Gut content analysis of juvenile shortnose suckers Chasmistes brevirostris Cope, 1879

An Undergraduate Thesis in Bioresource Research

Oregon State University

Pat McDonald

September 18, 1997

[Signatures and dates]
Gut content analysis of juvenile shortnose suckers, *Chasmistes brevirostris* Cope, 1879

INTRODUCTION

Ontogenetic niche shifts are critical times in a fish's life that need to be passed for survival, growth and recruitment (Gerking 1994, Osenberg et al. 1994). These niche shifts are identified by a change in feeding from one prey type to another. These shifts in feeding occur throughout growth and can be related to changes in gut morphology and mouth position (Stewart 1926, Macphee 1960).

The shortnose sucker (SNS) *Chasmistes brevirostris* was listed as endangered in 1988 with little known about it's feeding habits. Previous diet studies include a qualitative study of adult gut contents (Hazel 1969) and a quantitative study of juvenile gut contents (Buettner and Scoppettone 1990). Both studies examined gut contents of SNS caught during daylight hours.

This study quantifies gut contents of juvenile SNS and relates diet to ontogenetic changes in gut length, mouth and time of day. In addition, a selectivity index was used to compare gut contents and potential prey to determine if juvenile SNS exhibit selectivity.

MATERIALS AND METHODS

Juvenile SNS were captured at two sample sites, Modoc Point and Hagelstein Park in Upper Klamath Lake, Oregon during two sampling periods, July 18 and August 29, 1995. Fish were captured every 6 hrs over a 24 hr period with a 6x2m beach seine
(.48cm delta mesh) with a 2x2m bag. Fish were preserved in 10% formalin mixed with high alkaline lake water.

Invertebrate samples were collected at both sites during the first daylight sampling period in July and August and preserved in 95% ethanol. A .5 m ring size plankton net (2mm mesh) was used to sample (1 tow/site) the pelagic zone. During July sampling, a PVC pipe (6.35cm diameter) was used to sample the benthic zone with three core samples taken at each site. During August sampling, a metal cylinder (15.5cm diameter) was used with one core sample taken at each site. Both core samplers were inserted approximately 2 to 5 cm into the sediment.

Fish samples were rinsed in the lab with tap water, identified to species, enumerated and placed into 50% isopropanol. Juvenile suckers were x-rayed and specimens with a total vertebral count of 43 or less were considered SNS (Markle and Simon 1993).

Juvenile SNS were placed into five size classes that were determined by available sample size and month of collection (mm, SL); <19 (15-19), 20-29, 30-39, 40-49, and >50 (50-63). Fifty-two juvenile SNS were dissected by cutting from the anus to the isthmus region. Prior to gut removal, the esophageal and dorsal attachments were cut. Surrounding tissue was removed after the guts were placed in a petri dish.

Gut lengths were measured to the nearest millimeter from the esophagus to anus and the anterior 1/3 gut was cut open and its contents were washed into a petri dish. The guts of five SNS, representing each size class, were drawn to determine changes in gut morphology. Regression analysis was performed on standard length to gut length.
Prey items from the anterior 1/3 gut of fifty-two SNS were counted, identified to at least Order and weighed. Copepods were split into three categories; small (<.25mm), medium (> .25mm and <.75mm) and large (> .75mm) due to variation in size. Uniformity in size of other prey items precluded the use of size categories. Each food category went into individual glass vials containing 50% isopropanol. Representative samples of each food category were placed into preweighed aluminum boats for drying (36 hours at 70° C). Dried food categories were weighed to the nearest microgram using a Cahn 29 electrobalance. After five measurements the electrobalance was tared to avoid error by drift. Average weights of individual food items were calculated by dividing the total food category weight by the number of individual food items in that boat (Vondracek et al. 1982). The average weights were used to calculate the total weight of similar food items in other SNS guts. A second representative sample of small, medium and large Copepods were placed into preweighed aluminum boats, dried and weighed to obtain a more accurate weight. The two weights for each size class of Copepods were averaged.

Unidentifiable food items (detritus) and unquantifiable masses were labeled "miscellaneous" and included; worms, rocks, diatoms, algae, insect pieces, pollen (tentatively identified), and detritus. This category was analyzed for each size class by frequency of occurrence.

Other food items were quantified by the frequency of occurrence, numerical abundance and weight (Bowen 1983). From these values, the index of relative importance (IRI) was calculated for the five size classes of suckers (IRI = (percent by number + percent by weight)*frequency of occurrence)(Cailliet et al. 1986). An "adult
insect mix" category was created and included; unidentified Dipterans, Chironomids, Nymphomyiidae, and Coleopterans.

Food items with the highest IRI rating (Ostracods, Chydorids, Copepods and Chironomid larvae) were analyzed for change in importance over size using logistical regression on presence-absence plots. Food items were given a rating of 0 if absent or 1 if present. The percent of SNS in each size class that had the above food items present were plotted over standard length.

Diel feeding analysis was done by ANOVA's on total food item abundance, total food item weight and individual food item abundance (the four with the highest IRI rating). Gut contents from fish that were caught during the daylight hours (1000 to 1600, n=21) were compared to those caught during the night (2200 to 0500, n=14). Comparisons were made between day and night with July samples only (August sampling yielded 1 fish from night sampling).

Plankton and benthic samples were subsampled to identify potential prey items. A plankton splitter was used to obtain a 1/4 to 1/16 subsample of benthic core samples. The stirring bar method (Van Guelpen et al. 1982) was used to obtain a 1/32 to 1/64 subsample of plankton tows. Identification of items was to Order or Family.

Environmental abundance of invertebrates for each site was calculated by the percent composition each invertebrate made of the subsample. The percent composition of each invertebrate was assumed to be equal between Hagelstein and Modoc and was averaged. A category of "other" was created and composed; Annelids, Cnidarians,
Ephemeroptera, Coelopteran larvae, Hydracarina, Hemiptera and Isopoda. The representatives of this category were not found in juvenile SNS guts.

Averaged percent composition of invertebrates were used to calculate feeding selectivity. The formula, \( \frac{R_p - E_p}{R_p + E_p} \), was used to determine selectivity for six food items (Daphnia, Adult Insect mix, Chydorids, Ostracods, Copepods and Chironomid larvae), where \( R_p = \) percent by number in the gut and \( E_p = \) percent by number in the environment (Ivlev 1961). Selectivity index values range from -1 (avoidance) to 1 (selecting) and a 0 means an equal percent composition of prey in the gut and the environment.

RESULTS

Gut Length to Standard Length

A statistically significant relationship exists between gut length and standard length (\( P<.05, R^2=95.88\% \)). A plot of the fitted model is given in Figure 1.

Gut Morphology

A 14-18mm SNS (not shown) has a straight gut (Buettner and Scoppettone 1990). The first intestinal loop is formed at 19mm (Figure 2). At 25mm, gut complexity increases by coiling (Figure 3). The gut first follows a course posteriorly, loops to follow a course anteriorly, and then loops again to follow a course to the vent (Figure 3). Gut morphology is similar in a 30mm sucker with the loops lying mostly on the right side of the coelom (Figure 4). The gut continues coiling complexity anteriorly...
and covers both the left and right sides at 44mm (Figure 5). Gut morphology at 56mm is similar to that at 44mm (Figure 6).

Food Items Identified

Food items found in SNS guts included zooplankton, insects, and egg casings. Zooplankton were; Daphnia, Chydorids, Ostracods, Copepods, Amphipods and larval Chaoboridae. Insects were; Chironomid larvae, pupae and adults, adult Nymphomyiidae, larval Trichoptera, adult Coleopterans and adult Dipteran spp. and exuvia. Fifteen SNS had unidentified clear egg casings (0.5mm diameter) in their guts. Unidentified nauplii were found in SNS guts, but were not quantified.

"Miscellaneous" Analysis

Juvenile SNS <19mm have less "miscellaneous" items in their guts (44%)
by frequency of occurrence than larger size classes (Figure 7). The frequency of occurrence increases until becoming 100% in the 30-39mm size class and then decreases from 90% to 57% for the two largest size classes, respectively.

Index of Relative Importance

The IRI was calculated with results given in Table 1 and Figure 8. Chydorids are the most important (i.e. the highest IRI rating) to the smallest size class (<19mm).

Table 1. Calculated IRI values for 5 size classes (SL=mm) of suckers. *Ch. = chironomid and *Unid. = unidentified.

<table>
<thead>
<tr>
<th>Prey Item</th>
<th>&lt;19</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>&gt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Insect Mix</td>
<td>506</td>
<td>1114</td>
<td>0</td>
<td>102</td>
<td>4</td>
</tr>
<tr>
<td>Daphnia</td>
<td>830</td>
<td>501</td>
<td>132</td>
<td>126</td>
<td>13</td>
</tr>
<tr>
<td>Exuvia</td>
<td>112</td>
<td>42</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chydorids</td>
<td>1444</td>
<td>968</td>
<td>4916</td>
<td>7505</td>
<td>1527</td>
</tr>
<tr>
<td>Ostracods</td>
<td>1136</td>
<td>4288</td>
<td>1403</td>
<td>287</td>
<td>130</td>
</tr>
<tr>
<td>Copepods</td>
<td>133</td>
<td>1117</td>
<td>8831</td>
<td>7033</td>
<td>3418</td>
</tr>
<tr>
<td>Ch. Pupae</td>
<td>266</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>551</td>
</tr>
<tr>
<td>Ch. Larvae</td>
<td>0</td>
<td>493</td>
<td>64</td>
<td>506</td>
<td>4755</td>
</tr>
<tr>
<td>Unid. Eggs</td>
<td>0</td>
<td>137</td>
<td>622</td>
<td>1441</td>
<td>1253</td>
</tr>
</tbody>
</table>

with Ostracods, Daphnia and “adult insect mix" in decreasing importance. Ostracod importance peaks in the 20-29mm size class. Copepod and Chydorid importance is the highest among the 30-39mm and 40-49mm size class. Chironomid larvae and Copepods have the highest and second highest IRI rating in the >50mm size class, respectively.
Logistical Regression

There is no association between the presence of Ostracods and standard length in juvenile SNS (P>.05). A statistically significant relationship exists between standard length and the odds of finding the other three food items. The probability of having a Chydrorid in the gut (Figure 9) of a juvenile SNS increases by a factor of e^{0.151} for a 1 mm increase in standard length (P<.05). The probability of having a Copepod in the gut (Figure 10) of a juvenile SNS increases by a factor of e^{0.115} for a 1 mm increase in standard length (P<.05). The probability of having a Chironomid larvae in the gut (Figure 11) of a juvenile SNS increases by a factor of e^{0.096} for a 1 mm increase in standard length (p<.05), which is the strongest relationship.

Diel Analysis

In July, no statistically significant relationship exists between total food item abundance (ANOVA P>.05, n=35) or total food weight (ANOVA P>.05, n=35) in SNS guts and time of capture. No statistically significant relationship exists between time of capture and the number of Ostracods (ANOVA P>.05), Chydrorids (ANOVA P>.05), Copepods (ANOVA P>.05) or Chironomid larvae (ANOVA P>.05) in SNS guts.

Environmental Abundance

July samples showed a greater averaged percent composition for most invertebrates than August samples (Table 2). *Daphnia* had the highest averaged percent composition with Copepods, Ostracods, *Leptodora*, unidentified eggs and Chydrorids in decreasing percent composition. In August, *Daphnia* and adult insect mix had the
highest and second highest averaged percent composition, respectively. Chydorids and Copepods were third and fourth highest in averaged percent composition, respectively. *Leptodora* and unidentified eggs were not represented in August plankton tows.

**Table 2. Averaged percent composition of invertebrates found in subsamples of plankton tows made in July and August**

<table>
<thead>
<tr>
<th>Invertebrate</th>
<th>July Sampling</th>
<th>August Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Leptodora</em></td>
<td>8.61</td>
<td>0.00</td>
</tr>
<tr>
<td><em>Daphnia</em></td>
<td>50.66</td>
<td>46.75</td>
</tr>
<tr>
<td>Chydorids</td>
<td>3.48</td>
<td>16.33</td>
</tr>
<tr>
<td>Ostracods</td>
<td>10.84</td>
<td>2.60</td>
</tr>
<tr>
<td>Copepods</td>
<td>13.57</td>
<td>7.25</td>
</tr>
<tr>
<td>Ch. larvae</td>
<td>1.12</td>
<td>1.19</td>
</tr>
<tr>
<td>Adult insect mix</td>
<td>2.25</td>
<td>23.64</td>
</tr>
<tr>
<td>Unid. eggs</td>
<td>4.68</td>
<td>0.00</td>
</tr>
<tr>
<td>Amphipods</td>
<td>2.73</td>
<td>1.97</td>
</tr>
<tr>
<td>Other</td>
<td>2.59</td>
<td>0.86</td>
</tr>
</tbody>
</table>

July benthic core samples (Table 3) showed Copepods to have the highest average percent composition with Chironomid larvae, Other, Amphipods, and Ostracods in decreasing percent composition. In August, unidentified eggs had the highest average percent composition with Amphipods, Copepods, and Chironomid larvae in decreasing percent composition.

**Selective Feeding**

The selectivity index from plankton samples show the two smallest size classes (<19mm and 20-29mm) positively selecting for the adult insect mix (Figure 12). Between the second and third size class (20-29mm and 30-39mm), a shift occurs from
Table 3. Averaged percent composition of invertebrates found in subsamples of benthic core samples taken for July and August.

<table>
<thead>
<tr>
<th>Invertebrate</th>
<th>July Sampling</th>
<th>August Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptodora</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Daphnia</td>
<td>0.25</td>
<td>1.36</td>
</tr>
<tr>
<td>Chydorids</td>
<td>0.98</td>
<td>0.15</td>
</tr>
<tr>
<td>Ostracods</td>
<td>12.55</td>
<td>1.51</td>
</tr>
<tr>
<td>Copepods</td>
<td>30.70</td>
<td>17.85</td>
</tr>
<tr>
<td>Ch. larvae</td>
<td>20.27</td>
<td>17.02</td>
</tr>
<tr>
<td>Plankton mix</td>
<td>0.00</td>
<td>0.76</td>
</tr>
<tr>
<td>Benthic mix</td>
<td>0.15</td>
<td>0.00</td>
</tr>
<tr>
<td>Unid. eggs</td>
<td>0.84</td>
<td>31.24</td>
</tr>
<tr>
<td>Amphipods</td>
<td>13.26</td>
<td>21.17</td>
</tr>
<tr>
<td>Other</td>
<td>19.95</td>
<td>4.10</td>
</tr>
</tbody>
</table>

selecting this mixed category to avoiding it (negative index value). *Daphnia* were avoided by all size classes, but had the least avoidance from the smallest size class (Figure 13).

The selectivity index from benthic core samples show two shifting periods between the second and third size class. The first shift, SNS select for Ostracods and then begin to avoid them in larger size classes (Figure 14). The second shift occurs when Copepods are selected for in the third size class (Figure 15). Chironomid larvae are not selected for until the largest size class (>50mm) (Figure 16). Chydorids are selected for by all five size classes (Figure 17).

Discussion

The smallest size class (<19mm) feeds mostly at the surface and/or in the water column. This top-feeding stage was described for the white sucker *Catostomus*
commersoni (12-17mm) (Stewart 1926). The planktonic zooplankter, *Daphnia*, has its highest IRI rating in this size range, although the selectivity index for *Daphnia* is negative (Figure 13). The large environmental percent composition of *Daphnia* (Table 2) offset the small amount consumed by the <19mm size class. The mouth of the juvenile SNS at this stage is terminal (Buettner and Scoppetone 1990), and corresponds to a more planktonic feeding strategy than the larger size classes.

Chironomid exuvia has its highest IRI rating in this smallest size class. Also, *Daphnia* found in the guts appeared to be only the carapace, rather than the whole organism. These two food items (exuvia and *Daphnia* carapaces) probably provide little to no nutritional value juvenile SNS. This may provide evidence that smaller juvenile SNS are particulate feeding, but can’t distinguish between nutritional and non-nutritional food items. Large hatches of Chironomids combined with a large abundance of *Daphnia* could provide a condition that comprises growth and survival of SNS (<19mm).

The food items grouped in the "adult insect mix" are terrestrial in origin and are assumed to occur on the surface or in the water column. The IRI shows the adult insect mix category to be the most important food items for the first two size classes (Figure 8). Chydorids (highest IRI), a benthic zooplankter, comprised 25% of the food items in this size class. By frequency of occurrence, 75% of the Chydorids were found in the largest representatives of the smallest size class (19mm, n=4). Also, the frequency of occurrence of "miscellaneous" is lowest in SNS <19mm (Figure 7). This miscellaneous category contains primarily benthic items.

Juvenile SNS begin to consume less mid-water and surface prey and adapt to a more benthic feeding strategy in the 20-29mm size class. The first presence of
Chironomid larvae and an increase in Copepod and Ostracod importance supports this notion (Figure 8, Table 1). This stage is associated with the mouth of the sucker becoming sub-terminal (Buettner and Scoppettone 1990). Gut morphology has also changed from a straight (14-18mm, SL) to looped (19-30mm, SL) gut (Figure 2-4). A change in diet has been associated with this change in mouth position in other suckers and is thought to be a critical stage (Macphee 1960, Stewart 1927). Ostracods are the most important food item for 20-29mm juvenile SNS (Table 1). This is consistent with the logistical regression results, which found no association between length and the probability of finding an Ostracod in the gut.

The first ontogenetic niche shift is observed in the size class following mouth and gut changes (30-39mm). The adult insect mix becomes negatively selected for (Figure 12) and benthic prey item importance increases (Figure 8). Also, the occurrence of miscellaneous in 30-39mm SNS guts is one-hundred percent (Figure 7). Copepods first become selected for in this size class (Figure 15). All July SNS had the same availability of Copepods as possible prey, but only the 30-39mm size class positively selected for them. This is perhaps because the larger SNS have acquired the ability to find and capture these relatively mobile prey. Another shift is that Ostracods are avoided (Figure 14). This can not be explained, because it is apparent that the suckers can capture these food items at this larger size. Perhaps the Chydorids, which peak in importance in this size class (Table 1, Figure 8), and Copepods are more nutritional in value to the SNS at this stage of development.

Gut complexity is similar between the second and third size classes (Figures 3,4). However, based on gut length to standard length regression analysis equation (Figure 1),
the gut is increasing in length twice that of the sucker growth between 25mm and 30mm (A 5.0mm difference in SL, yields a 12.5mm difference in gut length).

In August (41 days later), Chydorids and Copepods remained a predominant part of the diet of juvenile SNS (Figure 8). A second possible ontogenetic niche shift occurs between the last two size classes (40-49mm and >50mm). Chironomid larvae are selected in the largest size class and they are the most statistically significant with logistical regression analysis (Figures 11,16). This representation by Chironomid larvae in gut samples of larger fish also occurs in *M. melanops* (41-100mm)(White and Haag 1977). This could be an instance where the Chironomid larvae can’t be handled until the sucker reaches a critical size. Mouth size and fish growth have been linked to abrupt changes in diet, with ontogenetic niche shifts occurring when the fish can physically handle the new prey item (Osenberg et al. 1994).

Diel analysis on gut contents of juvenile SNS shows more intensive feeding during daylight hours. This is similar to the findings of White and Haag (1977) for juvenile spotted suckers, *M. melanops*. However, it is thought that other suckers school during the day and spread out at night to feed individually (Marrin 1983).

The exception to daylight feeding is the higher presence of Ostracods in guts from SNS collected at night. Eight out of the nineteen SNS in the 20-29mm size class were caught at night, and four of those had Ostracods in their guts. However, those four SNS consumed over 90% of the total Ostracods found in the guts of that size class. This may either provide evidence of temporal resource partitioning, or perhaps the SNS are taking advantage of Ostracods when they may become more available prey. However, there are
no night environmental samples available at night to provide evidence for either conclusion.

Ontogenetic niche shifts are generally an observed universal phenomena in fishes (Werner and Gilliam 1984). Several studies on catostomids have demonstrated ontogenetic niche shifts (White and Haag 1977, and Marrin 1983) and some have specifically related it to mouth orientation and gut ontogeny (Macphee 1960 and Stewart 1926). Although the sample sizes in this study are small there is evidence that juvenile SNS diet shifts can be related to size increase, mouth orientation and gut ontogeny.

CONCLUSIONS

Food item importance changes as juvenile SNS grow in length and as they change their feeding strategies. Two ontogenetic niche shifts occur during juvenile SNS development from <19mm to >50mm. The first is related to the mouth becoming subterminal. Midwater organisms are the most important in small juveniles (<19mm). The 20-29mm SNS select less planktonic organisms and begin to select more benthic prey, as evident from the IRI and selectivity data (Figure 8). Then the first shift occurs in diet with adult insect mix being avoided (Figure 12) while benthic prey (Copepods) are positively selected (Figure 15). The second ontogenetic niche shift may occur in the largest size class, and may be related to handling or foraging efficiency (Figure 16).
REFERENCES CITED


Figure 2 - Intestinal tract of a 19mm SL shortnose sucker
Figure 3 - Intestinal tract of a 25mm SL shorthose sucker
Figure 4 - Intestinal tract of a 30mm SL shortnose sucker
Figure 5 - Intestinal tract of a 43.6mm SL shortnose sucker
Figure 6 - Intestinal tract of a 56mm SL shortnose sucker
Frequency of Fish With "Miscellaneous" Present in Gut

Figure 7
Index of Relative Importance

Size Class (SL, mm): 
- <19
- 20-29
- 30-39
- 40-49
- >50

Index Value

Figure 8

Legend:
- Adult Insect Mix
- Daphnia
- Exuvia
- Chydorid
- Ostracod
- Copepod
- Ch. Pupae
- Ch. larvae
- Unid. eggs
Plankton Tow Selectivity Index For Adult Insect Mix

Figure 12
Proportion of SNS with Chironomid Larvae in Guts vs. Standard Length

- X-axis: Standard Length (mm)
- Y-axis: Proportion with Chironomid Larvae

The graph shows a positive correlation between standard length and the proportion of SNS with chironomid larvae in their guts.
Proportion of SNS with Copepods in Guts vs. Standard Length

Figure 10
Proportion of SNS with Chydorids in Guts vs. Standard Length

Proportion with Chydorids vs. Standard Length (mm)
Plankton Tow Selectivity Index For Daphnia

Figure 13
Benthic Core Selectivity Index For Ostracods

Figure 14
Benthic Core Selectivity Index For Copepods

Figure 15
Benthic Core Selectivity Index For Chironomid Larvae

Figure 16
Figure 17

Benthic Core Selectivity Index For Chydorids