td>62</td>
<td>33</td>
<td>22</td>
</tr>
<tr>
<td>SG03</td>
<td>35</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>SG05</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>SG06</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>SG07</td>
<td>0</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>SG08</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>SG04</td>
<td>17</td>
<td>29</td>
<td>75</td>
</tr>
<tr>
<td>SG09</td>
<td>25</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>SG10</td>
<td>3</td>
<td>5</td>
<td>Total 322</td>
</tr>
</tbody>
</table>

SubTotal 156

Soil Samples
Samples Extracted by Tullgren Funnels
25 watt bulb, 24 hrs.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>5 cm deep sample</th>
<th>7.5 cm deep sample</th>
<th>12.5 cm deep sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG01A</td>
<td>10</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>SG02A</td>
<td>22</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>SG03A</td>
<td>32</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>SG05A</td>
<td>10</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>SG06A</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>SG07A</td>
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<td>7</td>
<td>0</td>
</tr>
<tr>
<td>SG08A</td>
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<td>7</td>
<td>2</td>
</tr>
<tr>
<td>SG04A</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>SG09A</td>
<td>11</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>SG10A</td>
<td>22</td>
<td>12</td>
<td>Total 26</td>
</tr>
</tbody>
</table>

SubTotal 58

Residue of Tullgren extracted by Flotation

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>5 cm deep sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG08R</td>
<td>7</td>
</tr>
<tr>
<td>SG09R</td>
<td>9</td>
</tr>
<tr>
<td>SG10R</td>
<td>6</td>
</tr>
</tbody>
</table>

Total 35

Total 24 for same samples extracted by Tullgren's.
Table 2. Soil samples extracted by flotation and Tullgren funnels.

<table>
<thead>
<tr>
<th></th>
<th>SG11</th>
<th>SG12</th>
<th>SG13</th>
<th>SG14</th>
<th>SG15</th>
<th>SG16</th>
<th>SG17</th>
<th>SG18</th>
<th>SG19</th>
<th>SG20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil Samples</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Samples Extracted by Flotation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Samples taken under <em>Acadia</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-12.5 cm deep sample.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mites</strong></td>
<td>21</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>10</td>
<td>16</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Collembola</strong></td>
<td>1</td>
<td>15</td>
<td>41</td>
<td>13</td>
<td>102</td>
<td>45</td>
<td>45</td>
<td>8</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>22</td>
<td>23</td>
<td>53</td>
<td>29</td>
<td>114</td>
<td>64</td>
<td>53</td>
<td>15</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td><strong>Soil Samples</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Samples Extracted by Tullgren Funnels</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 watts, 24 hrs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*these samples extracted for 48 hours.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-12.5 cm deep sample, under <em>Acadia</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mites</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Collembola</strong></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Soil samples taken under *Larrea divaricata*.

<table>
<thead>
<tr>
<th>Soil Samples</th>
<th>Sample Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples taken under <em>Larrea divaricata</em></td>
<td></td>
</tr>
<tr>
<td>5-15 cm deep samples</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Extracted by flotation Sample Numbers</th>
<th>Extracted by Tullgren Funnels-25 watt, 24 hrs. Sample Numbers</th>
<th>Residue from Tullgrens Extracted by flotation Sample Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample Numbers</td>
<td>Sample Numbers</td>
</tr>
<tr>
<td>Mites</td>
<td>0  3  0  2  1</td>
<td>0  0  0  0  0</td>
</tr>
<tr>
<td>Collembola</td>
<td>4  0  1  0  2</td>
<td>0  0  0  0  0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2  1  2  0  1</td>
<td>0  1  2  1  4</td>
</tr>
<tr>
<td>Total 19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Extracted by Tullgren Funnels 15 watts 24 hrs; 25 watts 12 hr. Sample Numbers

<table>
<thead>
<tr>
<th>Sample Numbers</th>
<th>Sample Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Numbers</td>
<td>S 26A  S 27A  S 28A  S 29A  S 30A</td>
</tr>
<tr>
<td>Mites</td>
<td>0  0  0  0  0</td>
</tr>
<tr>
<td>Collembola</td>
<td>0  0  0  0  0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0  1  4  0  3</td>
</tr>
<tr>
<td>Total 8</td>
<td></td>
</tr>
</tbody>
</table>
The organisms extracted by flotation exceeded those obtained by Tullgren methods by a factor of more than 2 to 1. When flotation methods were used to process residues already extracted by Tullgren methods, the organisms extracted by flotation exceeded those obtained by Tullgren methods by a factor of 2 to 1.

In view of the experience gained from the preceding sample series, the research design was modified for the succeeding series of soil samples. First, two different-sized soil cores were taken. One core sampler had a diameter of 5.2 cm, a length of 10.5 cm and a volume of 220 cc. The larger sampler had a diameter of 7.9 cm, a length of 45 cm and a volume of 2204.3 cc. The use of the different-dimensioned samplers made it possible to look at the effects of soil depth and soil volume on the number of organisms obtained.

Second, samples were taken at the base of the plant, one radius from the base, two radii from the base and three radii from the base. It is known that organisms are not uniformly distributed in nature but tend to be unevenly clumped. In soil this clumping is frequently related to the presence of plants. This sampling regime allowed us to investigate the question of where samples should be taken for optimum results.

Samples were placed in sealed containers and transported to the laboratory where each sample was thoroughly stirred and divided into two subsamples which were roughly equal in volume. The subsamples were weighed. One was placed in a Tullgren funnel for extraction and the other was extracted by a modification of the Salt-Hollick flotation method.

Third, extractions from the Tullgren funnels were examined at 8, 16, 24, 32, 40 and 48 hours following the start of the extraction. This made it possible to determine how long extractions should continue to obtain maximum efficiency.

Fourth, residues from Tullgren extractions were processed by flotation methods. Organisms obtained from these residues were considered to be errors of the Tullgren method.

Fifth, residues from flotation extractions were examined under binocular microscopes. Organisms obtained from these residues were considered errors of the flotation method.

Using the research design just described, samples were taken under Prosopis juliflora. Twenty samples were taken with the smaller core sampler and twenty with the larger sampler. Five samples with each sampler were taken at the base of the plant, 5 one radius from the base, 5 two radii from the base, and 5 three radii from the base of the plant. The samples were treated and processed as described above. The results are summarized in Table 4. In this summary only total organisms are listed. No attempt was made to present the data by taxonomic groups. This information is available in the raw data.

Clearly, flotation methods were more effective in extracting organisms from these samples. The subsamples extracted by flotation yielded a total of 49 organisms while the subsamples extracted by Tullgren funnels yielded 20 organisms. In addition, the residues from these Tullgren extractions which were processed by flotation yielded another 46 organisms which must be considered to be errors of the Tullgren methods. Microscopic examination of the residues from the subsamples extracted by flotation yielded no organisms. Samples taken with the smaller sampler yielded 66 organisms while those taken with the larger sampler yielded 49 organisms. The largest number of organisms were obtained from samples taken within two radii of the base of the plant. Beyond this the numbers of organisms decreased markedly. The totals for all extractions methods were: base of plant, 45; one radius, 39; two radii, 18; three radii, 13. No organisms were obtained from samples extracted by Tullgren funnels after 40 hours of extraction.
Figure 4. Soil samples under *Prosopis juliflora*.

Soil Sample Under *Prosopis juliflora*

Sample Designations: 1, at base of plant; 2, one radius from base; 3, two radii from base; 4, three radii from base.

Samples designated "A" were taken with smaller core 10.5 cm x 5.2 cm; 220 cc volume.

Samples designated only by numbers were taken with larger core 45 cm x 7.9 cm; 2204.3 cc volume.

Samples designated "R" were residues from Tullgren Funnels extracted by flotation.

Extraction by Tullgren Funnels

25 watts; 40 hrs

<table>
<thead>
<tr>
<th>Subsample Numbers</th>
<th>Organisms</th>
<th>1-1A</th>
<th>1-2A</th>
<th>1-3A</th>
<th>1-4A</th>
<th>1-1</th>
<th>1-2</th>
<th>1-3</th>
<th>1-4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>3</td>
<td>13</td>
</tr>
<tr>
<td>4-1A</td>
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</tr>
</tbody>
</table>

Extraction by Flotation

Subsample Numbers

<table>
<thead>
<tr>
<th>Subsample Numbers</th>
<th>Organisms</th>
<th>1-1A</th>
<th>1-2A</th>
<th>1-3A</th>
<th>1-4A</th>
<th>1-1</th>
<th>1-2</th>
<th>1-3</th>
<th>1-4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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Totals | 21 | 7 | 5 | 3 | 10 | 15 | 1 | 4 | 66

21 | 7 | 5 | 3 | 10 | 15 | 1 | 4 | 66
A series of samples were taken under *Larrea divaricata* using the research design described above. Twenty samples were taken with the smaller core sampler and twenty with the larger sampler. Five samples with each sampler were taken at the base of the plant, 5 one radius from the base, 5 two radii from the base, and 5 three radii from the base. The samples were treated and processed as described above. The results are summarized in Table 5.

Flotation methods were clearly more effective in extracting organisms from these subsamples. Subsamples extracted by flotation yielded 55 organisms while those extracted by Tullgren Funnels yielded 11 organisms. In addition, the residues from the Tullgren extractions which were further processed by flotation yielded 33 organisms which must be considered errors of the Tullgren method. Microscopic examination of the residues from subsamples extracted by flotation yielded one organism which must be considered an error of the flotation method. Samples taken with the smaller sampler yielded 37 organisms while those taken with the larger sampler yielded 61 organisms. The largest number of organisms were obtained from samples within two radii of the base of the plant. The totals for all extraction methods were: base of plant, 47; one radius from base, 37; two radii from base, 6; three radii from base, 8. No organisms were obtained from samples extracted by Tullgren funnels after 40 hours of extraction. Summarizing the results of the eight samples taken under *Prosopis* and *Larrea*, a total of 214 arthropods were extracted. Of these, 104 were obtained from samples taken with the smaller sampler and 110 were obtained from the samples taken with the larger sampler. This was somewhat surprising in view of the 10:1 sample volume difference between the two samplers. However, it is probably explained by the fact that the volume difference was due to a much greater length of the larger sampler rather than a great difference in diameter. It appears that most desert soil arthropods of the size encountered in this study live in the top 5 cm of soil where the organic content is higher. If this is true, the additional length of the larger sampler would not add many organisms to the total and the differences between the larger and smaller samplers would be small. This was the case in these studies.

The data from Tullgren Funnel extractions indicate that when a 25 watt bulb is used as the heat source, all of the organisms that are going to be extracted are extracted within 40 hours. Continuing Tullgren extractions past this time would not seem to be productive.

Both sets of samples, the one under *Larrea* and those under *Prosopis*, indicate that there is a relationship between distribution of soil organisms and proximity to plants. The number of organisms decreases markedly with increasing distance from the base of the plant.
Table 5. Soil sample under *Larrea divaricata*

Soil Sample
Under *Larrea divaricata*
Sample Designations: 1, at base of plant; 2, one radius from base; 3, two radii from base; 4, three radii from base.
Samples designated "A" were taken with smaller core 10.5 cm x 5.2 cm; 220 cc volume.
Samples designated only by number were taken with larger core 45 cm x 7.9 cm; 2204.3 volume.
Samples designated "R" were residues from Tullgren Funnel extracts by flotation.

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<th>Extraction by Tullgren Funnel</th>
<th>Extraction by Flotation</th>
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<table>
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| 1 1 0 0 0 0 0 0 2 | 0 2 0 1 1 4 1 0 8 |

| 3-1A 3-2A 3-3A 3-4A 3-1 3-2 3-3 3-4 Total | 3-1A 3-2A 3-3A 3-4A 3-1 3-2 3-3 3-4 Total |
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| 4-1A 4-2A 4-3A 4-4A 4-1 4-2 4-3 4-4 Total | 4-1A 4-2A 4-3A 4-4A 4-1 4-2 4-3 4-4 Total |
| 0 1 0 0 0 0 0 0 1 | 0 1 4 1 5 1 0 0 1 |

| 5-1A 5-2A 5-3A 5-4A 5-1 5-2 5-3 5-4 Total | 5-1A 5-2A 5-3A 5-4A 5-1 5-2 5-3 5-4 Total |
| 0 0 0 0 0 0 0 0 1 | 3 6 0 0 4 0 0 0 13 |

| 5-1AR 5-2AR 5-3AR 5-4AR 5-1R 5-2R 5-3R 5-4R Total | 5-1AR 5-2AR 5-3AR 5-4AR 5-1R 5-2R 5-3R 5-4R Total |
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DISCUSSION & CONCLUSIONS

It is quite clear from the data in this study that Tullgren separation of desert soil samples is not effective. One may miss over 70% of the organisms present in the sample.

Equally clear is the fact that Salt and Hollick flotation is highly effective in separating organisms from desert soil samples. When the flotation is carefully done, virtually none of the organisms present are missed. "Carefully done" should be emphasized as there are a number of little tricks that need to be mastered before flotation is highly efficient. Detailed information on the methods used in these tests is given in the recommendations to validation site coordinators. (Recorded in memoranda stored at the Biome head office in "Appendix C").

Several points about sampling procedure become obvious from the data. Samples must be taken with regard to plant density and dispersion since the organisms clearly have a clumped distribution pattern, centered around perennial shrubs. Figure 1 indicates the relationship between distribution of soil arthropods and distance from the base of the plant Larrea divaricata. Figure 2 indicates a similar relationship for Prosopis juliflora. The data indicated that extending the sampling two radii from the base of the plant will produce approximately 90% of the organisms. It would appear that extending the sampling distance further would not be productive in terms of numbers of organisms obtained.

Comparisons of Tullgren funnel methods and flotation methods by other investigators in other ecological situations have not shown the marked advantage for flotation methods that our results indicate. However, this is largely due to the fact that the efficiency of flotation methods goes down as the amount of organic material in the soil goes up. The more organic material there is present the more difficult is the task of separating arthropods and plant material by differential wetting and flotation. Most of the studies carried out by other investigators have been done in soils relatively rich in organic materials. Under these conditions flotation methods do not show the same marked advantage over other methods. With desert soils, where the organic content is low, flotation methods are clearly superior to Tullgren funnel methods.

Insects flying over the study area

Correlating the numbers of insects flying over a given area with the plants on which they feed and with their energy relationships is a formidable task. In fact, determining the numbers of insects in such a situation is also a formidable task. A number of methods have been tried including insect nets, sticky board traps, car borne nets and insect suction traps. In looking through the literature it appeared that the insect suction traps developed by Johnson and Taylor provided the best method of determining aerial insect numbers over periods of time. There seems to be less sample bias with these traps and there is the added advantage of being able to collect insects at hourly intervals over a 24-hour period. Taylor (1962) has investigated the effects of insect size, sampling rate, velocity and wind speed on the efficiency of these traps. Mathematical expressions have been developed relating insect catch to insect size, wind speed and sampling rates.

Some preliminary data was gathered using a 12" diameter Johnson and Taylor Insect Suction Trap. Twenty seven families of insects from eight different orders were caught in a 24-hour period. As expected, considerable variation was found in the daily period of activity of the various insects. In general the insects caught were small in size. Table 6 gives the catch during one 24-hour period.

More data needs to be collected using this method. It seems to have great promise in detailing activity periods for aerial insects. Because of the design of the trap, each hour's catch is separated from all others so it is possible to determine flight activity in a 24-hour period with accuracy.
Figure 1. Relationship between distribution of soil arthropods and distance from shrubs (Larrea). Broken line is cumulative percent of total sample. Solid line is numbers of organisms.

Figure 2. Relationship between distribution of soil arthropods and distance from plants (Prosopis juliflora). Broken line is cumulative percent of total sample. Solid line is numbers of organisms.
Table 6. Data sheet for 24-hour collection period using a 30 cm diameter Johnson and Taylor Aerial Suction Net.

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Invertebrates inhabiting litter on the ground.

Even a cursory examination of desert vegetation indicates that most of the vegetation is not eaten by anything but eventually falls to the ground and becomes litter or detritus. Winds blow it from place to place until it is finally stopped by some sort of an obstruction or depression. Observations indicate that litter accumulates under plants that have low-growing branches as well as in depressions and arroyos which form natural pockets. The accumulation is much greater under dense stands of plants than under spatially isolated plants. This produces areas of considerable abundance of litter which might serve as habitats for a variety of invertebrate forms.

Two different methods were investigated for examination of litter for invertebrate animals. Tullgren Funnels were compared with a modification of the Salt and Hollick flotation method. The Tullgren Funnels were found to be the most practical method for extracting organisms from this litter.

The Salt and Hollick method is very good for soil samples but its efficiency decreases rapidly as the organic content of the sample rises. In litter samples where virtually everything in the sample is organic, great difficulties arise in achieving separation of animal and plant materials. These difficulties are great enough to eliminate flotation as a recommended method of sampling litter samples.

It is our recommendation that litter samples be processed using Tullgren Funnels and carrying out the extraction process for a 40 hour period.

One surprising thing was the relatively small number of animals found in each of the litter samples. Considering the volume of material processed the numbers were very small indeed. By far the most abundant animals in the samples were the mites and ticks.

Organisms walking or running on the ground in the study area.

One group of organisms not sampled by any of the methods mentioned so far are large beetles, scorpions and spiders who walk on the surface of the ground. These organisms are known to occur widely in desert areas and undoubtedly occur on most of the validation sites. They are mobile, ground-dwelling, ground-active forms and can only be sampled during their above-ground activity periods. Typically they have been sampled by non-selective methods such as sunken can traps. As normally used, however, these can traps are not sufficiently accurate to allow any reasonable estimate of actual biomass of organisms on a given area.

Ahearn (1970) collected Tenebrionid beetles over a 15-month period at South Mountain Desert Park in Phoenix, Arizona, using pitfall traps. During this time nine different species were collected, with 5 species being especially numerous. Different arrangements and densities of traps were used and temperature, rainfall and relative humidity data were taken. Total biomass of each species was determined for each capture period and weekly percentage contributions of each beetle species to total collected biomass were determined. Collected biomass per unit of sampling area were determined by totalling the biomass value for each species and dividing this figure by the total exposed surface area of the pitfall traps.

MacMahon and one of his students carried on mark-recapture studies during the summer of 1971 using pitfall traps. Their data indicate that if you match trap dispersion with the dispersion pattern of the organism you may obtain quantitatively acceptable population estimates.

Preliminary studies were made utilizing time-lapse photography as a sampling method for ground-dwelling forms. Results are thus far inconclusive.
Sampling scorpion populations.

Scorpions are found at each of the validation sites, and at certain times of the year may be found in some abundance. Estimations of absolute numbers of scorpions are difficult to obtain however. Dr. Stanley C. Williams, Associate Professor of Biology at San Francisco State College, has provided the following information regarding sampling methods for scorpions. Dr. Williams has worked on this problem for a number of years and currently has a number of graduate students working on various aspects.

Dr. Williams recommends the ultraviolet detection method for scorpion sampling. "This method takes advantage of the property of the scorpion cuticle to convert ultraviolet radiation into visible light. Using this method, an observer walks through a suspected scorpion habitat at night with a portable ultraviolet light. Any scorpion within range on an exposed surface is easily detected by the bright greenish-yellow fluorescence of its cuticle against the dark background" (Williams, 1968). He suggests two different sampling regimes. One is the line transect. Walking a line transect at night using a small M-12 mineral light which has a 10-foot range and counting all the scorpions seen within that range will give a good approximation of numbers per unit area.

The second sampling regime consists of precisely defining the sampling area in advance and then thoroughly examining the area using a more powerful ultraviolet light, the safari light. This method gives accurate counts of even the smallest instars on the surface and in the entrance of burrows.

Dr. Williams emphasizes that the time of sampling (time after sunset) must be standardized, as well as the moon phase and season of the year. Sampling should not be done during or just after a rain. Each important scorpion species should be studied for a few consecutive nights to determine the age structure of the surface populations, the frequency of coming to the surface, the length of time spent on the surface, and when the population comes to the surface.

One of Dr. Williams' graduate students is working on absolute sampling methods for one species of scorpion -- studying the effects of rain, season, temperature, humidity and other environmental factors on the surface occurrence of the scorpion. He is also preparing a model that will predict the surface activity of scorpions given any combination of environmental conditions. This information will become available when the thesis is completed this spring.

LITERATURE CITED


