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Use of Shuswap Lake Foreshore by juvenile salmonids

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The foreshore (littoral zone) of large lakes such as Shuswap Lake are under considerable pressure from urbanization. Many beaches are naturally sandy (Figure 1), but cobble and boulder substrates cover many of the foreshore beaches (Figure 2). Cobble substrate is removed for private beach creation and collected in rows (Figure 3), riparian vegetation is cut, protective walls are built, emergent vegetation is removed, and small marshy bays are altered. We studied the littoral zone associated with the main arm of Shuswap Lake for 3 years. Field-work was conducted during spring and summer (April to August). This study was designed to define the role of Shuswap Lake's littoral zone as salmonid fish habitat and access the potential impacts of foreshore development.

Shuswap Lake is a large lake system located in the interior of British Columbia. This lake is an important source of Thompson River sockeye (*Oncorhyncus nerka*), chinook (*O. tshawytscha*), and coho (*O. kisutch*) salmon. Interior lakes, such as Shuswap Lake, have their lowest lake levels in March (March 22/2001 at 344.8 m elevation) and highest levels in June or July (June 14/1972 at 349.66 m elevation) associated with snowmelt (Kramer 2002). Lake levels annually rise from 3 to 4 m, freshly flooding a considerable portion of the lake margins and occasionally inundating surrounding riparian vegetation (i.e. 1997 and 1999; Kramer 2002). The largest single day increase in lake level was 24 cm (May 28/1972; Kramer 2002). From April to June, juvenile salmonids can exploit previously dry lake margins as the water levels rise. Fish can access alcoves, channels, and bordering wetlands previous isolated from the lake.

Juvenile chinook, coho and sockeye utilize the foreshore areas of Shuswap Lake for rearing and migration (Fedorenko and Pearce 1982; Graham and Russell 1979; Russell et al. 1980). Our attempts to capture fish by minnow trapping proved ineffective. We used a beach seine to capture juvenile salmonids during daylight in 1999 from sandy and cobble beaches (Figure 4). Juvenile salmonids were more numerous on sandy beaches than on cobble beaches (Anova; $P<.05$). Chinook juveniles were found most often on exposed sandy beaches, as were the few sockeye juveniles captured. Coho juveniles were limited in distribution. Coho fry were found within flooded backwater areas and not on exposed beaches. The highest densities of juvenile coho were associated with a backwater channel near the Adams River.

Juvenile chinook salmon fry were captured by pole-seine along the shallow flooded margins (< 1m depth) of Shuswap Lake in spring 2000 and 2001. Juvenile chinook used the littoral zone from March 28 to July 10. This estimate is slightly earlier and longer than the duration of foreshore use given by Russell et al. 1980 (April 25 to July 6). Their capture success along the lake margins declined rapidly in July. Graham and Russell (1979) documented a similar disappearance of juvenile chinook from the margins of Shuswap Lake in July.

These lake rearing, chinook juveniles, exhibited a strong nocturnal behaviour as night catches were 20-30 times greater than day catches (Figure 5). Night-time fishing using a 2-person pole-seine, 3m in width, was highly effective in catching juvenile salmonids. Juvenile salmon catches at night in late April were 2.4 fish/m of shore (Figure 5). At night juvenile chinook densities were greatest within the first ½ meter of foreshore (Figure 6). Four possible reasons for this strong nocturnal behaviour can be hypothesized; predation avoidance, more acceptable water temperatures, no UV radiation, and increased feeding opportunities on the flooding, shallow, lake edges. The relationship between water temperature, beach slope and the processing of terrestrial litter input is a critical feature of the littoral zone. Surface water temperatures indicate that shallow beaches have warmer edges and are more likely to process litter in early spring.

Invertebrates that land on the lake surface become a source of food for juvenile fish. We compared the relative inputs of insects from cleared open riparian shores with treed shores by using water traps (Figure 7; aluminium trays filled with water, a small quantity of detergent, and a drop of formalin). Four traps were used at each open (Figure 8) and treed site (paired design). A greater number of insects were captured from the open lakeshores than from the treed shores (Figure 9; paired-t-test; $P > .001$). This difference can be attributed to the larger input of flying aquatic insects associated with the open beaches (Figure 10). The input of terrestrial invertebrates was similar for treed and open shores.

Fish also feed on benthic Invertebrates. Attempts to measure the types and production levels associated with different substrates were not successful during the first two years. The majority of substrate baskets and the invertebrates that had colonized them (Figure 11), were never recovered. A benthic sampler that used a bilge pump to suck invertebrates from the shallow lake foreshore was used during the last year of study (Figure 12). It is hoped this new method will provide a better estimate of benthic productivity.

The feeding habitats of juvenile salmon were examined through analysis of fish stomach contents. The degree of flooding may influence the type of food items available to juvenile salmonids. In June of 1999, 2000, and 2001 chinook salmon were captured along the shore of Shuswap Lake. Fish samples taken in 2001 have yet to be analysised. The fish were seined from < 1.5m in depth. In 1999 the lake levels rose into the riparian zone flooding campsites and a few beach cabins. When the riparian vegetation was flooded; terrestrial items comprised (by weight) 14.6%, small larval fish (likely *cottidae*) represented 20.3%, and benthic items consisted of 42.4% of the diet (Figure 13). In 2000 lake-levels rose up the beaches, but did not flood into the shore vegetation. In that year when only the unconsolidated shore was covered with water; 9.4 % of the chinook diet was terrestrial, 10.3% was flying aquatic, no small fish were consumed, and 73.1% of the diet was benthic (Figure 14).

The invertebrates groupings eaten by juvenile chinook can be described in greater detail. For example, the benthic organisms consumed by juvenile chinook in June 1999 (Figure 15) were dominated by midge larva (Chironomidae, Orthocladinae and Corynoneura) and mayfly larva (Ephemeroptera and Ephemera simulans). In June 2000 (Figure 16), midge larva (Chironomidae, Orthocladinae, and Chironomini) were again dominant. However a benthic diptern (Bezzia) and two different mayfly species (*Paraleptophlebia bicomuta* and *Ephemerella inermis*) were common.

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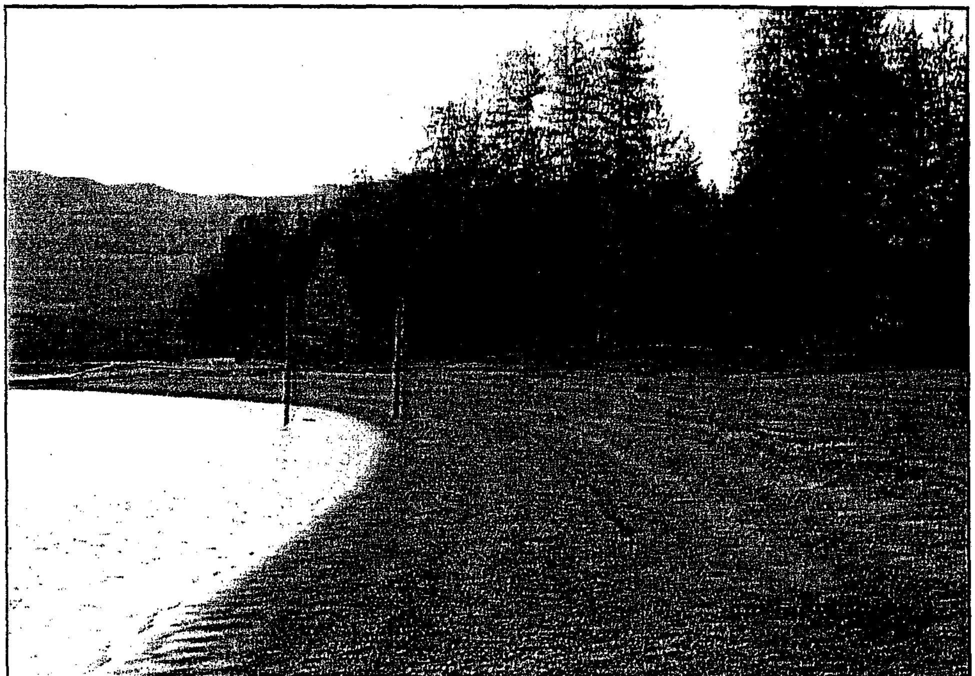

Figure 1. Sandy-gravel beach, Shuswap Lake.

Figure 2. Cobble beach, Shuswap Lake.

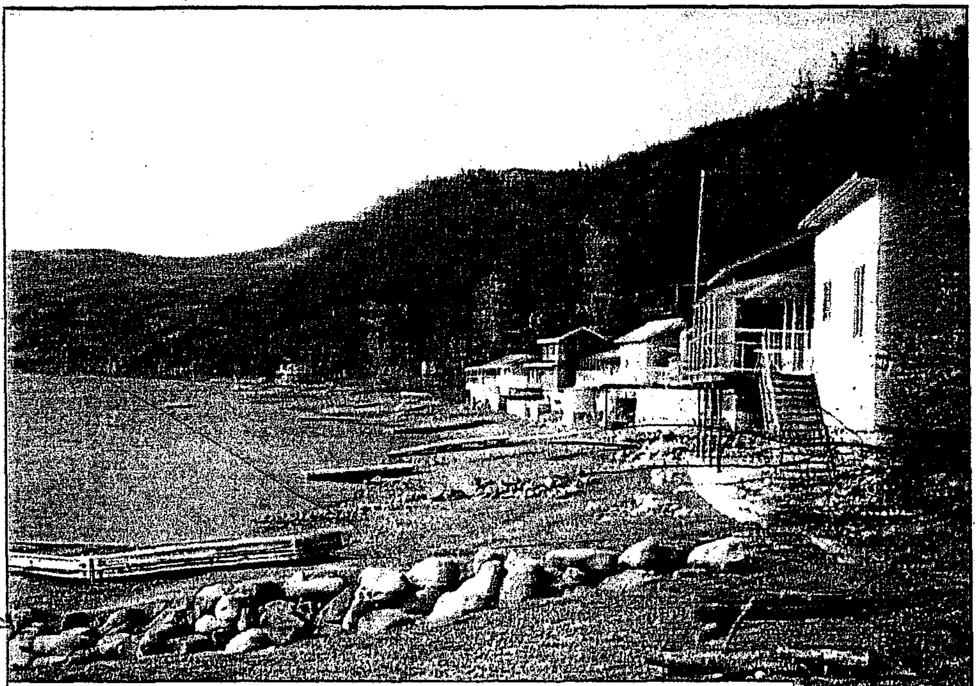

Figure 3. Foreshore development, wind-rowing of boulders.

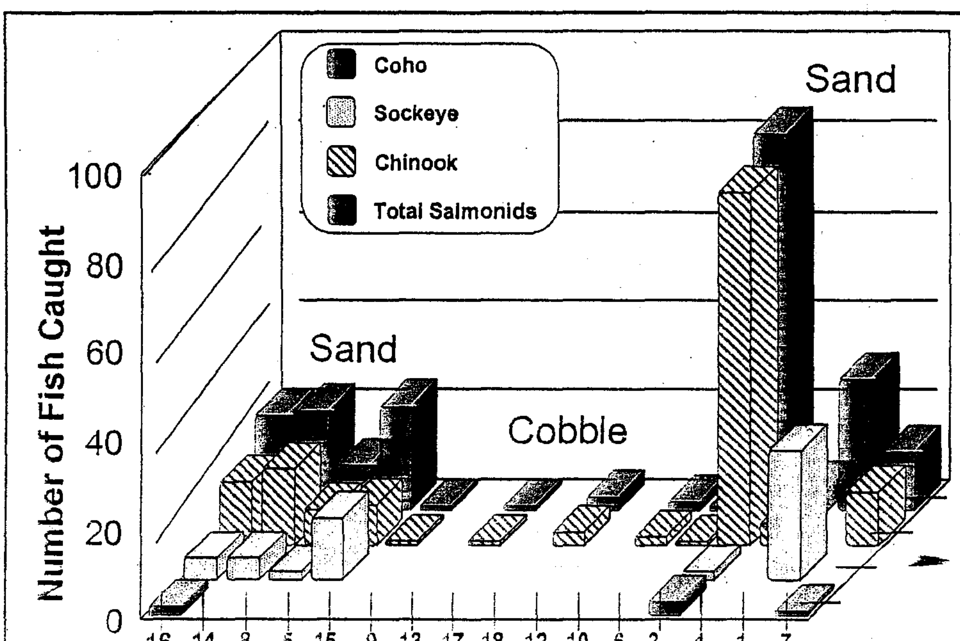

Figure 4. Comparison of catches on 8 sandy and 8 cobble beaches. Total salmonid catch was significantly greater on sandy beaches.

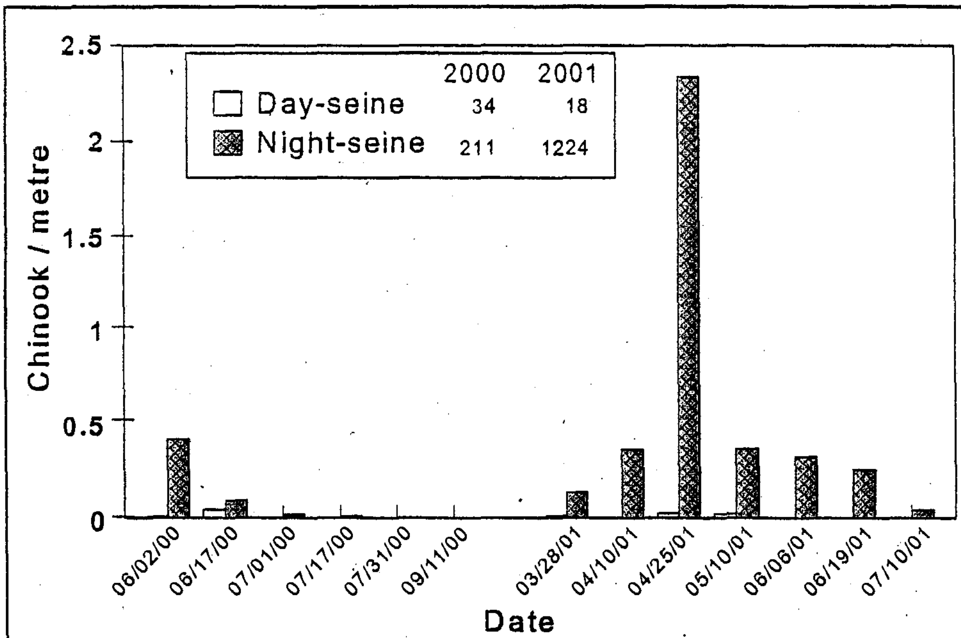

Figure 5. Juvenile chinook density was highest in late April and lake margin use was strongly nocturnal.

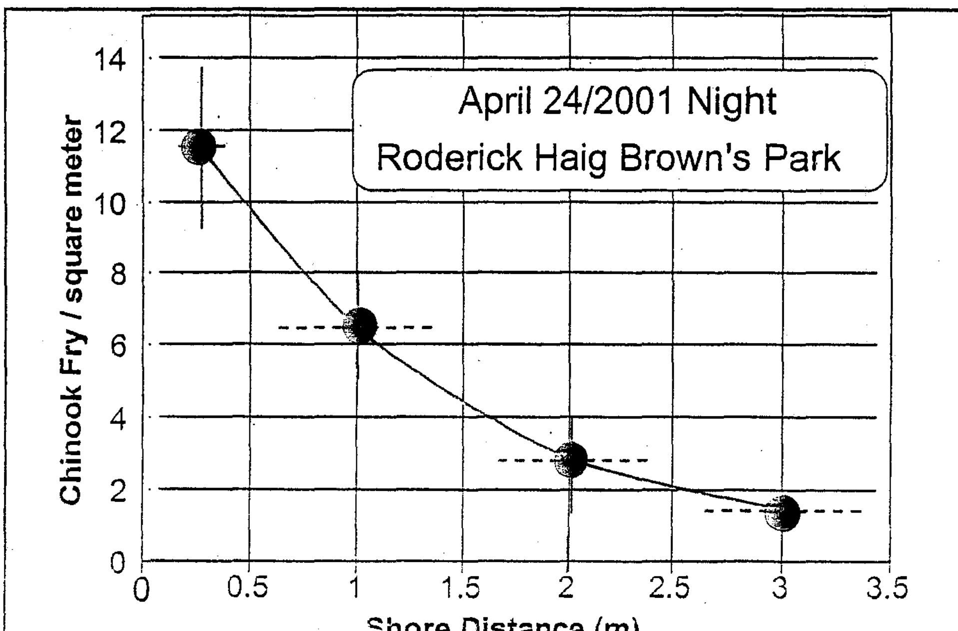

Figure 6. At night juvenile chinook were closely associated with the shallow (< 10 cm) lake margins.

Figure 7. Insect water traps (aluminium trays filled with water and a drop of detergent) were used to sample insect input to the lake surface.

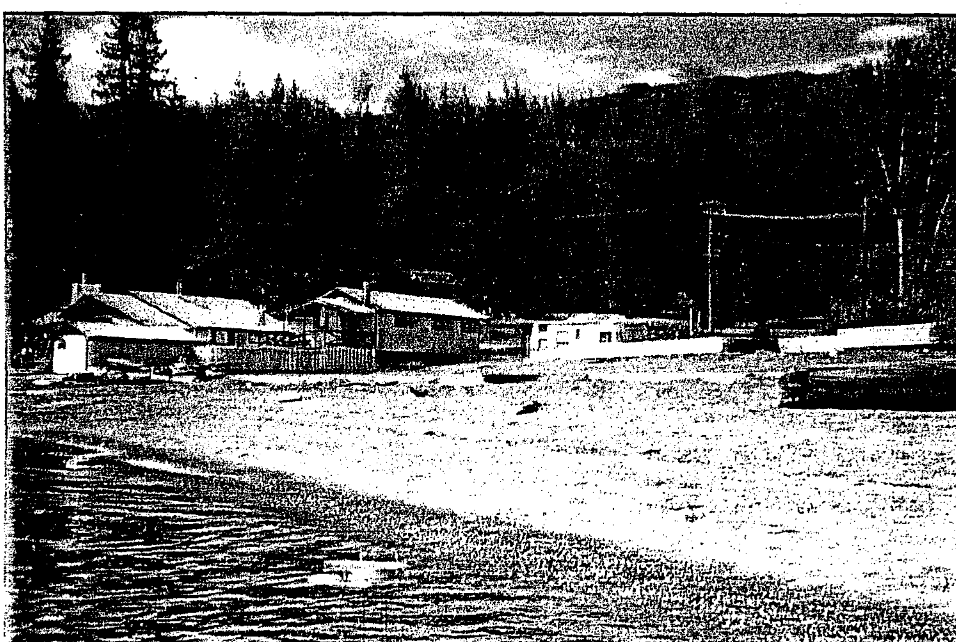

Figure 8. Along an open beach (no trees), 4 insect traps on stands were used to measure terrestrial and flying insect drop onto the lake surface.

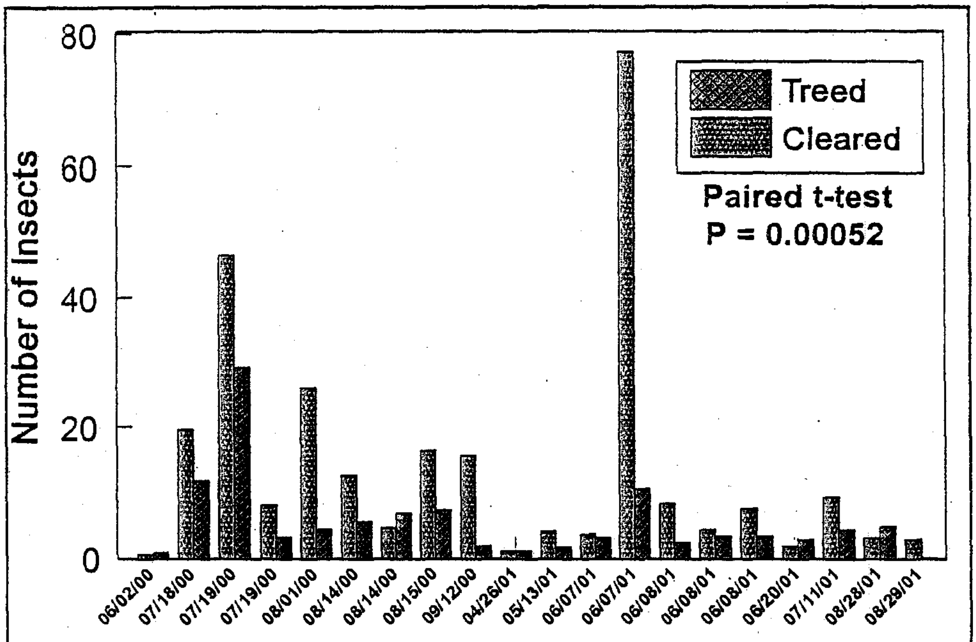

Figure 9. Comparison of treed and open beaches. Significantly more insects were captured from open areas.

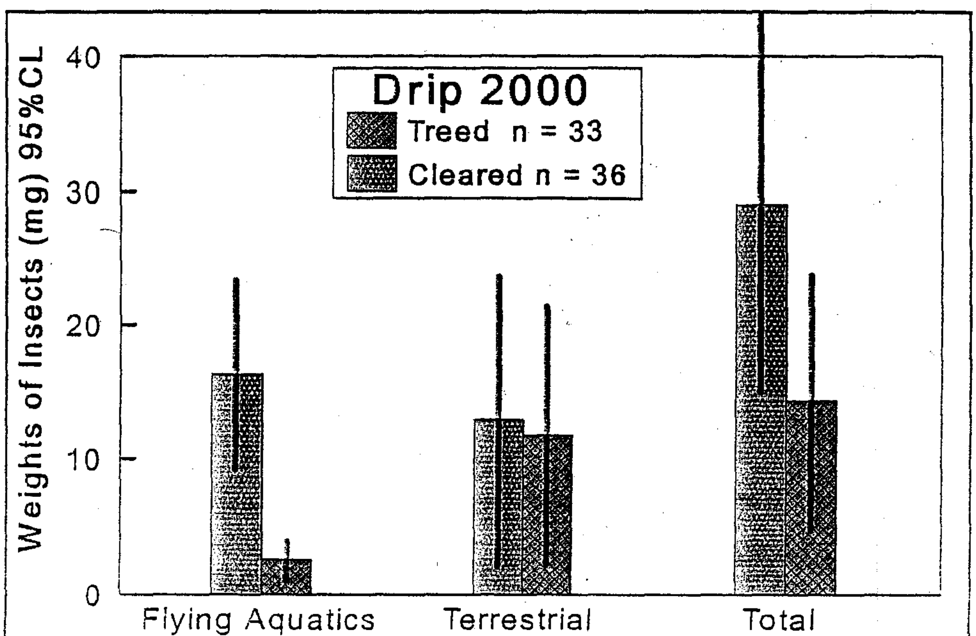

Figure 10. Difference in total weight of insects in traps was attributed to difference in flying aquatics and not to terrestrial insects.

Figure 11. Benthic substrate baskets were used with limited success.

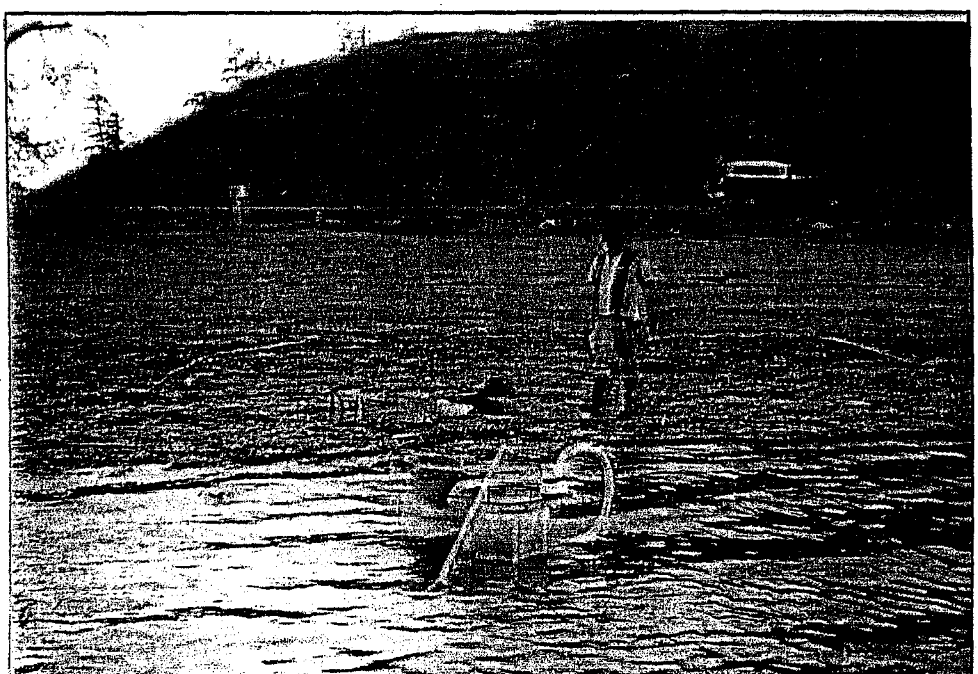

Figure 12. Benthic sampler using bilge pump to suck up invertebrates.

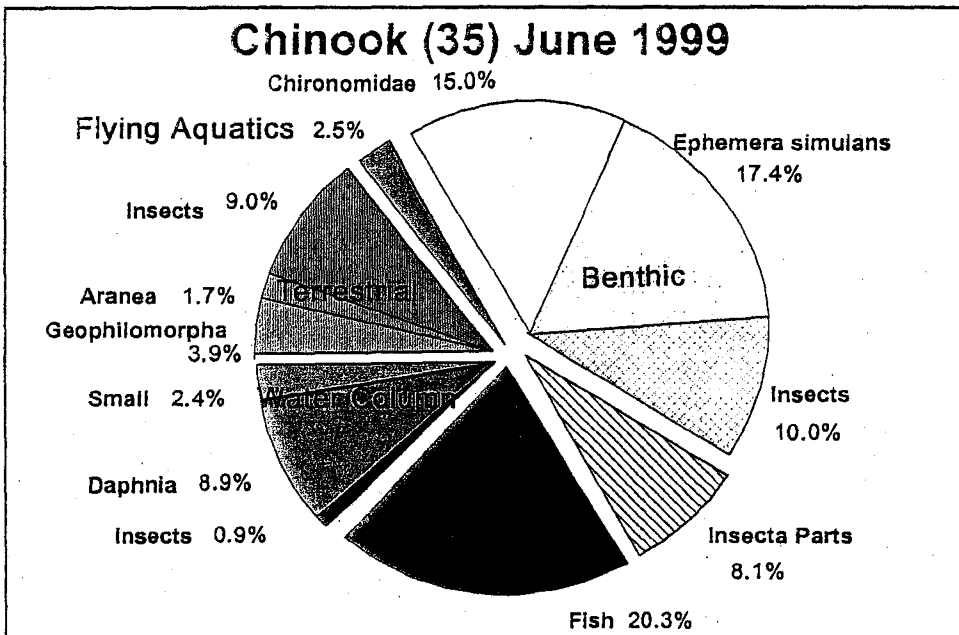

Figure 13. Chinook stomach contents, relative weights of major groups. Chinook captured by beach-seine and pole seine 1999.

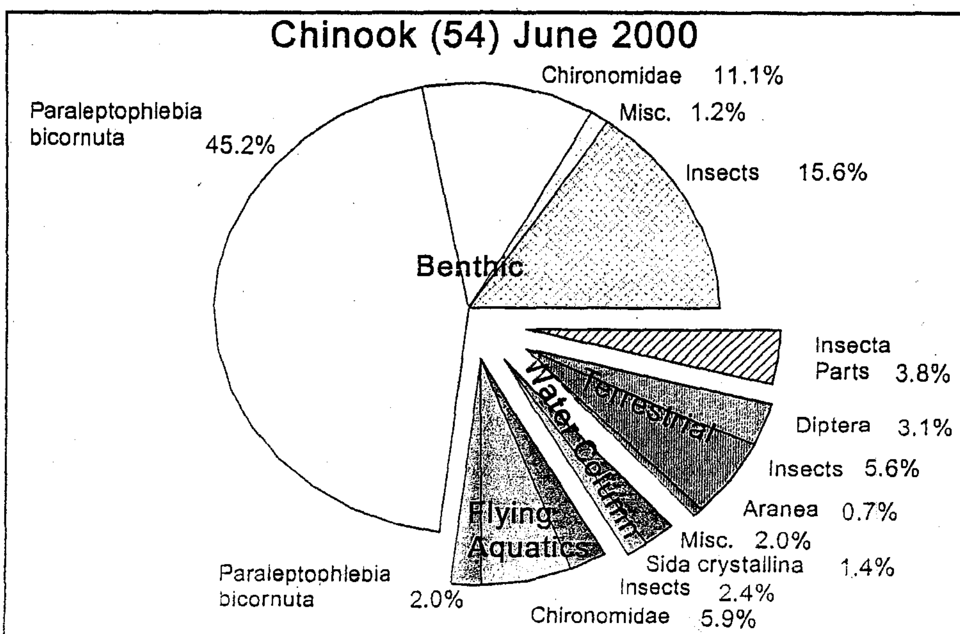

Figure 14. Chinook stomach contents, relative weights of major groups. Chinook captured by pole seine 2000.

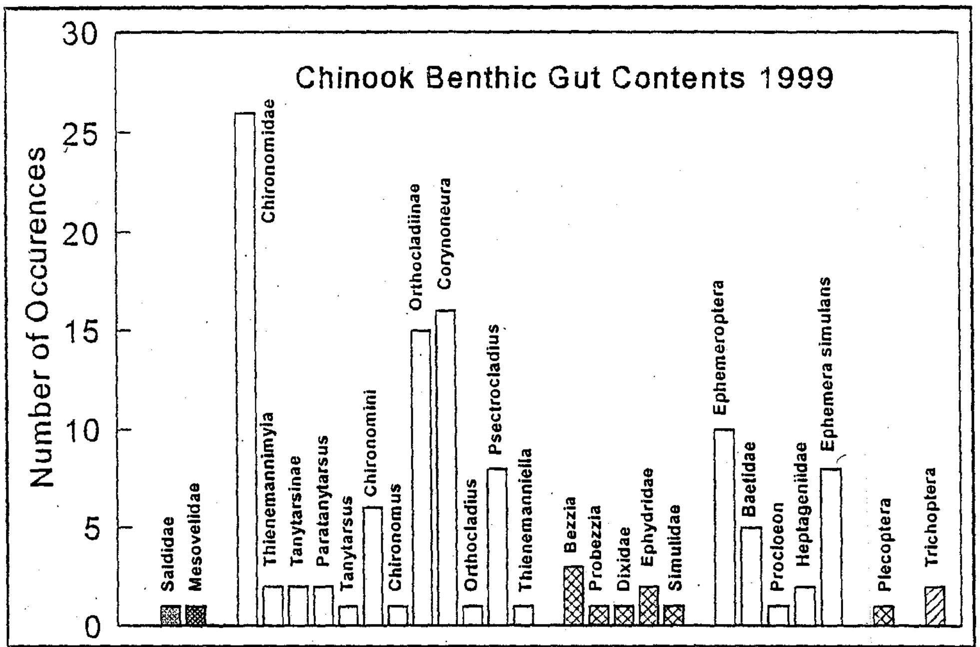

Figure 15. Benthic invertebrates (number of occurrences) identified in chinook stomachs taken in 1999.

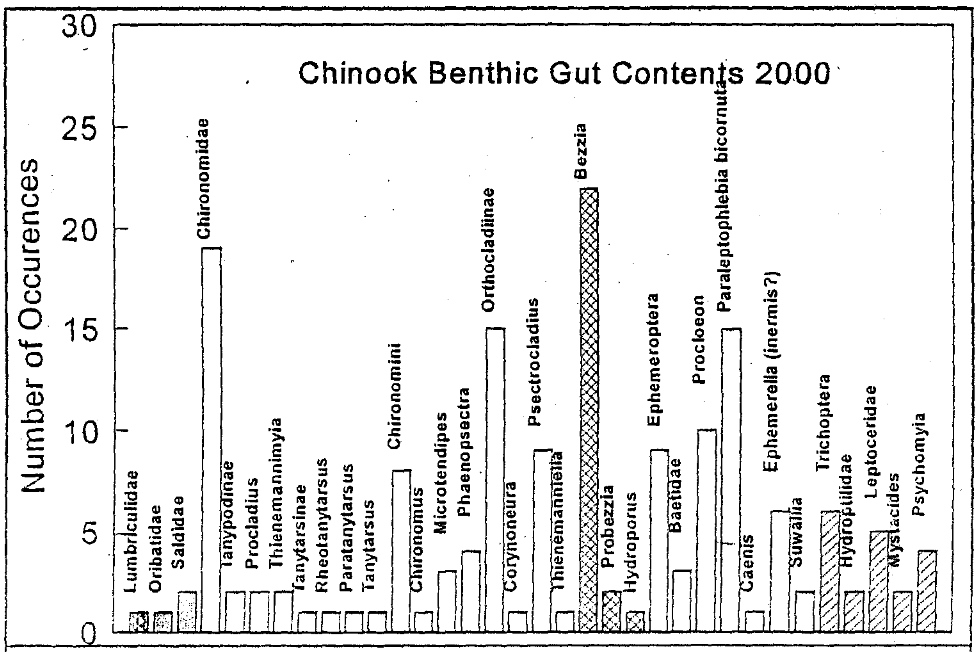

Figure 16. Benthic invertebrates (number of occurrences) identified in chinook stomachs taken in 2000.