Stomach Flushing: Effectiveness and Influence on Survival and Condition of Juvenile Salmonids

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Hydraulic stomach flushing was an effective method to analyze relative food consumption and feeding habits of young salmonids. Coho salmon (Oncorhynchus kisutch) stomachs were most effectively flushed — 99% of invertebrate organisms (96% of weight of stomach contents); 92% of organisms (83% of weight) were flushed from cutthroat trout (Salmo clarki) stomachs, 90% of organisms (77% of weight) were flushed from rainbow trout (Salmo gairdneri) stomachs. Stomach flushing did not affect survival of juvenile coho salmon. A significant difference in change in mean condition factor between wild and hatchery fish was found after 30 d (greater change in wild fish), and a significant change was observed between the mean condition factors of control and treated hatchery fish. No difference was found between control and treated wild fish.

Key words: stomach flushing, juvenile salmonids, survival, condition, food habits

Le curage hydraulique de l'estomac est une méthode efficace de détermination de l'importance relative des divers item consommés et des habitudes alimentaires des jeunes salmonidés. Les estomacs de saumons coho (Oncorhynchus kisutch) sont ceux qui sont le plus efficacement curés — 99% des invertébrés (96% du poids des contenus stomacaux); 92% des organismes (83% du poids) sont évacués des estomacs de truites fardées (Salmo clarki), 90% des organismes (77% du poids) sont évacués des estomacs de truites arc-en-ciel (S. gairdneri). Le curage stomacal n'affecte pas la survie des jeunes saumons coho. Nous observons une différence significative dans le changement de l'indice d'embonpoint de poissons témoins et de poissons d'élevage traités. Nous n'observons aucune différence entre les poissons témoins et les poissons sauvages traités.

Studies of the food and feeding habits of fish are important in the study of aquatic ecosystems. Heretofore, food habit studies have required that many fish be killed for stomach removal and examination. In small streams with low fish populations, the removal of a few fish can seriously deplete the population. Thus, several methods have been developed to remove stomach contents without injuring the fish. These include (1) pressing on the stomach after a rigid tube has been inserted (White 1930), (2) injecting emetics (Markus 1932), (3) gastroscope viewing (Dubets 1954), (4) tube flushing (Seaburg 1957), (5) inserting forceps (Wales 1962), (6) back flushing intestines and stomach by placement of a pressure tube into the vent (Baker and Fraser 1976), and (7) syringe flushing (Aho 1976).

In this study a syringe flushing technique (Aho 1976) was used for examination of stomach contents of three salmonids: coho salmon, Oncorhynchus kisutch; cutthroat trout, Salmo clarki; and rainbow (steelhead) trout, S. gairdneri. We used this technique during the past 3 yr and found it to be reasonably harmless to fish. This paper addresses the following questions: (1) How are contents flushed from the fish stomachs correlated with total contents? (2) Are certain food items more likely to be flushed? (3) Is there a difference in food recovery between sizes, species, or stocks of fish? (4) How does handling affect survival and condition?

Methods — Effectiveness of stomach flushing — With a portable, battery-powered electroshocker, 51 juvenile rainbow trout, 51 cutthroat trout, and 53 young coho salmon were collected. The rainbow were collected from Canyon Creek, central Oregon, on July 29, 1975; cutthroat and coho were taken from Green River, a coastal stream in the Siuslaw National Forest, on August 1, 1975. Fish of a given species were collected in less than 2 h. They were then anesthetized with MS-222, measured (fork length in millimeters), and the stomach contents were flushed into 56.7-g (2-ounce) collecting jars.

Flushing was done by inserting a blunt 5.1-cm No. 18 hollow needle mounted on a 20-mL syringe filled with water through the mouth and esophagus into the cardiac stomach. When the water was forced into the stomach, the stomach contents were flushed back through the esophagus and mouth and via a funnel into the collecting jar. Usually one 20-mL injection was sufficient to flush out all the available contents, although larger fish sometimes required an additional injection. Care was taken to remove food items caught in the mouth. Before sealing collection jars, a 10% formalin solution and labels were added. Each fish was killed after stomach flushing and the stomach was removed and preserved in a second labeled collecting jar.

In the laboratory, food items flushed from the stomachs were identified (family or genus) and counted, and each total stomach sample was freeze-dried and weighed to the nearest 0.1 mg. Certain fragments such as head capsules represented one organism for numerical purposes; all fragments were included in sample weight. Food remaining in the preserved stomachs was handled identically. Regression analyses were run to establish relationships between (1) fish size and species and (2) amount of material flushed from stomachs. Covariance analysis was used to compare slopes and intercepts.

Effects on survival and condition — Wild and hatchery coho salmon juveniles were used in this phase of the study. Wild fish were collected from Green River in western Oregon; hatchery fish were obtained from the Oregon Department of Fish and Wildlife Hatchery on Fall Creek. Green River and Fall Creek are in the Alsea River drainage. All fish were collected by electroshocking, including those from the hatchery pond.

The fish were brought to the laboratory and held in separate large holding tanks for 3 d. During this time and throughout the experiment, they were fed 1.6-mm Oregon Pellets. Treatments at the beginning of the experiment consisted of electroshocking, measuring (fork length in millimeters), weighing (nearest 0.1 g), and finclipping all fish (treatment 1). Additional treatments were anesthetizing (treatment 2), and anesthetizing and stomach flushing (treatment 3). Control fish (treatment 1) were not additionally treated.

Three wild fish of each treatment (nine total) were placed into each of 10 glass jars (18-L). Each jar was individually aerated and supplied with fresh water. Hatchery fish were similarly arrayed in an adjacent unit of 10 jars.
TABLE 1. Number of invertebrates and weight of contents in stomachs of three species of salmonids.

<table>
<thead>
<tr>
<th>Species</th>
<th>Fork length (mm)</th>
<th>Flushed</th>
<th>Remaining</th>
<th>Percent flushedb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Mean</td>
<td>Range</td>
<td>No.</td>
</tr>
<tr>
<td>Coho</td>
<td>53</td>
<td>65</td>
<td>52-92</td>
<td>596</td>
</tr>
<tr>
<td>Cutthroat</td>
<td>51</td>
<td>113</td>
<td>65-225</td>
<td>792</td>
</tr>
<tr>
<td>Rainbow</td>
<td>51</td>
<td>139</td>
<td>93-232</td>
<td>845</td>
</tr>
<tr>
<td>Total</td>
<td>155</td>
<td>105</td>
<td>52-232</td>
<td>2233</td>
</tr>
</tbody>
</table>

aFreeze-dried weight.
bPercentage of stomach contents flushed was derived by calculating the percentage flushed from each fish and then finding the mean of these percentages.

The conditions in all jars were identical. Individual fish within each jar were identified by utilizing combinations of adipose, dorsal, upper, and lower caudal finclips. A total of 90 hatchery and 90 wild fish were used; mean lengths were 67.3 and 68.3 mm, respectively. Fish that died during this study were removed as soon as possible from the jars. After 30 d the surviving fish were again measured and weighed. Differences in survival and condition were tested by analysis of variance. Condition factor \((K)\), a measure of relative robustness, was calculated as

\[ K = \frac{W}{L^3} \times 10^3 \]

where \(K\) is the condition factor, \(W\) is wet weight of fish in grams, and \(L\) is fork length of fish in millimetres.

Results and discussion — Effectiveness of stomach flushing — Flushing the 155 salmonid stomachs yielded a total of 2233 invertebrate organisms or 93% of the total number of prey (flushed and remaining) in the stomachs (Table 1). The total weight of stomach contents flushed from the three fish species was 5871 g or 85% of the total weight of contents (flushed and remaining).

Examination of several specimens revealed that the pyloris of rainbow trout was longer and the diameter of the esophagus smaller in relationship to stomach size than in the other two species. These differences could inhibit the force of hydraulic current in the posterior stomach and decrease passage of contents out through the esophagus. Coho salmon were the smallest fish studied, cutthroat trout were intermediate, and rainbow trout were the largest. Food items found in the rainbow trout stomachs included more larger prey, such as small crayfish \((Astacus\ sp.)\), sculpins \((Cottus\ sp.)\), large stoneflies (e.g. \(Acroneuria\ sp.)\), and large cased caddisflies such as \(Dicosmoecus\ sp.). These larger, more rigid forms were much more difficult to flush from the stomachs; as a result, the percentage of material flushed from stomachs of the larger rainbows was smaller than that flushed from cutthroat and coho stomachs. Conversely, food items found in coho stomachs were much smaller and more pliable (e.g. Diptera larvae and Ephemeroptera nymphs) and were not as likely to become lodged in the stomach or esophagus.

Despite removal of caddisfly (Trichoptera) cases, snail shells, stones, and large wood pieces prior to weighing, much of the freeze-dried and weighed material in the stomachs of the three fish species was non-digestible matter. Small sand and wood particles, skeletons of hard-bodied insects, and densely packed sclerites from fully digested arthropods made up the bulk of the stomach contents. These fragments and partially digested material are densely compacted in the pyloris in preparation for passage through the intestine. As fish become larger and the muscle mass of the stomach increases, dislodgement of the contents from the pyloric stomach becomes more difficult.

A regression analysis of fish length vs. percent by weight of stomach contents flushed from rainbow trout (Fig. 1) established a negative linear correlation \((r^2 = .32)\). This relationship did not exist for coho salmon \((r^2 = .05)\), or cutthroat trout \((r^2 = .02)\). This
may be due to a higher percentage of fish having stomachs totally flushed (74 and 43%, respectively, compared to 25% for rainbow trout) and a preponderance of smaller fish (mean fork length 65 and 113 mm, respectively, compared to 139 mm for rainbow trout). These data are generally consistent with those obtained by Aho (1976) for cutthroat trout.

When data for the three fish species are combined, it appears that as fish size increases, the percent of material that is flushed from the stomach decreases (Fig. 2). This may be somewhat influenced, as mentioned earlier, by slight anatomical differences in the stomach and esophagus among the three species or by differences in the consistency of food items taken by each species.

Effects on survival and condition — Seventy-six (84%) of the hatchery fish and 78 (87%) of the wild fish survived the experiment. There was no significant difference in survival in either group between treated and control fish after 30 d (Table 2). Aho (1976) obtained similar results with cutthroat trout. Electroshocking, which causes severe trauma (Edwards and Higgins 1973), was probably the major cause of mortality, although measuring, weighing, and finclipping probably caused additional stress.

A significant difference in change in condition factor (P ≤ .01) during the study was found between hatchery and wild fish when all treatments were considered together. The mean body condition of hatchery fish was poorer initially, but was less affected by treatment than that of wild fish. There was a significant difference (P < .05) in change in body condition between control and treated hatchery fish (Fig. 3). Mean condition factor was reduced to 96% (treatment 2) and 97% (treatment 3) of mean condition at the beginning of the experiment in the two treated groups; condition factor of control fish (treatment 1) was 103% of the original condition. No difference was found in change in body condition between control and treated wild fish. Considering the drastic change from their natural diet, i.e., from live invertebrates to Oregon Pellets, it is not surprising that they would do poorly. Any treatment differences that might have occurred would probably be masked by effects of diet change.

Use of Aniline Blue for Distinguishing Between Live and Dead Freshwater Zooplankton

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It is possible to distinguish between live and dead freshwater zooplankton after 15-min immersion in an aqueous solution of aniline blue. Organisms physiologically dead at the time of staining are dyed blue, whereas living organisms remain unstained. This mortal staining technique has been repeatedly used in evaluating the survival of individuals belonging to all major groups of freshwater zooplankton. It has special application where the survival of large numbers of plankters must be determined either within a short interval, for successive intervals, or where conditions do not permit such evaluations immediately following collection or treatment. Stained samples preserved in formalin showed no evidence of leaching when stored at 4-15°C for several months. This technique has been used successfully for entrainment studies for power plants with once-through cooling systems.

Key words: freshwater plankton, zooplankton, phytoplankton, ichthyoplankton, dead–live determinations, mortal staining, power plant(s) entrainment, industrial monitoring


Une immersion de 15 min dans une solution aqueuse de bleu d'aniline permet de distinguer entre le zooplancton d'eau douce vivants et le zooplancton mort. Les organismes physiologiquement morts au moment de l'immersion se colorent en bleu, alors que les organismes vivants ne prennent pas le colorant. On a utilisé cette technique à plusieurs reprises pour évaluer la survie d'individus appartenant à tous les principaux groupes de zooplanctontes d'eau douce. Elle est particulièrement utile lorsqu'il s'agit de déterminer la survie d'un grand nombre de planctontes, soit durant un court intervalle de temps pour plusieurs intervalles successifs, soit dans les cas où les conditions rendent impossibles de telles déterminations immédiatement après la collecte ou le traitement. Les échantillons colorés conservés dans de la formolina durant plusieurs mois à des températures de 4 à 15°C ne montrent aucun signe de décoloration. Cette technique a été utilisée avec succès dans des études d'entraînement dans les centrales électriques avec systèmes refroidisseurs monocyteques.

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