Benthic Invertebrates and Sediments in Vegetated and Nonvegetated Habitats at Three Intertidal Areas of the Columbia River Estuary, 1992

by

George T. McCabe, Jr.
and Susan A. Hinton,

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THE COLUMBIA RIVER ESTUARY, 1992

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Report of Research

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</tbody>
</table>
INTRODUCTION

The physical characteristics of the Columbia River estuary have been altered considerably by man during the last century. Major changes in the estuary were caused by such activities as jetty and pile-dike construction, diking of swamps and marshes, dam construction and operation, dredging, filling, and island construction (Sherwood et al. 1990). Deepening and maintenance of the navigation channel in the estuary have resulted in the creation of islands, including Miller Sands, Jim Crow Sands, and Rice Island.

Miller Sands, Jim Crow Sands, and Rice Island were created from material dredged from the navigation channel and are located in the same general area of the Columbia River estuary; however, the intertidal areas of these islands have undergone different degrees of wetland development, ranging from well developed (Miller Sands) to no development (Rice Island). Jim Crow Sands has intermediate wetland development. In 1992, the U.S. Army Corps of Engineers (COE) initiated a study to determine why the range in wetland development occurred at the three islands.

The COE proposed five research objectives to study the variations in wetland development at the three islands. The objectives included: 1) determination of topographic elevations, 2) mapping of plant species, 3) comparisons of wetland elevations to fluctuating water levels caused by daily tidal and seasonal river-flow changes, 4) sediment analyses for vegetated and nonvegetated intertidal sites, and 5) descriptions of benthic invertebrate communities at vegetated and nonvegetated intertidal sites. In mid-1992, the National Marine Fisheries Service (NMFS) agreed to cooperate with the COE to complete Objectives 4 and 5 at Miller Sands, Jim Crow Sands, and a remnant intertidal marsh in Grays Bay, which is adjacent to Rice Island.
2

METHODS

Sampling

Benthic samples were collected at Miller Sands, Jim Crow Sands, and the remnant intertidal marsh in Grays Bay in July and September 1992 (Fig. 1). At each area, two stations in intertidal vegetated habitats and two stations in adjacent nonvegetated habitats were sampled. The geographic locations of all stations were determined using the Global Positioning System (Appendix Table 1). At each station, 11 samples were collected using a PVC coring device (Fig. 2). The coring device had an inside diameter of 3.85 cm, a penetrating depth of 15 cm, and collected a 174.6-cm$^3$ sample. Ten of the samples collected at each station were used to determine species composition and abundance of benthic invertebrates; one sample was used by the COE to characterize the sediment. Each benthic invertebrate sample was preserved in a buffered formaldehyde solution ($\geq 4\%$) containing rose bengal, an organic stain. In the laboratory, samples were washed with water through a 0.5-mm screen. All organisms were sorted from the residue, identified to the lowest practical taxon, counted, and stored in 70% ethanol. The eleventh sample was placed in a labeled plastic bag and refrigerated for later analysis of grain size, percent silt/clay, and percent volatile solids by the COE North Pacific Division Materials Laboratory, Troutdale, Oregon.

Data Analyses

Benthic invertebrate data were analyzed by station to determine species composition and densities (both total and by species). Benthic invertebrate densities were compared between vegetated and nonvegetated habitats, between months, and between areas using three-way analysis of variance (ANOVA) (Minitab Inc. 1991). Two-way ANOVA was used
Figure 1.--Benthic invertebrate and sediment sampling stations in three wetland areas in the Columbia River estuary, July and September 1992. Odd-numbered stations were vegetated habitats and even-numbered stations were nonvegetated.
Figure 2.--PVC coring device used to collect benthic invertebrate and sediment samples in three wetland areas in the Columbia River estuary, July and September 1992.
to compare densities when three-way ANOVA could not be used due to significant interaction between factors. Data were transformed to $\log_{10}$ of ($\text{mean number of organisms/m}^2$) prior to running ANOVA. Densities of the amphipod *Corophium salmonis* were transformed to $\log_{10}$ of [($\text{mean number of organisms} + 1)/\text{m}^2$] prior to analysis. One was added to the densities because of some zero values (Sokal and Rohlf 1969). Means of the 10 samples from each station provided the basic data entries for the statistical tests. When ANOVA results were significant ($P < 0.05$) for area, Fisher's protected least significant difference (FPLSD) (Petersen 1985) was used to identify significant differences between areas.

Median grain size (mm), percent silt/clay, and percent volatile solids were determined for each station. Three-way ANOVA was used to compare each of these sediment characteristics between areas, between months, and between vegetated and nonvegetated habitats. When ANOVA results were significant ($P < 0.05$) for area, FPLSD was used to identify significant differences between areas. Percent silt/clay values were transformed to $\log_{10}$ value prior to running ANOVA.

RESULTS

Benthic Invertebrates

Similar numbers of taxa or invertebrate categories were identified in samples collected at the three wetlands, with 31 in July and 36 in September (Appendix Table 2). The number of taxa or invertebrate categories collected at individual stations ranged from 6 at Station M1 (Miller Sands, vegetated) in July, to 22 at Station M3 (Miller Sands, vegetated) in September (Fig. 1; Table 1).
Table 1.--Summary of benthic invertebrate collections at Miller Sands, Jim Crow Sands, and Grays Bay, Columbia River estuary, July and September 1992. Odd-numbered stations were vegetated habitats and even-numbered stations were nonvegetated.

<table>
<thead>
<tr>
<th>Station(a)</th>
<th>Number of taxa or categories</th>
<th>Number (/m^2)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>JULY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>6</td>
<td>15,290</td>
<td>6,929</td>
</tr>
<tr>
<td>M3</td>
<td>17</td>
<td>36,335</td>
<td>20,068</td>
</tr>
<tr>
<td>M2</td>
<td>9</td>
<td>55,749</td>
<td>23,985</td>
</tr>
<tr>
<td>M4</td>
<td>12</td>
<td>48,103</td>
<td>26,949</td>
</tr>
<tr>
<td>J9</td>
<td>9</td>
<td>73,014</td>
<td>58,938</td>
</tr>
<tr>
<td>J11</td>
<td>14</td>
<td>75,162</td>
<td>40,674</td>
</tr>
<tr>
<td>J10</td>
<td>9</td>
<td>21,904</td>
<td>6,495</td>
</tr>
<tr>
<td>J12</td>
<td>7</td>
<td>68,290</td>
<td>24,008</td>
</tr>
<tr>
<td>G5</td>
<td>11</td>
<td>35,820</td>
<td>18,601</td>
</tr>
<tr>
<td>G7</td>
<td>8</td>
<td>37,280</td>
<td>20,481</td>
</tr>
<tr>
<td>G6</td>
<td>9</td>
<td>21,389</td>
<td>8,234</td>
</tr>
<tr>
<td>G8</td>
<td>8</td>
<td>19,327</td>
<td>5,497</td>
</tr>
<tr>
<td><strong>SEPTEMBER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>18</td>
<td>53,687</td>
<td>13,098</td>
</tr>
<tr>
<td>M3</td>
<td>22</td>
<td>59,958</td>
<td>10,856</td>
</tr>
<tr>
<td>M2</td>
<td>14</td>
<td>84,353</td>
<td>26,688</td>
</tr>
<tr>
<td>M4</td>
<td>19</td>
<td>45,183</td>
<td>20,117</td>
</tr>
<tr>
<td>J9</td>
<td>14</td>
<td>46,643</td>
<td>24,256</td>
</tr>
<tr>
<td>J11</td>
<td>21</td>
<td>155,993</td>
<td>43,184</td>
</tr>
<tr>
<td>J10</td>
<td>8</td>
<td>38,655</td>
<td>7,244</td>
</tr>
<tr>
<td>J12</td>
<td>16</td>
<td>140,789</td>
<td>38,384</td>
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<tr>
<td>G5</td>
<td>14</td>
<td>76,364</td>
<td>18,699</td>
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<td>G7</td>
<td>9</td>
<td>44,858</td>
<td>31,770</td>
</tr>
<tr>
<td>G6</td>
<td>10</td>
<td>89,163</td>
<td>15,993</td>
</tr>
<tr>
<td>G8</td>
<td>13</td>
<td>100,845</td>
<td>17,441</td>
</tr>
</tbody>
</table>

\(a\) The letter in the station name denotes the area: M = Miller Sands, J = Jim Crow Sands, and G = Grays Bay.
Major benthic invertebrates collected at Miller Sands included oligochaetes; bivalves, particularly Corbicula fluminea and Pisidium spp.; ostracods; amphipods, particularly Corophium salmonis and Hyalella azteca; chironomid larvae and pupae; and invertebrate eggs (Table 2; Appendix Table 3). Major benthic invertebrates at Jim Crow Sands included the polychaete Neanthes limnicola; oligochaetes; the gastropod Lithoglyphus virens; bivalves, particularly Corbicula fluminea and Pisidium spp.; ostracods; the amphipod Hyalella azteca; chironomid larvae and pupae; and invertebrate eggs. At Grays Bay, the polychaete Neanthes limnicola; oligochaetes; the bivalve Corbicula fluminea; the amphipod Corophium salmonis; harpacticoid copepods; chironomid larvae; and invertebrate eggs were the dominant forms.

At all three wetlands, benthic invertebrate densities at individual stations were high, with all values exceeding 15,000 organisms/m² (Table 1). Benthic invertebrate densities at Stations G8, J11, and J12 in September exceeded 100,000 organisms/m². Benthic invertebrate densities (total) were significantly higher in September than in July (ANOVA, P < 0.05); however, there were no significant differences between the three wetlands or between vegetated and nonvegetated habitats (P > 0.05). Densities of C. salmonis were significantly higher in September than in July and significantly higher in nonvegetated habitats than in vegetated habitats. In addition, C. salmonis densities were significantly higher in the Grays Bay wetland than in either the Miller Sands or Jim Crow Sands wetlands (ANOVA, FPLSD; P < 0.05) (Table 2).

Oligochaete densities were not significantly different between months. Overall statistical comparisons of oligochaete densities by area and habitat type (vegetated vs. nonvegetated) could not be done because of significant interaction (P < 0.05) between these two factors. If habitat type is excluded as a factor in ANOVA (i.e., two-way ANOVA is used), then oligochaete densities at Jim Crow Sands were significantly higher than
Table 2.—Densities (mean numbers/m²) of major benthic invertebrate taxa or categories collected in vegetated and nonvegetated habitats at Miller Sands, Jim Crow Sands, and Grays Bay, Columbia River estuary, July and September 1992. Less abundant taxa are included in totals, but are not listed individually.

<table>
<thead>
<tr>
<th>Taxon/category</th>
<th>July</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number/m²</td>
<td>SD</td>
</tr>
<tr>
<td><strong>MILLER SANDS, vegetated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>11,940</td>
<td>6,786</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>1,160</td>
<td>936</td>
</tr>
<tr>
<td>Pisidium spp.</td>
<td>86</td>
<td>264</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>6,271</td>
<td>5,853</td>
</tr>
<tr>
<td>Hyalella azteca</td>
<td>2,019</td>
<td>3,405</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>3,006</td>
<td>4,393</td>
</tr>
<tr>
<td>Invertebrate eggs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>25,813</td>
<td>18,167</td>
</tr>
<tr>
<td><strong>MILLER SANDS, nonvegetated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>31,224</td>
<td>19,483</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>644</td>
<td>876</td>
</tr>
<tr>
<td>Pisidium spp.</td>
<td>902</td>
<td>1,838</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>4,853</td>
<td>4,174</td>
</tr>
<tr>
<td>Corophium salmonis</td>
<td>215</td>
<td>960</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>12,112</td>
<td>12,224</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>258</td>
<td>404</td>
</tr>
<tr>
<td>Total</td>
<td>51,926</td>
<td>25,137</td>
</tr>
<tr>
<td><strong>JIM CROW SANDS, vegetated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>56,307</td>
<td>48,528</td>
</tr>
<tr>
<td>Lithoglyphus virens</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>2,706</td>
<td>2,543</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>8,461</td>
<td>5,050</td>
</tr>
<tr>
<td>Hyalella azteca</td>
<td>43</td>
<td>192</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>4,810</td>
<td>3,965</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>43</td>
<td>192</td>
</tr>
<tr>
<td>Total</td>
<td>74,088</td>
<td>49,298</td>
</tr>
<tr>
<td><strong>JIM CROW SANDS, nonvegetated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neanthes limnicola</td>
<td>558</td>
<td>936</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>34,961</td>
<td>24,476</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>773</td>
<td>617</td>
</tr>
<tr>
<td>Pisidium spp.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>2,706</td>
<td>3,069</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>5,025</td>
<td>4,972</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>258</td>
<td>629</td>
</tr>
<tr>
<td>Invertebrate eggs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>45,097</td>
<td>29,312</td>
</tr>
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</table>
Table 2.--Continued.

<table>
<thead>
<tr>
<th>Taxon/category</th>
<th>July</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number/m²</td>
<td>SD</td>
</tr>
<tr>
<td><strong>GRAYS BAY, vegetated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>25,082</td>
<td>18,441</td>
</tr>
<tr>
<td><em>Corophium salmonis</em></td>
<td>215</td>
<td>472</td>
</tr>
<tr>
<td>Harpacticoida</td>
<td>8,332</td>
<td>8,421</td>
</tr>
<tr>
<td><em>Chironomidae larvae</em></td>
<td>773</td>
<td>1,574</td>
</tr>
<tr>
<td>Invertebrate eggs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>36,550</td>
<td>19,056</td>
</tr>
</tbody>
</table>

| **GRAYS BAY, nonvegetated** |               |                |               |                |
| Neanthes limnicola       | 4,252         | 2,323          | 1,203         | 705            |
| Oligochaeta              | 5,712         | 3,181          | 4,510         | 2,046          |
| Corbicula fluminea       | 1,546         | 1,169          | 1,117         | 1,009          |
| *Corophium salmonis*     | 7,516         | 3,457          | 79,800        | 13,599         |
| Invertebrate eggs        | 0             | 0              | 5,884         | 4,266          |
| **Total**                | 20,358        | 6,895          | 95,004        | 17,354         |

* For each habitat type (vegetated or nonvegetated) within an area, a mean was calculated by averaging all replicates collected in that habitat.

* Standard deviation.
densities at Grays Bay; however, there were no significant differences in oligochaete densities between Miller Sands and Jim Crow Sands or between Miller Sands and Grays Bay. There were no significant differences in densities of insects (all taxa combined) between months or habitat types. Insect densities (primarily chironomids) were significantly higher at the Miller Sands and Jim Crow Sands wetlands than at the Grays Bay wetland.

Sediments

Median grain size was not significantly different between months or between vegetated and nonvegetated habitats (ANOVA; \( P > 0.05 \)); however, it was significantly different between areas (ANOVA, FPLSD; \( P < 0.05 \)) (Table 3). Median grain size was significantly larger at Grays Bay than at Miller Sands and Jim Crow Sands \((P < 0.05)\). In addition, median grain size was significantly larger at Miller Sands than at Jim Crow Sands \((P < 0.05)\). Combining data for July and September, median grain sizes averaged 0.1302 mm at Grays Bay, 0.1099 mm at Miller Sands, and 0.0722 mm at Jim Crow Sands.

Percent silt/clay was not significantly different between July and September \((P > 0.05)\); however, percent silt/clay was significantly higher in vegetated habitats than in nonvegetated habitats \((P < 0.05)\). Percent silt/clay was significantly higher at Jim Crow Sands than at Grays Bay, but there were no significant differences between Miller Sands and Jim Crow Sands or between Miller Sands and Grays Bay. Combining data for July and September, percent silt/clay averaged 24.6% at Jim Crow Sands, 15.5% at Miller Sands, and 10.6% at Grays Bay.

Percent volatile solids were significantly higher in September than in July \((P < 0.05)\). There were no significant differences in percent volatile solids between areas
Table 3.--Sediment characteristics at Miller Sands, Jim Crow Sands, and Grays Bay, Columbia River estuary, July and September 1992. Odd-numbered stations were vegetated habitats and even-numbered stations were nonvegetated.

<table>
<thead>
<tr>
<th>Station*</th>
<th>Median grain size (mm)</th>
<th>Silt/ clay(%)</th>
<th>Volatile solids(%)</th>
<th>Median grain size (mm)</th>
<th>Silt/ clay(%)</th>
<th>Volatile solids(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JULY</td>
<td></td>
<td></td>
<td>SEPTMBER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>0.1088</td>
<td>17.3</td>
<td>1.2</td>
<td>0.1166</td>
<td>15.2</td>
<td>1.1</td>
</tr>
<tr>
<td>M3</td>
<td>0.1436</td>
<td>8.5</td>
<td>0.6</td>
<td>0.0883</td>
<td>15.4</td>
<td>1.7</td>
</tr>
<tr>
<td>M2</td>
<td>0.1166</td>
<td>11.1</td>
<td>0.9</td>
<td>0.0947</td>
<td>23.3</td>
<td>1.5</td>
</tr>
<tr>
<td>M4</td>
<td>0.1436</td>
<td>8.2</td>
<td>1.1</td>
<td>0.0670</td>
<td>25.3</td>
<td>1.7</td>
</tr>
<tr>
<td>J9</td>
<td>0.0718</td>
<td>21.7</td>
<td>1.0</td>
<td>0.0670</td>
<td>33.8</td>
<td>2.2</td>
</tr>
<tr>
<td>J11</td>
<td>0.0508</td>
<td>47.4</td>
<td>1.5</td>
<td>0.0583</td>
<td>38.0</td>
<td>1.6</td>
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<td>J10</td>
<td>0.0947</td>
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<td>1.1</td>
<td>0.0883</td>
<td>7.3</td>
<td>1.5</td>
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<tr>
<td>J12</td>
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<td>0.0883</td>
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<td>1.6</td>
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<td>G5</td>
<td>0.1539</td>
<td>7.0</td>
<td>1.0</td>
<td>0.1166</td>
<td>16.7</td>
<td>1.6</td>
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<tr>
<td>G7</td>
<td>0.1088</td>
<td>17.7</td>
<td>1.6</td>
<td>0.1166</td>
<td>18.3</td>
<td>1.9</td>
</tr>
<tr>
<td>G6</td>
<td>0.1339</td>
<td>6.6</td>
<td>1.0</td>
<td>0.1250</td>
<td>8.1</td>
<td>1.1</td>
</tr>
<tr>
<td>G8</td>
<td>0.1436</td>
<td>5.2</td>
<td>0.7</td>
<td>0.1436</td>
<td>5.0</td>
<td>1.2</td>
</tr>
</tbody>
</table>

* The letter in the station name denotes the area: M = Miller Sands, J = Jim Crow Sands, and G = Grays Bay.
or between vegetated and nonvegetated habitats (P > 0.05). Combining data for July and September, percent volatile solids averaged 1.2% at Miller Sands, 1.4% at Jim Crow Sands, and 1.3% at Grays Bay.

DISCUSSION

Results from this study strongly suggest that both vegetated and nonvegetated habitats in wetlands at Miller Sands, Jim Crow Sands, and Grays Bay have high standing crops of benthic invertebrates in July and September. Benthic invertebrate densities at individual stations frequently exceeded 35,000 organisms/m². Benthic invertebrate densities in the three wetlands were much higher than densities in a deeper (8-13 m), higher water-velocity area between Miller Sands and Jim Crow Sands (NMFS unpublished data). In July 1992, mean benthic invertebrate densities at individual stations in the deeper area were less than 5,400 organisms/m². However, in September 1992, mean benthic invertebrate densities at individual stations in the deeper area were less than 36,200 organisms/m², but in all three wetlands were greater than 38,000 organisms/m². Mean benthic invertebrate densities at Miller Sands in both vegetated and nonvegetated wetland habitats were higher in July and September 1992 than those reported for nine nonvegetated intertidal stations sampled at Miller Sands in July and September 1991 (Hinton et al. 1992). Densities in July and September 1991 averaged 20,125 organisms/m² and 23,481 organisms/m², respectively. In the present study, mean benthic invertebrate densities in all sampled habitats at Miller Sands in July and September 1992 were greater than 25,800 organisms/m² (Table 2). At the Grays Bay wetland, mean benthic invertebrate densities were higher than those reported for 25 stations located in nonvegetated intertidal and shallow subtidal areas adjacent to Rice Island (Hinton et al. 1992). In July and September 1991, benthic invertebrate densities
at the 25 stations averaged 12,833 organisms/m² and 35,915 organisms/m², respectively. At the Grays Bay wetland in 1992, benthic invertebrate densities in the nonvegetated habitat averaged 20,358 organisms/m² in July and 95,004 organisms/m² in September.

Significantly higher benthic invertebrate densities in September than in July suggest that recruitment occurred. For example, there was a large increase in C. salmoides numbers between July and September. At Grays Bay, densities of C. salmoides in the nonvegetated habitat increased from 7,516 organisms/m² in July to 79,800 organisms/m² in September. In the vegetated habitat at Grays Bay, C. salmoides densities increased from 215 organisms/m² in July to 15,778 organisms/m² in September.

Holton et al. (1984) observed that C. salmoides densities were lowest in Grays Bay at the end of July, with subsequent increases in August and September. They attributed the increases in August and September to the fall generation of juveniles. Holton et al. (1984) reported C. salmoides densities ranging from 4,122 organisms/m² in late July 1981 to 31,754 organisms/m² in February 1981.

Both vegetated and nonvegetated habitats of the wetlands are ecologically important to the estuary. In addition to supporting high densities of benthic invertebrates, vegetated habitats produce "macrodetritus," an important food resource for C. salmoides (Sherwood et al. 1990). Nonvegetated habitats of the estuary have the highest standing crops of C. salmoides, an important prey for fishes in the estuary, including juvenile salmonids (McCabe et al. 1983, 1986). Both of these habitat types are ecologically important and must be protected.

This study represents a temporally and spatially limited description of the vegetated and nonvegetated wetland habitats at Miller Sands, Jim Crow Sands, and Grays Bay. To better describe these habitats at the three areas, additional benthic sampling should be
conducted. The number of sampling stations at each area should be increased and sampling should be done at least quarterly.

This report does not constitute NMFS's formal comments under the Fish and Wildlife Coordination Act or the National Environmental Policy Act.

ACKNOWLEDGMENTS

We thank Geoff Dorsey for assistance in collecting benthic samples, and Sheila Turner for sorting and identifying benthic invertebrates. The COE, Portland District provided the sediment analyses. Also, we thank Benjamin Sandford for his advice regarding statistical analyses of the data.
REFERENCES


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Petersen, R. G.


Sokal, R. R., and F. J. Rohlf.

Appendix Table 1.--Station locations at Miller Sands, Jim Crow Sands, and Grays Bay, Columbia River estuary, July and September 1992.

<table>
<thead>
<tr>
<th>Station</th>
<th>Vegetated (V)</th>
<th>Nonvegetated (NV)</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>V</td>
<td></td>
<td>46°14.789</td>
<td>123°39.545</td>
</tr>
<tr>
<td>M3</td>
<td>V</td>
<td></td>
<td>46°15.180</td>
<td>123°39.209</td>
</tr>
<tr>
<td>M2</td>
<td>NV</td>
<td></td>
<td>46°14.811</td>
<td>123°39.550</td>
</tr>
<tr>
<td>M4</td>
<td>NV</td>
<td></td>
<td>46°15.102</td>
<td>123°39.226</td>
</tr>
<tr>
<td>J9</td>
<td>V</td>
<td></td>
<td>46°14.922</td>
<td>123°35.061</td>
</tr>
<tr>
<td>J11</td>
<td>V</td>
<td></td>
<td>46°14.918</td>
<td>123°34.874</td>
</tr>
<tr>
<td>J10</td>
<td>NV</td>
<td></td>
<td>46°14.885</td>
<td>123°35.096</td>
</tr>
<tr>
<td>J12</td>
<td>NV</td>
<td></td>
<td>46°14.874</td>
<td>123°34.807</td>
</tr>
<tr>
<td>G5</td>
<td>V</td>
<td></td>
<td>46°16.618</td>
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</tr>
<tr>
<td>G7</td>
<td>V</td>
<td></td>
<td>46°16.596</td>
<td>123°41.701</td>
</tr>
<tr>
<td>G6</td>
<td>NV</td>
<td></td>
<td>46°16.590</td>
<td>123°41.806</td>
</tr>
<tr>
<td>G8</td>
<td>NV</td>
<td></td>
<td>46°16.589</td>
<td>123°41.708</td>
</tr>
</tbody>
</table>

*The letter in the station name denotes the area:  M = Miller Sands, J = Jim Crow Sands, and G = Grays Bay.*
### Appendix Table 2.

Invertebrate taxa collected at Miller Sands, Jim Crow Sands, and Grays Bay, Columbia River estuary, July and September 1992.

<table>
<thead>
<tr>
<th>Taxon/category</th>
<th>July</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydra spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nemertea</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Nematomorpha</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Polychaeta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neanthes limnicola</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Hirudinea</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Gastropoda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planorbidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physa spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithoglyphus virens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bivalvia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisidium spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ostracodida</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Amphipoda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyalella azteca</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corophium salmonis</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Corophium spinicorne</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pontoporeia hoyi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copepoda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harpacticoida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insecta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corixidae</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Diptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diptera larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diptera pupae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culicidae adult</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chironomidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Chironomidae adult</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ceratopogonidae larvae</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Dolichopodida larvae</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Trichoptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichoptera larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agralea spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coleoptera larvae</td>
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<td>x</td>
</tr>
<tr>
<td>Ephemeroptera larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collembola</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Arachnida</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Appendix Table 2.--Continued.

<table>
<thead>
<tr>
<th>Taxon/category</th>
<th>July</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydracarina</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Invertebrate eggs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of taxa/categories</td>
<td>31</td>
<td>36</td>
</tr>
</tbody>
</table>
Appendix Table 3.---Summaries of benthic invertebrate surveys (by station) conducted in July and September 1992 in vegetated and nonvegetated habitats at Miller Sands, Jim Crow Sands, and Grays Bay, Columbia River estuary. Odd-numbered stations were vegetated habitats and even-numbered stations were nonvegetated.

<table>
<thead>
<tr>
<th>Station: M1</th>
<th>Date: 16 Jul 92</th>
<th>Sample size: 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxon/category</td>
<td>Total number</td>
<td>Frequency of occurrence (%)</td>
</tr>
<tr>
<td>Nematomorpha</td>
<td>2</td>
<td>10.0</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>121</td>
<td>100.0</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>13</td>
<td>80.0</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>34</td>
<td>80.0</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>7</td>
<td>60.0</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>1</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Number of taxa/categories: 6
Mean number/sample: 17.8 Standard deviation/sample: 8.1
Mean number/m²: 15,290.0 Standard deviation: 6,928.9

<table>
<thead>
<tr>
<th>Station: M2</th>
<th>Date: 16 Jul 92</th>
<th>Sample size: 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxon/category</td>
<td>Total number</td>
<td>Frequency of occurrence (%)</td>
</tr>
<tr>
<td>Nematomorpha</td>
<td>8</td>
<td>30.0</td>
</tr>
<tr>
<td>Neanthes limnicola</td>
<td>16</td>
<td>100.0</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>502</td>
<td>100.0</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>2</td>
<td>20.0</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>36</td>
<td>90.0</td>
</tr>
<tr>
<td>Hyalella azteca</td>
<td>1</td>
<td>10.0</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>80</td>
<td>100.0</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>3</td>
<td>30.0</td>
</tr>
<tr>
<td>Hydcarcarina</td>
<td>1</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Number of taxa/categories: 9
Mean number/sample: 64.9 Standard deviation/sample: 27.9
Mean number/m²: 55,748.5 Standard deviation: 23,985.0
Appendix Table 3.—Continued.

<table>
<thead>
<tr>
<th>Taxon/category</th>
<th>Total number</th>
<th>Frequency of occurrence (%)</th>
<th>Mean number /m²</th>
<th>Standard deviation /m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nemertea</td>
<td>6</td>
<td>30.0</td>
<td>515.4</td>
<td>923.4</td>
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<tr>
<td>Oligochaeta</td>
<td>157</td>
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<td>13,486.1</td>
<td>7,311.8</td>
</tr>
<tr>
<td>Gastropoda</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Planorbidae</td>
<td>7</td>
<td>50.0</td>
<td>601.3</td>
<td>814.9</td>
</tr>
<tr>
<td>Lithoglyphus virens.</td>
<td>3</td>
<td>30.0</td>
<td>257.7</td>
<td>414.9</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>14</td>
<td>70.0</td>
<td>1,202.6</td>
<td>1,159.5</td>
</tr>
<tr>
<td>Pisidium spp.</td>
<td>2</td>
<td>20.0</td>
<td>171.8</td>
<td>362.2</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>112</td>
<td>90.0</td>
<td>9,620.7</td>
<td>6,425.5</td>
</tr>
<tr>
<td>Hyalella azteca</td>
<td>47</td>
<td>80.0</td>
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<td>3,927.0</td>
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<tr>
<td>Corixidae</td>
<td>2</td>
<td>10.0</td>
<td>171.8</td>
<td>543.3</td>
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<tr>
<td>Diptera pupae</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Diptera larvae</td>
<td>3</td>
<td>30.0</td>
<td>257.7</td>
<td>414.9</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>63</td>
<td>80.0</td>
<td>5,411.6</td>
<td>5,249.3</td>
</tr>
<tr>
<td>Trichoptera</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Trichoptera larvae</td>
<td>2</td>
<td>10.0</td>
<td>171.8</td>
<td>543.3</td>
</tr>
<tr>
<td>Arachnida</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Hydracarina</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
</tbody>
</table>

Number of taxa/categories: 17

Mean number/sample: 42.3 Standard deviation/sample: 23.4

Mean number/m²: 36,335.3 Standard deviation: 20,067.8
Appendix Table 3.—Continued.

<table>
<thead>
<tr>
<th>Taxon/category</th>
<th>Total number</th>
<th>Frequency of occurrence (%)</th>
<th>Mean number /m²</th>
<th>Standard deviation /m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligochaeta</td>
<td>225</td>
<td>100.0</td>
<td>19,327.3</td>
<td>8,467.3</td>
</tr>
<tr>
<td>Gastropoda</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Planorbidae</td>
<td>2</td>
<td>20.0</td>
<td>171.8</td>
<td>362.2</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>13</td>
<td>70.0</td>
<td>1,116.7</td>
<td>996.0</td>
</tr>
<tr>
<td><em>Fissidium</em> spp.</td>
<td>21</td>
<td>80.0</td>
<td>1,803.9</td>
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<td>Ostracoda</td>
<td>77</td>
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<td>6,614.2</td>
<td>4,740.5</td>
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<tr>
<td>Hyalella azteca</td>
<td>7</td>
<td>30.0</td>
<td>601.3</td>
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</tr>
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<td>Corophium salmonis</td>
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<td>10.0</td>
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<td>1,358.2</td>
</tr>
<tr>
<td>Diptera pupae</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
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<td>100.0</td>
<td>17,351.6</td>
<td>15,598.0</td>
</tr>
<tr>
<td>Chironomidae pupae</td>
<td>3</td>
<td>30.0</td>
<td>257.7</td>
<td>414.9</td>
</tr>
<tr>
<td>Hydracarina</td>
<td>3</td>
<td>20.0</td>
<td>257.7</td>
<td>579.8</td>
</tr>
</tbody>
</table>

Number of taxa/categories: 12

Mean number/sample: 56.0  Standard deviation/sample: 31.4
Mean number/m²: 48,103.4  Standard deviation: 26,948.5
Appendix Table 3.--Continued.

<table>
<thead>
<tr>
<th>Station: G5</th>
<th>Date: 16 Jul 92</th>
<th>Sample size: 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxon/category</td>
<td>Total number</td>
<td>Frequency of occurrence (%)</td>
</tr>
<tr>
<td>Neanthes limnicola</td>
<td>9</td>
<td>50.0</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>285</td>
<td>100.0</td>
</tr>
<tr>
<td>Hirudinea</td>
<td>1</td>
<td>10.0</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>10</td>
<td>80.0</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>5</td>
<td>40.0</td>
</tr>
<tr>
<td>Corophium salmonis</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>Harpacticoida</td>
<td>87</td>
<td>90.0</td>
</tr>
<tr>
<td>Diptera larvae</td>
<td>1</td>
<td>10.0</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>14</td>
<td>40.0</td>
</tr>
<tr>
<td>Trichoptera</td>
<td>1</td>
<td>10.0</td>
</tr>
<tr>
<td>Collembola</td>
<td>1</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Number of taxa/categories: 11
Mean number/sample: 41.7
Mean number/m²: 35,819.9

<table>
<thead>
<tr>
<th>Station: G6</th>
<th>Date: 16 Jul 92</th>
<th>Sample size: 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxon/category</td>
<td>Total number</td>
<td>Frequency of occurrence (%)</td>
</tr>
<tr>
<td>Nemertea</td>
<td>1</td>
<td>10.0</td>
</tr>
<tr>
<td>Neanthes limnicola</td>
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<td>90.0</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>73</td>
<td>100.0</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
<td>18</td>
<td>80.0</td>
</tr>
<tr>
<td>Ostracoda</td>
<td>4</td>
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Number of taxa/categories: 9
Mean number/sample: 24.9
Mean number/m²: 21,388.8

Standard deviation/sample: 21.7
Standard deviation: 18,600.7
Appendix Table 3.--Continued.

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Number of taxa/categories: 8
Mean number/sample: 43.4 Standard deviation/sample: 23.8
Mean number/m²: 37,280.2 Standard deviation: 20,480.9

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Number of taxa/categories: 8
Mean number/sample: 22.5 Standard deviation/sample: 6.4
Mean number/m²: 19,327.3 Standard deviation: 5,496.5
## Appendix Table 3.--Continued.

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<td>Diptera larvae</td>
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<td>Chironomidae larvae</td>
<td>29</td>
<td>80.0</td>
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<td>Dolichopodidae larvae</td>
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<tr>
<td>Hydracarina</td>
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Number of taxa/categories: 9
Mean number/sample: 85.0
Mean number/m²: 73,014.1

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<td>Oligochaeta</td>
<td>189</td>
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<td>Corbicula fluminea</td>
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<tr>
<td>Ostracoda</td>
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<td>Pontoporeia hovii</td>
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<tr>
<td>Chironomidae larvae</td>
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<td>Coleoptera larvae</td>
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Number of taxa/categories: 9
Mean number/sample: 25.5
Mean number/m²: 21,904.2

Mean number/sample: 25.5
Mean number/m²: 21,904.2
Appendix Table 3.--Continued.

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<td><strong>Frequency of occurrence (%)</strong></td>
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<td>50.0</td>
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<td>Ostracoda</td>
<td>92</td>
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<td>Hyalella azteca</td>
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<tr>
<td>Insecta</td>
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<td>10.0</td>
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<tr>
<td>Diptera</td>
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<td>10.0</td>
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<tr>
<td>Diptera larvae</td>
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<td>20.0</td>
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<tr>
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<tr>
<td>Ceratopogonidae larvae</td>
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<td>Dolichopodidae larvae</td>
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Number of taxa/categories: 14
Mean number/sample: 87.5 Standard deviation/sample: 47.4
Mean number /m²: 75,161.6 Standard deviation: 40,673.5

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<td><strong>Frequency of occurrence (%)</strong></td>
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<td>Diptera larvae</td>
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<tr>
<td>Chironomidae larvae</td>
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<td>100.0</td>
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<tr>
<td>Chironomidae pupae</td>
<td>6</td>
<td>40.0</td>
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Number of taxa/categories: 7
Mean number/sample: 79.5 Standard deviation/sample: 27.9
Mean number /m²: 68,289.7 Standard deviation: 24,008.2
Appendix Table 3.—Continued.

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<th>Frequency of occurrence (%)</th>
<th>Mean number /m²</th>
<th>Standard deviation /m²</th>
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</thead>
<tbody>
<tr>
<td>Nemertea</td>
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<td>20.0</td>
<td>257.7</td>
<td>579.8</td>
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<tr>
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<td>9,227.2</td>
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<tr>
<td>Bivalvia</td>
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<td>85.9</td>
<td>271.6</td>
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<td>85.9</td>
<td>271.6</td>
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<tr>
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<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
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<tr>
<td>Ceratopogonidae larvae</td>
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<td>20.0</td>
<td>257.7</td>
<td>579.8</td>
</tr>
<tr>
<td>Trichoptera larvae</td>
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<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
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<tr>
<td>Coleoptera</td>
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<td>271.6</td>
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<td>271.6</td>
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Number of taxa/categories: 18

Mean number/sample: 62.5
Standard deviation/sample: 15.2

Mean number/m²: 53,686.9
Standard deviation: 13,097.8
Appendix Table 3.--Continued.

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<th>Frequency of occurrence (%)</th>
<th>Mean number /m²</th>
<th>Standard deviation /m²</th>
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<tbody>
<tr>
<td>Neanthes limnicola</td>
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<td>579.8</td>
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<tr>
<td>Trichoptera larvae</td>
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Number of taxa/categories: 14

Mean number/sample: 98.2 Standard deviation/sample: 31.1

Mean number/m²: 84,352.8 Standard deviation: 26,688.0
### Appendix Table 3.—Continued.

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<th>Standard deviation/m²</th>
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<td>85.9</td>
<td>271.6</td>
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<td>Ostracoda</td>
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<td>171.8</td>
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<td>271.6</td>
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<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
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<td>171.8</td>
<td>362.2</td>
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<td>724.4</td>
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<td>Trichoptera larvae</td>
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<td>271.6</td>
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Number of taxa/categories: 22

Mean number/sample: 69.8

Standard deviation/sample: 12.6

Mean number/m²: 59,957.5

Standard deviation: 10,856.4
Appendix Table 3.--Continued.

<table>
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<tr>
<th>Taxon/category</th>
<th>Total number</th>
<th>Frequency of occurrence (%)</th>
<th>Mean number /m²</th>
<th>Standard deviation /m²</th>
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<td>271.6</td>
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<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Lithoglyphus virens</td>
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<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Corbicula fluminea</td>
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Number of taxa/categories: 19

Mean number/sample: 52.6

Mean number/m²: 45,182.9
Appendix Table 3.—Continued.

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Number of taxa/categories: 14

Mean number/sample: 88.9 Standard deviation/sample: 21.8
Mean number/m²: 76,364.2 Standard deviation: 18,699.1
Appendix Table 3.--Continued.

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Number of taxa/categories: 10
Mean number/sample: 103.8
Standard deviation/sample: 18.6
Mean number/m²: 89,163.2
Standard deviation: 15,992.5

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Number of taxa/categories: 9
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Standard deviation/sample: 37.0
Mean number/m²: 44,858.4
Standard deviation: 31,770.4
Appendix Table 3.—Continued.

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<th>Mean number /m²</th>
<th>Standard deviation /m²</th>
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Number of taxa/categories: 13

Mean number/sample: 117.4

Standard deviation/sample: 20.3

Mean number/m²: 100,845.4

Standard deviation: 17,441.2
## Appendix Table 3.--Continued.

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**Number of taxa/categories:** 14  
**Mean number/sample:** 54.3  
**Standard deviation/sample:** 28.2  
**Mean number/m²:** 46,643.2  
**Standard deviation:** 24,255.5

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**Number of taxa/categories:** 8  
**Mean number/sample:** 45.0  
**Standard deviation/sample:** 8.4  
**Mean number/m²:** 38,654.6  
**Standard deviation:** 7,243.6
Appendix Table 3.--Continued.

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Number of taxa/categories: 21

Mean number/sample: 181.6 Standard deviation/sample: 50.3

Mean number/m²: 155,992.6 Standard deviation: 43,184.0
## Appendix Table 3—Continued.

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<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Dolichopodidae larvae</td>
<td>2</td>
<td>20.0</td>
<td>171.8</td>
<td>362.2</td>
</tr>
<tr>
<td>Trichoptera larvae</td>
<td>1</td>
<td>10.0</td>
<td>85.9</td>
<td>271.6</td>
</tr>
<tr>
<td>Invertebrate eggs</td>
<td>8</td>
<td>30.0</td>
<td>687.2</td>
<td>1,201.2</td>
</tr>
</tbody>
</table>

Number of taxa/categories: 16

Mean number/sample: 163.9

Standard deviation/sample: 44.7

Mean number/m²: 140,788.5

Standard deviation: 38,384.1