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# Diet and growth of longfin smelt and juvenile sockeye salmon in Lake Washington

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## Introduction

In Lake Washington (Seattle, Washington, USA) longfin smelt (*Spirinchus thaleichthys*) and juvenile sockeye salmon (*Oncorhynchus nerka*) are generally the most abundant planktivorous species. Several studies have been conducted on feeding and population ecology of smelt (DRYFOOS 1965, MOULTON 1970, 1974, TRAYNOR 1973, EGGERS et al. 1978), and sockeye salmon (e.g. WOODEY 1972, TRAYNOR 1973, EGGERS 1982, EGGERS et al. 1978, DOBLE & EGGERS 1978).

In the 1960's smelt fed mainly on *Diaptomus, Diaphanosoma* and mysids (*Neomysis mercedis*) and juvenile sockeye fed principally upon *Epischura* and *Diaphanosoma;* Lake Washington was eutrophic and was characterized by: (1) high abundance of blue-green algae (*Oscillatoria* spp.) and mysids, (2) low abundance of planktivorous fishes and *Daphnia* spp. The Lake Washington environment has changed significantly since the 1960's. There has been: (1) a decrease in the dissolved phosphorus content (2) an increase in the lake transparency (3) a decrease in the abundance of *Oscillatoria* spp. (4) a decline in mysid abundance (5) an increase in the abundance of smelt and juvenile sockeye and (6) dominance by *Daphnia* spp. in the crustacean zooplankton community (EDMONDSON & LITT 1982, EGGERS et al. 1978, and EDMONDSON & ABELLA 1988). Because of these modifications in the Lake Washington environment, previous accounts of the feeding habits and growth of the planktivorous fish species may not correspond to the current conditions.

The objectives of this study were to:
(i) describe the feeding habits and growth of longfin smelt and sockeye salmon in Lake Washington and
(ii) assess the potential for competition between the two species.

## Materials and methods

Longfin smelt and juvenile salmon were captured in Lake Washington from 1985 to 1990, with a 3 m Isaacs-Kidd midwater trawl towed behind the research vessel, Clifford Barnes. We began sampling about one hour after sunset because the feeding intensity of juvenile salmon and longfin smelt is highest during this period (DRYFOOS 1965, DOBLE & EGGERS 1978). Fish were caught at selected depths from five areas in the limnetic zone of the lake that generally correspond to sites sampled by previous investigators. All fish were preserved in 10 % formalin immediately after they were retrieved from the net.

In the laboratory, all fish were measured to the nearest 0.1 mm and weighed to the nearest 0.01 g. Prey species in the stomachs were identified under a binocular dissecting microscope. Twenty *Daphnia* from each fish were measured from the anterior margin of the carapace to the base of the tail spine using an ocular micrometer attached to the microscope. If less than twenty *Daphnia* were observed, all *Daphnia* in the stomach were measured.

To determine dietary overlap between smelt and juvenile sockeye salmon, we applied SCHOENER's (1970) index to the diet data collected in summer and fall 1987. The equation is given as:

$$\alpha = 1 - 0.5\,(\sum_{i=1}^{n} |P_{xi} - P_{yi}|),$$

where
$P_{xi}$ is the proportion of prey type $i$ in the diet of species $x$,
$P_{yi}$ is the proportion of prey type $i$ in the diet of species $y$,
$n$ is the number of prey types.

Seasons of the year were categorized following the convention of DRYFOOS (1965), winter = January–March, spring = April–June, summer = July–September and fall = October–December.

## Results

Only diet information collected in summer and fall (1987–1990) will be presented here. Smelt spend approximately two years in the lake. They spawn in tributaries between January and March and fry enter the lake starting in April or May. As there are generally two year classes in the lake, it is easy to separate different ages.

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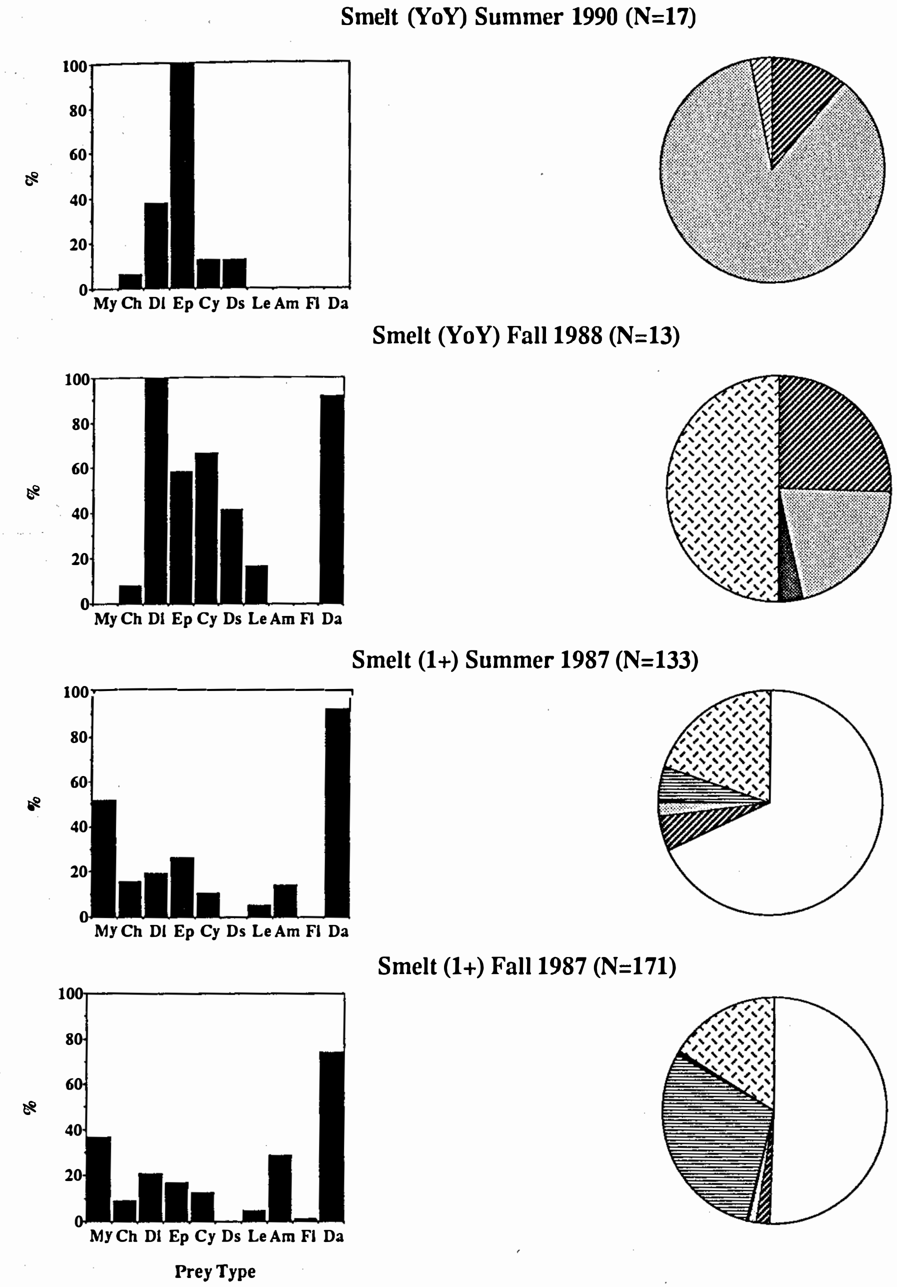


Fig. 1. Diet of longfin smelt in Lake Washington during summer and fall. Histograms are Frequency of Occurrence (% of Fish) with selected prey types in their stomachs. (My = *Neomysis mercedis,* Ch = Chironomid larvae, Di = *Diaptomus ashlandi,* Ep = *Epischura nevadensis,* Cy = *Cyclops bicuspidatus,* Ds = *Diaphanosoma,* Le = *Leptodora kindtii,* Am = Amphipods, Fi = Fish fry and larvae, Da = *Daphnia* spp.). Pie charts are percent composition by dry weight of prey in smelt stomachs. □ = *Neomysis mercedis,* = Chironomid larvae, = Copepod spp., = *Diaphanosoma,* = *Leptodora kindtii,* = Amphipods, = Fish fry and larvae, = *Daphnia* spp.

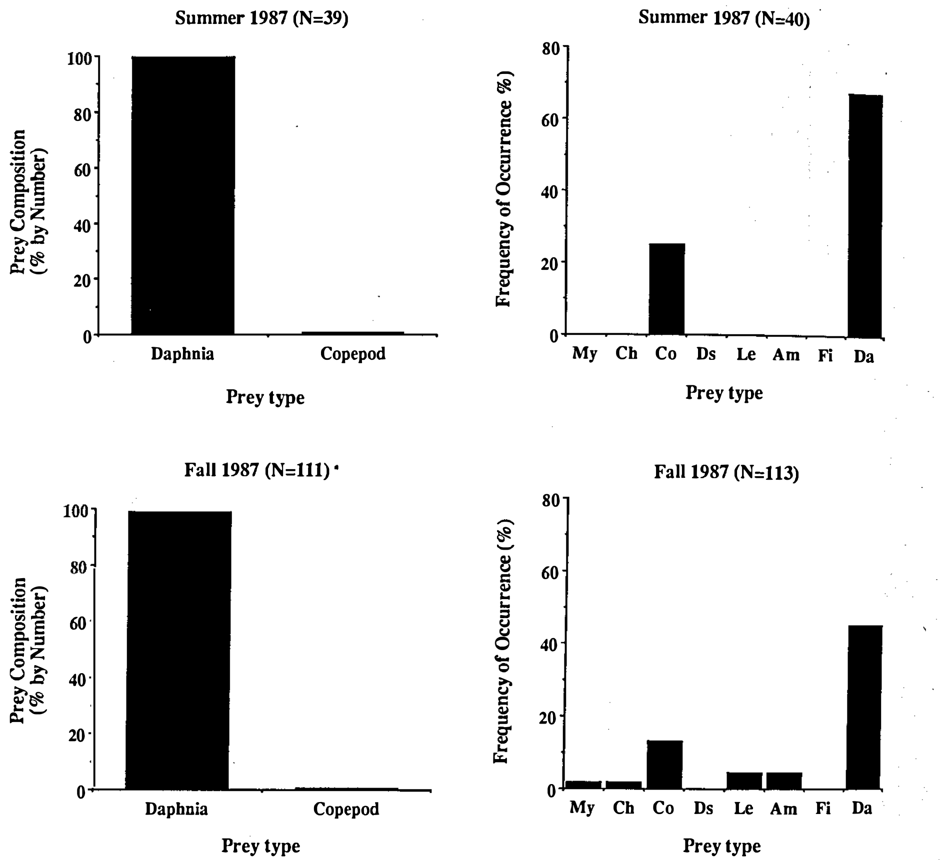


Fig. 2. Percent composition (by number and frequency of occurrence) of prey items in juvenile sockeye salmon stomachs for summer and fall seasons. Co = Copepod spp. See Fig. 1 for other prey types.

Fig. 1 indicates the prey assemblage for young of the year (YoY) and yearling and older (1+) smelt for summer and fall. During the summer YoY smelt prey heavily upon the copepod species, *Epischura* and *Diaptomus*. *Cyclops*, *Diaphanosoma* and chironomids were also observed but only in 10% or fewer stomachs. In terms of dry weight, copepod species (especially *Epischura*) were the most important, followed by chironomid larvae (Fig. 1). *Daphnia* spp. occurred in more than 80% of YoY smelt stomachs in fall and were the most important crustacean prey (50%) by weight. Frequency of occurrence for copepod species ranged from 50 – 100% but other prey species were observed in comparatively few of the fish examined. Although chironomids were present in less than 10% of the fish, they accounted for about 25% of the prey dry weight for YoY smelt (Fig. 1).

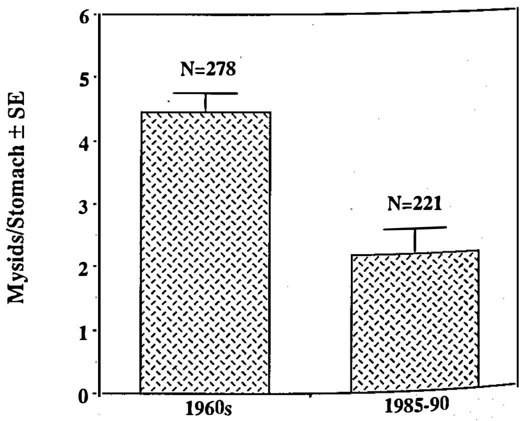


Fig. 3. Mean number of mysids observed in stomachs of longfin smelt collected from Lake Washington. Data for 1960s was obtained from Dryfoos (1965); data for 1985 – 1990 is from our study.



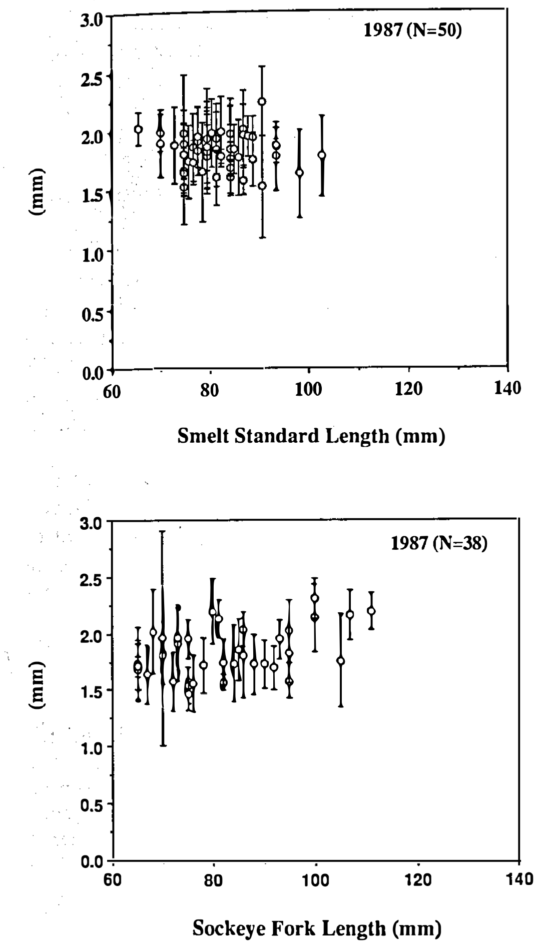


Fig. 4. Mean size of *Daphnia* spp. in stomachs of longfin smelt and juvenile sockeye salmon. Error bars are the standard deviation of *Daphnia* mean length for individual fish.

Mysids were the most important prey on a dry weight basis for 1+ smelt in summer followed by *Daphnia*. The contribution of copepod species was negligible. Similarly, only a small fraction of smelt ate fish (Fig. 1). During the fall, 1+ smelt predominantly consumed mysids, amphipods and *Daphnia*, even though fish, *Leptodora* and chironomid larvae were also observed (Fig. 1).

For sockeye salmon juveniles *Daphnia* dominated the diet numerically and in frequency of occurrence in summer and fall (Fig. 2). Other prey types such as fish larvae, amphipods, mysids, *Leptodora* and chironomids were of minor importance.

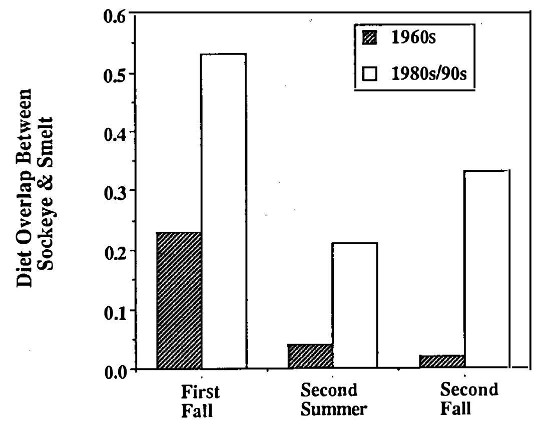


Fig. 5. Diet overlap values between juvenile sockeye salmon and longfin smelt, calculated from percent composition by weight. Values for 1960s were calculated using data from Dryfoos (1965) and Woodey (1972); values for 1980s/1990s are based on data presented in this paper.

Diet overlap between sockeye salmon and 1+ smelt calculated in terms of number of prey, was high in summer (0.96) and fall (0.95), as well as overlap between sockeye salmon and YoY smelt (0.81) in fall. In contrast overlap between sockeye salmon and 1+ smelt expressed on a basis of prey dry weight was low in summer (0.21) and fall (0.33). Values obtained between sockeye salmon and YoY smelt were much lower in summer (0.02), than in fall (0.53).

## Discussion

Compared with earlier studies of feeding by longfin smelt and juvenile sockeye salmon, our results show a dramatic change in the diets of these species following a change in the zooplankton composition in Lake Washington. In the 1960's, YoY smelt diet consisted of about 38% and 77% (dry weight) mysids in summer and fall respectively (Dryfoos 1965). In this study, no mysids were found in the stomachs of YoY smelt. There is also evidence that 1+ smelt consume fewer mysids (Fig. 3) than they did in the early 1960s. The switch from mysids has caused more predation to occur on *Daphnia*, chironomids and amphipods.

Similarly, sockeye salmon have shifted their diet from mainly copepod species and *Diaphanosoma* to predominantly *Daphnia* spp. This change in sockeye diet is not unexpected because: (1) the abundance of *Daphnia* has increased (Edmondson

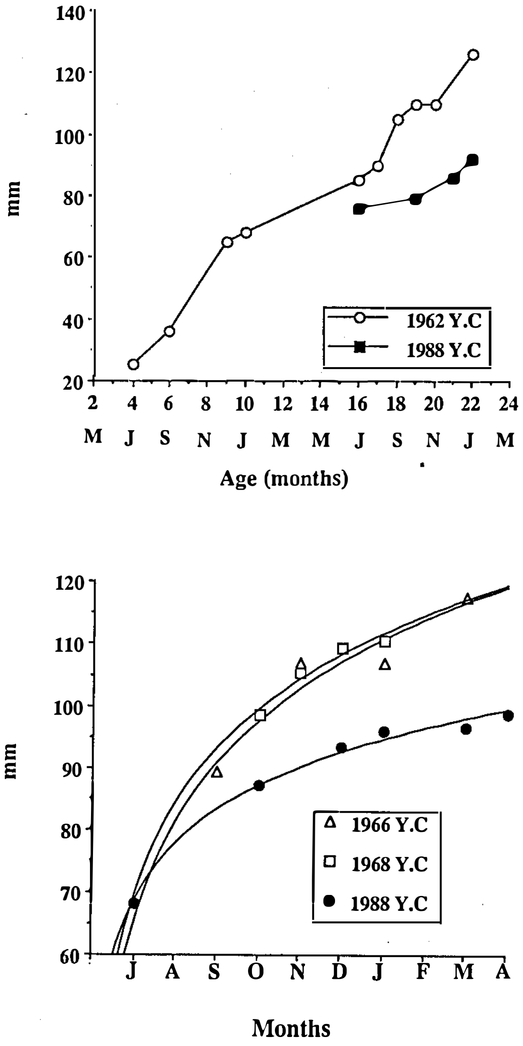


Fig. 6. Growth trajectories of longfin smelt (above) and juvenile sockeye salmon (below). The 1962 year class data for smelt is from Dryfoos (1965); 1966 and 1968 year classes for sockeye are from Woodey (1972); 1988 year class is from this study. Values are recorded as standard length for smelt and fork lengths for sockeye.

& Litt 1982) and (2) *Daphnia* spp. are a favorite prey for salmonids (Eggers 1982, Holm & Moller 1984).

It is believed that reduction of mysid abundance occurred due to smelt predation (Moulton 1974, Edmondson & Abella 1988). Since mysids are efficient predators on cladoceran crustaceans (Murtaugh 1981 a, b), reduction of mysid density in the lake and the associated increase in *Daphnia* abundance should benefit juvenile sockeye. However, a number of studies have documented that smelt (*Osmerus* spp.) can adversely affect other planktivorous species by reducing the density of large-sized cladoceran prey (Reif & Tappa 1966, Lammens et al. 1985, Siegfried 1987). Therefore, the increase in longfin smelt abundance, and a shift in their diet to one that is substantially composed of *Daphnia* increase their potential for competition with sockeye juveniles. The similar size of *Daphnia* consumed by these species (Fig. 4), coupled with increased diet overlap (Fig. 5) support this contention. Finally, if we compare the growth rates of smelt and sockeye for the 1980's and 1960's we see a substantial decrease for both species (Fig. 6) although the cause for these declines has not yet been documented.

The above information indicate a broad diet breath for smelt and an increase in diet convergence between smelt and sockeye. The extent of their feeding interaction will depend on the abundance of smelt, sockeye and mysids and the availability of alternate prey such as amphipods.

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