RESEARCH AND DEVELOPMENT SECTION

Oregon Department of Fish and Wildlife
Fish Division

Northern Squawfish (Ptychocheilus oregonensis) Predation
on Juvenile Salmonids in the Willamette River Basin
Northern Squawfish (Ptychocheilus oregonensis)
Predation on Juvenile Salmonids
in the Willamette River basin

David V. Buchanan, Robert M. Hooton, and John R. Moring

Oregon Department of Fish and Wildlife
Research and Development Section

March 1980

1/ Present address: Maine Cooperative Fishery Research Unit, Department of Zoology, University of Maine, Orono, Maine 04469.
ABSTRACT

Predation by northern squawfish (*Ptychocheilus oregonensis*) on salmonids was studied in lower, free-flowing areas of the Willamette River drainage, Oregon. During the spring of 1976 and 1977, 1,127 northern squawfish were collected by electrofishing and seining. All captured squawfish were immediately processed. Almost 59% of the squawfish stomachs contained food items, but only 2.0% contained salmonids. Principal foods were insects, crayfish, and sculpins (Cottidae), and the majority of squawfish (94-95%) had not consumed more than one principle food type. We suggest that previous reports of squawfish predation in flowing rivers were often based on artificial situations (below dams or following hatchery releases), which could have inflated salmonid predation values.

INTRODUCTION

Northern squawfish (*Ptychocheilus oregonensis*) predation on salmonids in enclosed water bodies has been well documented (Foerster and Ricker 1941; Ricker 1941; Thompson and Tufts 1967). Sims et al. (1977) noted that squawfish were a major predator on young emigrating salmonids immediately below Columbia River dams, and Thompson (1959) found squawfish predation on salmonids in the lower free-flowing sections of the Columbia River from Astoria to McNary Dam. All these studies used gill nets to capture squawfish, and the stomachs were not analyzed for 24 to even 72 h after capture. Recent work by Steigenberger and Larkin (1974) indicates that squawfish can clear digestive tract contents in 24 h. They suggest that workers using gill nets may have underestimated the extent of salmonid predation by squawfish and that selective control of squawfish may produce greater benefits than previously reported.

This study was conducted during peak outmigration of salmonids to determine the extent of salmonid predation by squawfish in the lower free-flowing
areas of the Willamette River basin. Squawfish were captured in the spring of 1976 and 1977 in seines and with electrofishing gear to eliminate inherent bias of gillnet sampling. Stomach contents of all squawfish were examined immediately after capture to eliminate possible digestion bias.

MATERIALS AND METHODS

Northern squawfish and several species of salmonids were captured in the following study sites in the Willamette Basin in 1976: 1) the lower Willamette River between Buena Vista and Independence (18 km); 2) the Santiam River between Interstate Highway 5 (1-5) and the confluence with the Willamette River (10 km); and 3) the lower McKenzie River, from the 1-5 Bridge to the confluence with the upper Willamette River (7 km) (Fig. 1). In 1977 the Santiam section was extended from the 1-5 Bridge to Jefferson (15 km) and the McKenzie section was extended from the 1-5 Bridge to Hayden Bridge (24 km). The Willamette River section was not sampled in 1977.

The study sections were sampled by seining or drift boat electrofishing. Seines were 30.5 m x 2.5 m with 1 cm² mesh. The boat was equipped with a 2,500 watt generator and a Coffelt Model 2C VVP electrofisher with probes. The Coffelt unit was operated with pulsed direct current at 600 volts. A longhandled dip net with 1 cm² mesh was used to retrieve stunned fish. Seines were used to sample the deeper pools, while the electrofishing gear sampled riffles and shoreline areas less than 2 m deep.

Sampling began in April and continued through June, coinciding with peak outmigration of several species of anadromous salmonids (*Oncorhynchus* spp., *Salmo gairdneri*). In 1976, each section was sampled 3 times per week. In 1977, the Santiam River section was sampled 3 times weekly, while the McKenzie River section was sampled twice weekly. On each sampling day, a standardized effort of 2 h of electrofishing and 6 standard seine hauls were made. Sampling usually began between 0600 and 0700 and was completed 6 h later.
Fig. 1. Approximate location of sampling sites for northern squawfish in the Willamette River basin, 1976 and 1977 (1, 2, and 3).
The numbers of squawfish and emigrating or residual salmonids in each study section was not estimated. However, substantial numbers of anadromous hatchery salmonids were released upstream of the study sections (Table 1). We assumed that many of these hatchery fish emigrated through the study sections during the sampling periods. More than 4.7 million fish were released above the Santiam study section in 1976, while only 1.45 million were released in 1977. Conversely, only 0.55 million hatchery fish were released above the McKenzie section in 1976, and 1.0 million were released in 1977. Most of these releases were made in the upper, fast flowing sections of the Willamette tributaries, including areas near Foster Dam on the South Santiam, Minto Dam on the North Santiam, and Leaburg Dam on the McKenzie. We sampled each of these upper release areas with electrofishing gear for 4 days to compare the abundance of squawfish in the hatchery release areas and in our study sections.

An unscheduled release of 11,700 steelhead trout (Salmo gairdneri) was made into our Santiam study section on April 16, 1976. Normally all hatchery releases were made at least 30 km upstream from our study areas. Because these fish were uniquely marked, they provided an opportunity to study the effects of an introduced concentration of salmonids in an area populated with squawfish.

All captured squawfish were immediately processed. In 1976, we recorded individual lengths, stomach contents, and sex. In 1977, only lengths and stomach contents were determined. The frequency of occurrence of food items was computed as the number (or percentage) of squawfish stomachs in a sample which contained a given food item.
Table 1. Anadromous hatchery salmonids released in spring 1976 and 1977 in the Willamette River basin upstream of the squawfish study sections.

<table>
<thead>
<tr>
<th>River</th>
<th>Year</th>
<th>Steelhead (Salmo gairdneri)</th>
<th>Fall chinook salmon (Oncorhynchus tshawytscha)</th>
<th>Spring chinook salmon (O. tshawytscha)</th>
<th>Coho salmon (O. kisutch)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>McKenzie</td>
<td>1976</td>
<td>150,000</td>
<td>0</td>
<td>400,000</td>
<td>70,000</td>
<td>620,000</td>
</tr>
<tr>
<td>Santiam</td>
<td>1976</td>
<td>450,000</td>
<td>2,270,000</td>
<td>1,950,000</td>
<td>50,000</td>
<td>4,720,000</td>
</tr>
<tr>
<td>Willamette</td>
<td>1976</td>
<td>600,000(^a)</td>
<td>5,320,000(^a)</td>
<td>6,620,000(^a)</td>
<td>280,000</td>
<td>12,820,000</td>
</tr>
<tr>
<td>McKenzie</td>
<td>1977</td>
<td>130,000</td>
<td>0</td>
<td>900,000</td>
<td>0</td>
<td>1,030,000</td>
</tr>
<tr>
<td>Santiam</td>
<td>1977</td>
<td>400,000</td>
<td>190,000</td>
<td>860,000</td>
<td>0</td>
<td>1,450,000</td>
</tr>
</tbody>
</table>

\(^a\)/ Smolts released in the McKenzie and Santiam systems were included in the Willamette group since these fish could also have emigrated past this lower study section.
RESULTS

Squawfish-Salmonid Abundance

Relative to salmonids, fewer numbers of squawfish were caught each year on the McKenzie River than on the Santiam or Willamette rivers (Table 2). When only squawfish and salmonids are considered, 3.5% of the fish in 1976 from the lower McKenzie River were squawfish, while 12.7% and 8.5% of the fish from the lower Santiam and Willamette rivers, respectively, were squawfish. The relative abundance of squawfish and salmonids was similar in 1977. Only 3.3% of the fish collected in the lower McKenzie River were squawfish, while 11.0% of the fish sampled in the lower Santiam River were squawfish. These results only pertain to salmonids and squawfish greater than or equal to 7.0 cm in length because the mesh size of the seine and dip net was too large to capture smaller fish.

Table 2. Number of northern squawfish and migrating or residual salmonids collected in study sections of the lower McKenzie, Santiam, and Willamette rivers in spring 1976 and 1977.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Squawfish</td>
<td>52</td>
<td>230</td>
<td>270</td>
<td>165</td>
<td>410</td>
</tr>
<tr>
<td>Salmonids</td>
<td>1,449</td>
<td>1,575</td>
<td>2,924</td>
<td>4,846</td>
<td>3,320</td>
</tr>
<tr>
<td>Hatchery steelhead smolts</td>
<td>60</td>
<td>463</td>
<td>139</td>
<td>224</td>
<td>428</td>
</tr>
<tr>
<td>Wild steelhead smolts</td>
<td>5</td>
<td>118</td>
<td>14</td>
<td>65</td>
<td>207</td>
</tr>
<tr>
<td>Resident rainbow trout</td>
<td>50</td>
<td>7</td>
<td>3</td>
<td>332</td>
<td>158</td>
</tr>
<tr>
<td>Resident cutthroat trout</td>
<td>174</td>
<td>154</td>
<td>23</td>
<td>588</td>
<td>134</td>
</tr>
<tr>
<td>Hatchery spring chinooka/</td>
<td>196</td>
<td>51</td>
<td>245</td>
<td>317</td>
<td>219</td>
</tr>
<tr>
<td>Wild spring chinooka/</td>
<td>27</td>
<td>30</td>
<td>256</td>
<td>93</td>
<td>43</td>
</tr>
<tr>
<td>Fall chinook salmona/</td>
<td>937</td>
<td>721</td>
<td>2,244</td>
<td>3,187</td>
<td>2,115</td>
</tr>
<tr>
<td>Coho salmon smolts</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>40</td>
<td>16</td>
</tr>
</tbody>
</table>

a/ The separation between spring and fall chinook is arbitrary and was done by size. Chinook less than 10 cm were considered fall chinook while fish greater than 10 cm were separated into hatchery or wild spring chinook by degree of fin erosion.
The number of squawfish and wild rainbow (*S. gairdneri*) or cutthroat trout (*S. clarki*) caught per sampling day in 1976 and 1977 fluctuated between the study rivers. Catches averaged 6.0, 11.8 and 12.9 squawfish and 30.2, 7.9, and 1.1 resident trout per day on the McKenzie, Santiam, and Willamette sampling sites, respectively, with standard effort in each study section.

Numbers of squawfish captured were higher in the lower stretches of rivers. We sampled squawfish in the upper sections of the North Santiam, South Santiam and McKenzie rivers to compare the relative abundance of squawfish in the areas of major hatchery releases of spring chinook salmon and steelhead smolts. Each section was approximately 25 km in length. Sampling sites on the main Santiam produced 11.8 squawfish per day, while 1.5 and 8.4 squawfish per day were captured in the upper North Santiam and upper South Santiam, respectively. The lower McKenzie sites produced 6.0 squawfish per day, while no squawfish were caught in the upper McKenzie during four days of effort.

**Squawfish Stomach Contents**

We found that squawfish predation on salmonids in a natural free-flowing system was not as great as that reported in lakes or in artificial situations, such as immediately below a dam or at a hatchery release site. Stomachs of 1,127 squawfish were examined immediately after their capture, and 59% contained food (Table 3). A total of 17% of the stomachs in the 1976 and 25% of the stomachs in 1977 contained fish or fish parts. However, most of these fish were not salmonids, but were primarily sculpins (Cottidae). Only 3% of the stomachs in 1976 and 1% of the stomachs in 1977 contained salmonids. This pattern of food habits was similar for all study sections.

<table>
<thead>
<tr>
<th>Food items&lt;sup&gt;a/&lt;/sup&gt;</th>
<th>1976</th>
<th>1977</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%&lt;sup&gt;b/&lt;/sup&gt;</td>
<td>Number</td>
</tr>
<tr>
<td>Squawfish examined</td>
<td>552</td>
<td>59.4</td>
<td>575</td>
</tr>
<tr>
<td>Stomachs with food</td>
<td>328</td>
<td>59.4</td>
<td>334</td>
</tr>
<tr>
<td>A. Fish</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Salmonids</td>
<td>18</td>
<td>3.3</td>
<td>5</td>
</tr>
<tr>
<td>a) Steelhead trout</td>
<td>8</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>b) Trout</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
</tr>
<tr>
<td>c) Salmon</td>
<td>9</td>
<td>1.6</td>
<td>2</td>
</tr>
<tr>
<td>d) Unknown</td>
<td>1</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>2. Sculpins</td>
<td>64</td>
<td>11.6</td>
<td>98</td>
</tr>
<tr>
<td>3. Other fish&lt;sup&gt;c/&lt;/sup&gt;</td>
<td>15</td>
<td>2.7</td>
<td>40</td>
</tr>
<tr>
<td>B. Insects</td>
<td>128</td>
<td>23.2</td>
<td>77</td>
</tr>
<tr>
<td>C. Crayfish</td>
<td>69</td>
<td>12.5</td>
<td>104</td>
</tr>
<tr>
<td>D. Other food&lt;sup&gt;d/&lt;/sup&gt;</td>
<td>54</td>
<td>9.8</td>
<td>30</td>
</tr>
</tbody>
</table>

<sup>a/</sup>Four major food types are listed; some squawfish stomachs contained more than one food type so that subtotal percentages can be greater than the total percentages.

<sup>b/</sup>Percentage based on the total number of squawfish examined, percentages containing food items.

<sup>c/</sup>Cyprinidae, Catostomidae, and Petromyzontidae.

<sup>d/</sup>Algae, fish eggs, earthworms, berries, and leaves.

The unscheduled release of hatchery steelhead smolts in the Santiam River sampling area may have increased the percentage of salmonids found in squawfish stomachs in 1976. A total of 18 salmonids were identified in squawfish stomachs, of which 7 (approximately 40%) were steelhead smolts from this release group.

The 552 squawfish sampled in 1976 was consisted of 31% males, 48% females and 21% immature fish. Squawfish captured in 1976 and 1977 had a mean length frequency of 30 cm, with a range from 8 to 55 cm (Fig. 2). Fork lengths of squawfish that had eaten salmonids ranged from 16.5 to 48 cm. Twenty-five
Fig. 2. Length frequency distributions for northern squawfish caught in the Willamette basin in spring, 1976 and 1977.
percent of the squawfish that had eaten salmonids were less than 30 cm in length, while the remaining 75% were greater than 30 cm. More than 90% of the squawfish examined could have been potential predators on juvenile salmonids based on a size criteria.

DISCUSSION

Squawfish predation on salmonids in larger free-flowing systems, such as the Willamette River, is less than that reported in other types of aquatic systems. Thompson and Tufts (1967) found that 32% of squawfish sampled with gill nets from Lake Wenatchee, Washington, contained hatchery-released sockeye salmon (Oncorhynchus nerka). Similarly, Sims et al. (1977) found that 21% of gillnet-captured squawfish, immediately below lower Granite Dam on the Columbia River, contained salmonid remains. Only 2% of the stomachs of the 1,127 squawfish that we captured during the peak outmigration months of April, May and June contained salmonids. Our percentage may be inflated by the seven steelhead found in the stomachs of squawfish captured in the localized area of a hatchery release. Deletion of these fish would reduce the overall percentage to 1.4%.

Thompson (1959) captured 3,546 squawfish with gill nets in the lower, freeflowing Columbia River from Astoria to McNary Dam. He found 7.5% of the squawfish examined contained salmonids. Salmon and sculpins comprised 87% and 6%, respectively, of all fish found in his squawfish stomachs. In our study, salmonids and sculpins comprised 10% and 68%, respectively, of all fish found in squawfish stomachs. Though Thompson's study covered a large area in the lower Columbia River, much of his data was gathered in areas immediately below five fish hatcheries and should not be considered representative of the total river or of natural conditions.

Ricker (1941) used gill nets to capture squawfish and found that 81% of the sampled squawfish had empty stomachs. Thompson (1959) used similar gear to
capture squawfish, and reported 63% empty stomachs. We immediately inspected squawfish after capture by seine or electrofishing and detected only 41% with empty stomachs.

Steigenberger and Larkin force-fed squawfish to determine digestion rates. The normal evacuation rate may be even more rapid, as force-feeding has been shown to slow digestion in walleye (Stizostedion vitreum) (Swenson and Smith 1973). These results suggest that those authors who used gill nets which were not checked for 24 to 72 h after setting, may have underestimated the food consumption of squawfish. By using seines and electrofishing gear, we could more rapidly examine stomach contents before digestive processes could influence the results. Consequently, we found a higher percentage of stomachs containing food items.

We separated the food of northern squawfish into four major categories and found that only 5% and 6% of the squawfish sampled in 1976 and 1977, respectively, contained more than one kind of major food item. Thompson (1959) noted that only 3% of the squawfish containing food had consumed more than one kind of food item. Apparently, squawfish are opportunistic and will concentrate specifically on the food source that is most abundant or easiest to capture. For example, 40% of the salmonids found in squawfish stomachs were from the unscheduled release of steelhead smolts in the Santiam River in 1976. This opportunistic behavior may explain why squawfish are such active predators on salmonids immediately after a hatchery release or below a dam, where unnaturally high concentrations and disorientation can occur and weak and stunned fish are present.

The Willamette River may contain areas of optimum and less optimum habitat for northern squawfish. Habitat may be affected by differences in cover, temperature, flow, depth, substrate, and gradient. Our data indicate that
squamfish abundance may be inversely related to the river gradient. No squawfish were found in the upper McKenzie where the gradient is relatively high (3.72 m/km). In sections of the upper North Santiam River with an intermediate gradient (1.92 m/km) small numbers of squawfish were present. Most squawfish were collected in the Willamette (12.9 fish/day), the lower Santiam (11.8 fish/day), and the lower McKenzie (6 fish/day) rivers, which had gradients of 0.34, 0.99 and 1.04 m/km, respectively. Trout and other salmonids are adapted for living in swifter waters than squawfish, and may chase squawfish out of their territories (Moyle 1975). Other environmental factors may account for differences in squawfish abundance in the lower sections of the Willamette, Santiam, and McKenzie rivers.

Public agencies have used chemicals to attempt to reduce or eradicate squawfish, though Becker (1975) and Li (1975) believe that chemical treatment to control non-game fish in trout streams is a management concept which should be reevaluated because our knowledge of the ecological impacts is limited. Meyer (1966) reports that after incomplete kills, fishing generally improves for short periods until undesirable fishes increased to their former abundance. Rotenone has been widely used to control squawfish in rivers and lakes (Pintler and Johnson 1958, Lennon et al. 1970). This piscicide is not selective and will kill most fish species as well as many invertebrates. The long-term effects of this type of treatment may actually increase squawfish predation on salmonids in free-flowing rivers. If squawfish and their more abundant natural foods (e.g. sculpins, crayfish, aquatic insects) are destroyed in an area, other squawfish, may soon recolonize the treated area (Reid 1971). However, certain preferred food items, such as sculpins, are slow recolonizers (Bond 1963). As a result, predation on hatchery-released salmonids could be higher in the years following treatment, and competition between squawfish and salmonids for existing food items could be increased.
Squoxin (1, 1' methylenedi-2-naphthol) is a selective piscicide which is 3-100 times more toxic to squawfish than salmonids (MacPhee and Ruelle 1969). Spot applications of squoxin immediately below a dam or prior to a hatchery release may be beneficial when the immediate release site has a known population of squawfish. However, we found overall squawfish predation to be quite low in lower sections of free-flowing river systems, and piscicide treatment in these areas may not be economically or biologically justified to improve anadromous fish runs or resident salmonid populations.

ACKNOWLEDGMENTS

Partial financial support for this research was provided by Columbia River Fishery Development (National Marine Fisheries Service) and Dingell-Johnson (U.S. Fish and Wildlife Service) funds. We thank T. J. Lichatowich, and M. G. Wade for field assistance and data summation, and W. A. Kinunen, J. Pomeroy, B. J. Smith, S. Williams, and J. S. Ziller for field collection. Dr. H. W. Li (Oregon Cooperative Fishery Research Unit), K. Howe (Oregon State University) E. J. Wagner, J. A. Lichatowich, and P. J. Howell (Oregon Department of Fish and Wildlife) kindly reviewed the manuscript.
LITERATURE CITED

Becker, G. 1975. Fish toxification: biological sanity or insanity? p. 41-53
  In P. H. Eschmeyer (ed.). Rehabilitation of fish populations with toxicants:


Foerster, R. E. and W. E. Ricker. 1941. The effect of reduction of predaceous
  fish on survival of young sockeye salmon at Cultus Lake. J. Fish.
  Res. Board Can. 5:315-335.

  of ponds, lakes, and streams with fish toxicants: a review. FAO Fish.

Li, H. W. 1975. Competition and coexistence in stream fish, p. 19-30 In
  Symposium on trout/non-gamefish relationships in streams. Water

MacPhee, C. and R. Ruelle. 1969. A chemical selectively lethal to squawfish
  Ptychocheilus oregonensis and P. umpquaœ). Trans. Am. Fish. Soc. 98:
  676-684.

  In A. Calhoun (ed.) Inland fisheries management. Calif. Dep. Fish and
  Game.

Moyle, P. B. 1975. California trout streams: the way they were, probably,
  p. 9-17. In Symposium on trout/non-gamefish relationships in streams.

Pintler, H. E. and W. C. Johnson. 1958. Chemical control of rough fish in
  the Russian River drainage, California. Calif. Fish and Game 44:91-124.


15