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SHOREBIRD PREDATION ON BENTHIC MACROINVERTEBRATES IN AN IRRIGATION RESERVOIR

Janet R. Mihuc1,2, Charles H. Trost1,3, and Timothy B. Mihuc1,4

ABSTRACT.—American Falls Reservoir in southeastern Idaho is an irrigation reservoir used as an inland feeding stopover by many shorebird species. Six exclosure experiments were conducted during the 1990 drawdown period to investigate shorebird predation impact on benthic macroinvertebrate populations. The study sites differed in sediment composition, sediment slope, invertebrate densities, and shorebird abundance. Shorebird predation significantly affected invertebrate densities in only 1 of 6 experiments (Aberdeen Mouth). This site had higher sediment slope and slower water recedence than other study sites, resulting in concentration of shorebird predation on a smaller area of newly exposed sediment. Shorebird predation had the greatest impact on medium size class chironomid larvae at Aberdeen Mouth. Our results suggest that inland sites such as American Falls Reservoir represent viable shorebird habitat and may be managed to insure consistent prey availability. Drawdown rate, sediment slope, invertebrate densities, and shorebird abundance are all important factors influencing shorebird predation. Monitoring shorebird abundance and predation impact on invertebrate densities may help in manipulating drawdown rate to provide adequate shorebird prey. Management of inland sites for shorebird use may become more important in the future as human encroachment in coastal areas continues.

Key words: benthic macroinvertebrates, exclosures, Idaho, management, predation, shorebirds.

Reliable and food-rich staging areas are essential for migrating shorebirds (Senner and Howe 1984, Myers et al. 1987, Paulson 1993). Although coastal staging areas support the largest numbers of migrating shorebirds, many inland staging areas exist and may become more important as human encroachment upon coastal areas continues (Skagen and Knopf 1993). Knowledge concerning shorebird inland use is limited compared to coastal staging areas. The focus of this study was to quantify shorebird use of food resources at a freshwater inland staging area, American Falls Reservoir, Idaho. The annual presence of >30,000 individuals and >30 species of shorebirds during fall migration has been documented at this reservoir (Taylor et al. 1992). Common probing or benthic-feeding species using the reservoir include Baird’s Sandpiper (Calidris bairdi), Western Sandpiper (Calidris mauri), Long-billed Dowitcher (Limnodromus scolopaceus), Lesser Yellowlegs (Tringa flavipes), and Marbled Godwit (Limosa fedoa).

Exclosures are commonly used to assess shorebird predation in marine and estuarine environments (Schneider 1978, Bloom 1980, Quammen 1981, Schneider and Harrington 1981, Raffaei and Milne 1987). In this study exclosures were used to assess experimentally the impact of shorebird predation on benthic macroinvertebrates at several American Falls Reservoir sites. Sites differed in sediment composition, sediment slope, and rate of sediment exposure. Investigating the impact of shorebird predation at different sites may help identify physical factors that influence predation.

STUDY AREA

American Falls Reservoir is an east–west oriented, shallow-depth impoundment located on the Snake River, southeastern Idaho. The reservoir is part of the Bureau of Reclamation’s Minidoka project that provides irrigation water to thousands of hectares of land in southern and eastern Idaho. The Snake River enters the reservoir in the Springfield Bottoms at the northeastern end and exits through a dam at the southwestern end. Located at an elevation of 1328 m, the reservoir at full capacity is 35.4 km long, has a surface area of 23,503 ha, and has 161 km of shoreline. Annual drawdown

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typically begins in April and continues through September (Fig. 1), and is most rapid between June and late August when irrigation water demand is greatest. Several kilometers of mudflats consisting mainly of sand and silt are exposed at this time.

Six experiments were conducted at the reservoir in summer 1990 (Table 1). Study sites differ in sediment composition and sediment slope and were selected because of observed shorebird foraging activity in the area. The slope of the sediment \( \tan^{-1} \left[ \text{depth of placement (m)} / \text{distance from shoreline (m)} \right] \) ranges from 0.35° to 2.69° (Table 2). The Bronco site is on the east side of the reservoir. Two experiments were conducted at Aberdeen Bay on the west side of the reservoir: one at Back Bay at the back of the bay and the other at Aberdeen Mouth at the mouth of the bay. Willow and Silo sites are at the southern end of the reservoir, within 5 km of the dam. Two experiments were conducted at the Willow site.

**METHODS**

For each experiment at each site we placed treatment sets in water depth inaccessible to probing shorebirds and conducted benthic sampling the day after water had receded beyond the treatment sets. A treatment set included 1 exclosure, 1 open control, and 1 exclosure control (Quammen 1981, Fig. 2). Six treatment sets were used during each experiment. The open control was marked by 4 wooden stakes. The exclosure control, which consisted of a top and 1 side to allow shorebird access, was used to account for any influence the exclosure itself might have on shorebird predation. Exclosures consisted of 4 sides and a top. Exclosures and exclusion controls were constructed of hardware cloth (1-cm² mesh) stapled to wooden stakes (65 cm long). The area within each exclosure or control was 0.25 m².

We carried treatment sets from the water's edge and placed them underwater 8.5–37 m from the shoreline (Table 1) by pushing each set into the sediment until the bottom edge of the hardware cloth was at least 2 cm below the sediment surface. Wooden stakes of the open control were pushed down to a depth equal to the other 2 treatment types. We carried all treatment sets to the placement area from a downshore point to minimize sediment disturbance between treatments and the shoreline. The 6 treatment sets were placed in a row parallel to the shoreline in the same water depth (Fig. 2). Arrangement of the exclosure and 2 controls in each treatment set was random. Placement depth for treatment sets in each experiment ranged from 19 to 40 cm (Table 1). Reservoir drawdown was constant and averaged 14 (±3 s) cm/day during the study period (July to mid-August 1990). The rapid drawdown resulted in the treatment sets being submerged 1–4 d at each site (Table 1).

Benthic macroinvertebrates were sampled the day after the water had completely receded beyond all treatment sets. Because treatment sets were placed parallel to the shoreline, all became exposed at the same time and were sampled simultaneously according to the following procedures: We took randomly spaced cores of sediment with a 5-cm-diameter, 10-cm-long plastic core tube. Two cores were taken from each exclosure and control and then combined to represent a single sample, generating 6 samples for each treatment type (exclosure, exclusion control, open control) during each experiment. Sediment cores taken in the field were placed in plastic sample bags and either sorted or frozen as soon as possible. Before sorting, we sieved samples (0.25-mm mesh sieve), leaving only invertebrates and organic matter. All invertebrates were sorted from the samples, preserved in 95% ethanol, and later identified and counted with the use of a binocular dissecting microscope. Three distinct size classes of chironomid larvae, differentiated by
TABLE 1. Summary of experimental design parameters including water depth in which treatments were placed and initial distance of treatments from shoreline.

<table>
<thead>
<tr>
<th>Site name</th>
<th>Placement date</th>
<th>Sampling date</th>
<th>Placement depth (cm)</th>
<th>Distance from shore (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronco</td>
<td>18 July</td>
<td>20 July</td>
<td>23</td>
<td>37</td>
</tr>
<tr>
<td>Back Bay</td>
<td>26 July</td>
<td>28 July</td>
<td>40</td>
<td>8.5</td>
</tr>
<tr>
<td>Silo</td>
<td>6 August</td>
<td>9 August</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Aberdeen Mouth</td>
<td>9 August</td>
<td>14 August</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td>Willow (experiment 1)</td>
<td>14 August</td>
<td>16 August</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>Willow (experiment 2)</td>
<td>18 August</td>
<td>20 August</td>
<td>22</td>
<td>35</td>
</tr>
</tbody>
</table>

TABLE 2. Sediment slope and sediment composition at each study site.

<table>
<thead>
<tr>
<th>Site name</th>
<th>Sediment slope</th>
<th>% silt (&lt;0.62 mm)</th>
<th>% sand (0.62-1.6 mm)</th>
<th>% gravel (&gt;1.6 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronco</td>
<td>0.35</td>
<td>28.8</td>
<td>71.2</td>
<td>0</td>
</tr>
<tr>
<td>Back Bay</td>
<td>2.69</td>
<td>31.7</td>
<td>40.0</td>
<td>28.3</td>
</tr>
<tr>
<td>Silo</td>
<td>0.76</td>
<td>48.0</td>
<td>40.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Aberdeen Mouth</td>
<td>1.25</td>
<td>96.6</td>
<td>3.4</td>
<td>0</td>
</tr>
<tr>
<td>Willow (experiment 1)</td>
<td>0.36</td>
<td>73.4</td>
<td>26.6</td>
<td>0</td>
</tr>
<tr>
<td>Willow (experiment 2)</td>
<td>0.36</td>
<td>78.2</td>
<td>21.8</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 2. Depiction of the placement of 2 treatment sets parallel to the shoreline. A treatment set consisted of 1 enclosure (E), 1 enclosure control (EC), and 1 open control (OC). Ordering of the enclosure and controls in each treatment set was random.

Head capsule size and body length (small, <5 mm; medium, 5-10 mm; large, >10 mm), were counted separately. We took 1 sample from each study site and analyzed it for sediment composition. This sample was wet-sieved through 2 sieves to separate it into gravel (>1.6 mm), sand (>0.62 mm), and silt (<0.62 mm) components. After removing invertebrates, we dried the sample at 60°C for 72 h and weighed it. Percentages of gravel, sand, and silt at the study site were then calculated from the components and total weight of the sample (Table 2).

A daily estimate of shorebird abundance in the immediate vicinity of the treatment sets was calculated beginning the day after sets were placed and continuing through the day benthic sampling was conducted. Direct counts were made of all probing species in a 100-m area of shoreline in front of the treatment sets. This area was designated by 2 small flags placed at both ends of the transect. For a period of 30 min each morning, we counted all shorebirds at 5-min intervals (Wilson 1988). Counts of probing species were used to calculate a mean and standard deviation, which when doubled represented an hourly estimate. Multiplying the hourly estimate by 24 yielded a daily estimate of shorebird abundance during each experiment.
Comparison of shorebird abundance across all study sites was possible because daily estimates were based on counts taken at a similar time at each study site.

An independent $t$ test was used to compare invertebrate density data from the 2 types of controls, addressing the effect of exclosure presence on shorebird predation. An ANOVA was used to compare invertebrate density data from all 3 treatment types at each site. Total invertebrate density data were analyzed as well as large and medium size class density data for chironomid larvae. We used size class data analysis to address the possibility of shorebird feeding preference for either size class, and a linear regression to investigate the relationship between sediment composition and invertebrate densities at each site.

**RESULTS**

Benthic prey items available to shorebirds at American Falls Reservoir included chironomid larvae and tubificid worms. Invertebrate densities differed across study sites (Fig. 3). Most chironomid larvae consisted of *Chironomus* sp.
(90–95%), but some *Procladius* sp. also were found. Chironomid larvae were the predominant benthic prey item, constituting 40–100% of total benthic invertebrates found in exclosures during each experiment. The majority of chironomid larvae in samples were represented by the large and medium size classes. Individuals of these 2 size classes were 1–2 mm larger in diameter than tubificid worms. Densities of large and medium size class chironomid larvae were similar at each site but differed somewhat across sites (Fig. 4). The largest number of chironomid larvae were found at the Silo site, the smallest number at Back Bay.

No differences (*P* > 0.05) in total invertebrate densities occurred between the 2 control types in any experiments. A difference (*P* < 0.05) between total invertebrate density among the 3 treatment types occurred only during the Aberdeen Mouth experiment (Fig. 3). Comparison of chironomid size class data from the treatment types revealed a difference (*P* < 0.05) only in the medium size class of chironomids at Aberdeen Mouth (Fig. 4). The impact
of shorebird predation on the large size class of chironomids at this site was noticeable but not significant ($P < 0.10$). At the Silo site the medium size class of chironomids suffered greater predation impact than the large size class, but this difference was not significant ($P < 0.10$; Fig. 4).

Sand and silt dominated all sites (Table 2). The percentage of these 2 fractions varied from site to site, but linear regression results indicated no effect of sand ($r = 0.22$, $P > 0.05$) or silt concentration ($r = -0.22$, $P > 0.05$) on benthic invertebrate densities. Because of the rapid water drawdown during the experiments, more than 10 m of sediment was exposed or under shallow water (<5 cm) each day at 4 of the 5 sites. At Aberdeen Bay where 2 experiments were conducted (Back Bay, Aberdeen Mouth), 0–5 m of sediment was exposed each day. Daily estimates of shorebird abundance varied widely, ranging from 14 during the Silo experiment to over 6000 during the Bronco experiment (Table 3).

**DISCUSSION**

Management of American Falls Reservoir for irrigation purposes has created a unique and dynamic environment with gradually sloping sediment, constant rate of summer drawdown, and little submerged vegetation (Taylor et al. 1993). These characteristics represent ideal habitat for foraging shorebirds during migration (Rundel and Fredrickson 1981, Kushlan 1989, Helmiers 1991). Shorebird abundance data were not useful predictors of predation impact on invertebrate densities at the study sites. This may be because birds were foraging over large areas of freshly available sediment each day, and counts were taken during only 1 window of time daily. Significant shorebird predation effect on benthic prey populations was found only at Aberdeen Mouth. Shorebird predation at this site had a greater impact on medium size class chironomids (Fig. 4), suggesting a feeding preference for size class. The possibility of feeding preference should not be overlooked in management decisions concerning shorebirds. Further study of shorebird preference for prey size or species in freshwater environments is needed.

Comparing conditions at the Aberdeen Mouth site to those at other study sites was useful in identifying factors that influenced shorebird predation impact during this study. At Aberdeen Mouth, treatment sets were exposed to shorebird predation at least 24 h longer than at other sites because the mouth of the small bay has a steeper sediment slope than all other sites except Back Bay. The combination of steeper slope and drainage of water from the bay resulted in slower water recession. Shorebird predation at the Aberdeen Mouth site was concentrated on 0–2 m of freshly exposed sediment each day rather than 5–10 m of freshly exposed sediment typical of the other study sites. The longer exposure and concentration of shorebird predation on a smaller area of sediment probably accounts for the observed impact on invertebrate densities at the Aberdeen Mouth site. Although sediment slope was steepest at the Back Bay site (Table 2), the minimal impact of shorebird predation was probably due to much lower invertebrate densities (Fig. 3) and shorebird abundance (Table 3) compared to the other study sites. Our results suggest that sediment slope, invertebrate densities, and shorebird abundance should all be monitored and considered in combination when making management decisions regarding shorebird predation.

Conditions at American Falls Reservoir are a contrast to conditions in coastal areas.

**Table 3.** Daily abundance estimates (mean ± standard deviation) of shorebirds during each experiment. Numbers of counts reflect different lengths of each experiment.

<table>
<thead>
<tr>
<th>Site name</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bronco</strong></td>
<td>6034 ± 1482</td>
<td>630 ± 199*</td>
<td>60 ± 44*</td>
<td>240 ± 40</td>
</tr>
<tr>
<td><strong>Back Bay</strong></td>
<td>15 ± 1</td>
<td>254 ± 151</td>
<td>117 ± 67</td>
<td>103 ± 81*</td>
</tr>
<tr>
<td><strong>Silo</strong></td>
<td>14 ± 36</td>
<td>240 ± 40</td>
<td>41 ± 109*</td>
<td>103 ± 81*</td>
</tr>
<tr>
<td><strong>Aberdeen Mouth</strong></td>
<td>1008 ± 469</td>
<td>254 ± 151</td>
<td>117 ± 67</td>
<td>103 ± 81*</td>
</tr>
<tr>
<td><strong>Willow (experiment 1)</strong></td>
<td>3408 ± 1761</td>
<td>2722 ± 511*</td>
<td>103 ± 81*</td>
<td></td>
</tr>
<tr>
<td><strong>Willow (experiment 2)</strong></td>
<td>199 ± 216*</td>
<td>630 ± 199*</td>
<td>60 ± 44*</td>
<td></td>
</tr>
</tbody>
</table>

* = last day surveyed
latter are characterized by many shorebirds feeding on a limited shoreline exposed during low tide (Myers 1983, Burger 1984). Coastal studies have documented a significant impact of shorebird predation on invertebrate densities (Schneider 1978, Schneider and Harrington 1981, Quammen 1984). At American Falls Reservoir the constant summer drawdown rate provides large areas of newly exposed sediment daily, and shorebird densities are lower than at coastal areas. Our results suggest that current prey densities in both sandy and silty mudflats are adequate to support shorebirds using American Falls Reservoir: This potential is encouraging because if shorebird densities were to increase, use of the traditional feeding areas might gradually increase over time (Myers et al. 1987). Although further study of inland sites is needed, conservation and management of these sites should continue.

Our results and those of other studies have identified criteria for evaluating inland areas as potential shorebird staging areas. Impoundments currently used for irrigation purposes may need only minor adjustments to accommodate migrating shorebirds. A gradually sloping, silty or sandy sediment with little or no vegetation is most favorable (Helmers 1991). An annual drawdown would favor prey colonization by tubificid worms and certain chironomid species and discourage colonization by aquatic vegetation (Helmers 1991). The drop in water level must coincide with known migration periods of shorebird species that would potentially use the area (Hands et al. 1991, Taylor et al. 1993). A gradual but continual drop in water level would insure a renewing source of available prey (Rundle and Fredrickson 1981, Kushlan 1989). Prey densities will likely vary across space and time and should be monitored throughout the migration period. Ability to manipulate the drawdown rate on a seasonal or yearly basis is important. Faster drawdown may be necessary to compensate for sediment slope in some impoundments. The drawdown rate may also be manipulated to accommodate numbers of shorebirds using the area in relation to densities of available prey. Monitoring the impact of shorebird predation on invertebrate populations could be accomplished using exclosures, thus providing data for decisions concerning drawdown rate (Skagen and Knopf 1993).

ACKNOWLEDGMENTS

This research, conducted as part of a master's thesis, was funded by grants from the Bureau of Reclamation, Sigma Xi, and Idaho State University Graduate Student Research and Scholarship Committee. Dr. L. Ferrington provided confirmation of identification of chironomid larvae. Dan Taylor and 3 anonymous reviewers provided valuable critiques of the manuscript.

LITERATURE CITED


Received 24 May 1996
Accepted 21 April 1997