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SIZE SELECTION OF THE SLIMY SCULPIN (*COTTUS COGNATUS*) ON *GAMMARUS MINUS* PREY

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ABSTRACT

According to optimal foraging theory, a predator will select higher quality (e.g., larger) prey when prey are abundant. Our hypothesis was that slimy sculpins (*Cottus cognatus*) should preferentially feed upon the largest individuals of the freshwater amphipod *Gammarus minus*. We tested this hypothesis by comparing the size of *G. minus* selected by sculpins with the average length of *G. minus* in a population. This study was conducted at two mid-Appalachian springs that supported healthy populations of both *G. minus* and *C. cognatus*. In the spring with abundant *G. minus*, the size of selected individuals was significantly larger than the average size of individuals within the population. In the spring with a considerably lower density of *G. minus*, the size selected was not significantly larger than the average size within the population. These results are in accord with optimal foraging theory.

Keywords: Cottus cognatus, *freshwater spring ecology,* Gammarus minus, *optimal foraging theory, prey selection.*

INTRODUCTION

The amphipod *Gammarus minus* lives in the benthos of cold, relatively alkaline freshwater springs. This species is the common prey of many predators found in springs and streams, including the slimy sculpin, *Cottus cognatus*. These species offer an excellent model system for studying the various factors affecting predator-prey relationships.

Animals are generally selective about the food that they consume, and it is thought that this selectivity is important to their relative fitness (Werner et al., 1983). This belief is basic to optimal foraging theory, which predicts that organisms should maximize their food intake per unit of time (Ricklefs and Miller, 1999). Several studies have shown that fish select comparatively large individuals of a species to maximize energy gain (e.g., Newman and Waters, 1984; Rincon and Lobon-Cervia, 1999).

Our hypothesis was that the slimy sculpin should select larger than average *G. minus* as prey, as predicted by optimal foraging theory. To test this idea we compared the mean lengths of *G. minus* found in two spring populations with their mean lengths in the digestive tracts of coexisting sculpins.

This kind of prey-selection study may lead to a better understanding of the evolutionary process. In particular, size-selective predation may help explain why prey species are often smaller in habitats with predators than those without.

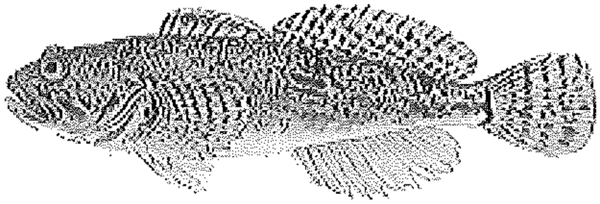

Figure 1. The slimy sculpin, Cottus cognatus.

FIELD SITES

The study sites were two freshwater springs in the mid-Appalachian area of Central Pennsylvania. Williamsburg Spring is located in the town of Williamsburg in Blair County, Pennsylvania (Fig. 2A). At the time of this study, the spring had a pH of 6.32 and a temperature of 13.0° C. Blue Spring is located on Blue Springs Farm in Huntingdon County, Pennsylvania (Fig. 2B). This spring had a pH of 7.47 and a temperature of 11.0° C. These springs were chosen because they have abundant populations of *C. cognatus* and *G. minus*, though *G. minus* more is abundant Williamsburg Spring than Blue Spring.

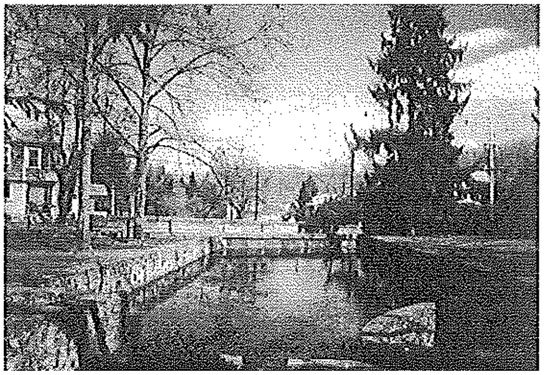

Figure 2A. Williamsburg Spring

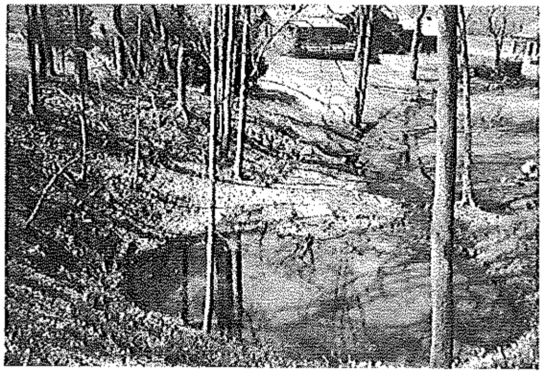

Figure 2B. Blue Spring

METHODS AND MATERIALS

Sculpins were caught using hand nets (Fig. 3), and transported in buckets to the laboratory. Ten random samples of *G. minus* in the benthos of each spring were collected using a plastic cylinder with a mesh window on one side and a mesh pouch on the other. The cylinder was placed into the spring with the

Figure 3. Method for capturing sculpins.

mesh window upstream and the pouch downstream. The sediment was then stirred by a dowel. The mesh window allowed the water to flow through the cylinder and exit the mesh pouch, trapping the amphipods in the pouch. At the time of collection, springwater temperature was measured with a mercury thermometer and pH with a Markson field pH meter.

In the laboratory, we used metric rulers to measure the body lengths (base of first antenna to base of telson) of *G. minus* collected from each spring stream and from the digestive tracts of coexisting *C. cognatus*. Gut-benthos comparisons of amphipod body length were made using t-tests.

RESULTS

At Williamsburg Spring a total of 48 *C. cognatus* were collected and their stomachs dissected to find *G. minus*. Of these sculpins 27 contained *G. minus* and 21 contained other prey (Table 1). At Blue Spring a total of 37 *C. cognatus* were collected and dissected. In this sample 15 sculpins contained *G. minus* and 22 contained other prey (Table 1). More but smaller amphipods were found in the benthos and in sculpin stomachs in Williamsburg Spring than in Blue Spring (Tables 1-3). The number of samples compared to the total number of benthic *G. minus* collected reveals the density of *G. minus*. The density for Williamsburg Spring was 14.4 *G. minus* per sample, whereas the density for Blue Spring was 2.6 *G. minus* per sample (Table 3).

Table 1. Numbers and body lengths of the amphipod Gammarus minus ***found in the stomachs of the sculpin*** Cottus cognatus ***at Williamsburg and Blue Springs.***

						Length of *G. minus*	
Spring	No. fish	No. *G.minus*	*C. cognatus* with *G.minus*	*C. cognatus* with other prey	No. *G.minus* per fish	Mean (mm)	Standard Deviation
Williamsburg	48	43	27	21	0.90	4.63	0.88
Blue	37	24	15	22	0.65	5.62	2.05

Table 2. Numbers and body lengths of benthic Gammarus minus *collected in Williamsburg and Blue Springs*

		Length of *G. minus* caught	
Spring	No. *G. minus*	Mean (mm)	Standard Deviation
Williamsburg	72	3.53	0.98
Blue	91	5.18	1.68

Table 3. Numbers of benthic Gammarus minus *collected per sample in Williamsburg and Blue Springs.*

Spring	No. of samples	Total *G. minus*	No. *G. minus* per sample
Williamsburg	5	72	14.4
Blue	35	91	2.6

The body lengths of Williamsburg Spring *G. minus* were significantly greater in sculpin stomachs than in the benthos (Table 4). However, no significant difference was found for Blue Spring *G. minus* (Table 5). These patterns are further shown in Figs. 4 and 5. In addition, body lengths of the amphipods found in sculpin stomachs were unrelated to sculpin length (Fig. 6); and sculpins with amphipods in their stomachs did not differ significantly in length from those that had other prey in their stomachs (Tables 6, 7). Finally, benthic *G. minus* in Williamsburg Spring were significantly smaller than those in Blue Spring (Table 8).

Table 4. Comparison of the body lengths of Williamsburg Spring Gammarus minus *in the benthos versus sculpin stomachs.*

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Two Sample T-Test and Confidence Interval


Two sample T for Williams stomach

Williams      N      Mean     StDev   SE Mean
1            43      4.57      1.23      0.19
2            72      3.53      1.19      0.14

T = 4.44  P = 0.0000  DF = 85
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Table 5. Comparison of the body lengths of Blue Spring Gammarus minus *in the benthos versus sculpin stomachs.*

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Two Sample T-Test and Confidence Interval


Two sample T for Blue stomach

Blue cau      N      Mean     StDev   SE Mean
1            24      5.62      2.05      0.42
2            92      5.18      2.01      0.21

T = 0.93  P = 0.36  DF = 35
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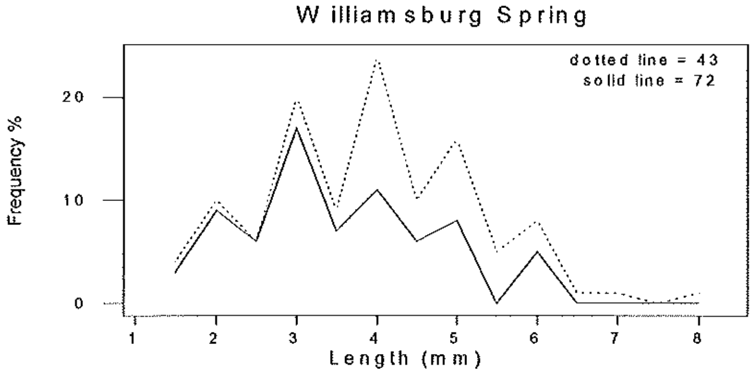

Figure 4. Size-frequency distribution of Gammarus minus *in sculpin stomachs (dotted line) and in the benthos (solid line) of Williamsburg Spring.*

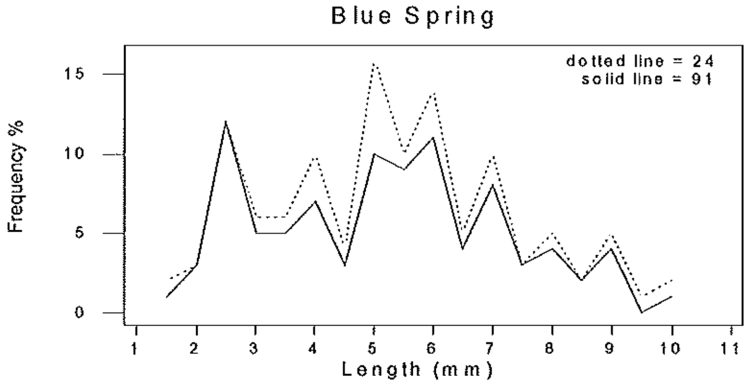

Figure 5. Size-frequency distribution of Gammarus minus *in sculpin stomachs (dotted line) and in the benthos (solid line) of Blue Spring.*

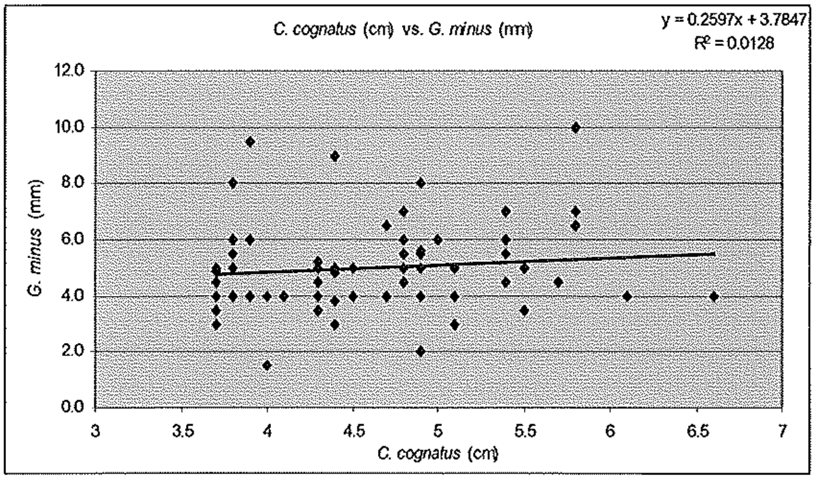

Figure 6. Body lengths of Gammarus minus *found in sculpin stomachs in relation to sculpin body length.*

Table 6. Body lengths of Williamsburg Spring sculpins with Gammarus minus *versus other prey in their stomachs.*

Two-Sample T-Test and CI: Other prey vs. G.minus Williams, C2

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Two-sample T for Other prey vs. G.minus Williams

C2           N     Mean    StDev   SE Mean
Other Prey  21    5.157    0.832      0.18
G. minus    27    4.733    0.656      0.13

T-Value = 1.92  P-Value = 0.063  DF = 37
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Table 7. Body lengths of Blue Spring sculpins with Gammarus minus *versus other prey in their stomachs*

Two-Sample T-Test and CI: Other prey vs. G. minus Blue, C4

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Two-sample T for Other prey vs. G. minus Blue

C4           N     Mean    StDev   SE Mean
Other prey  22     5.00     1.42      0.30
G. minus    15    4.373    0.849      0.22

T-Value = 1.69  P-Value = 0.101  DF = 34
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Table 8. Comparison of body lengths of benthic Gammarus minus ***from Williamsburg Spring vs. Blue Spring***

Two-Sample T-Test and CI: Benthic G.minus Williamsburg vs. Blue

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Two-sample T for Benthic Williams

Benthic      N     Mean    StDev   SE Mean
1           72     3.53     1.19      0.14
2           92     5.18     2.01      0.21

T-Value = -6.56  P-Value = 0.000  DF = 151
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DISCUSSION

The sculpin *Cottus cognatus* showed significant size-specific prey selection in Williamsburg Spring, but not in Blue Spring. Therefore, our original hypothesis that sculpins would selectively eat larger *Gammarus minus* was only partially verified. However, this difference between spring populations can be explained by optimal foraging theory, which predicts that animals become more selective as their prey increase in abundance. Two lines of evidence suggest that amphipod prey were more abundant in Williamsburg Spring than in Blue Spring. First, the number of amphipods caught per sample was higher in Williamsburg Spring (Table 3). Second the number of amphipods per sculpin stomach was also higher in Williamsburg Spring (Table 1). Therefore, sculpins may have been more selective in Williamsburg Spring because their amphipod prey were more abundant there. This difference in predatory selectivity may also explain why *G. minus* was significantly smaller in Williamsburg Spring than in Blue Spring.

These patterns suggest that further studies of the ecology of this predator-prey system would be worthwhile. For example, if sculpins and other predators preferentially capture large prey, then not only the body size of *G. minus*, but also various aspects of its life history (e.g., age at first maturation and offspring size and number) may be modified, as suggested by Wellborn (1994) and Glazier (1999). Further research is also needed to determine whether sculpins choose larger prey for nutritional reasons or simply because they are more conspicuous and thus require less time and energy to find them.

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