An Investigation into the Consumption of Wild Food Organisms, and the Possible Effects of Lights on Predation, by Caged Atlantic Salmon in British Columbia

D. E. Hay, B. A. Bravender, D. J. Gillis, and E. A. Black

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, B.C. V9T 6N7

2004

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2662

Fisheries and Oceans Canada
Science

Pêches et Océans Canada
Sciences

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent des problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2662

2004

AN INVESTIGATION INTO THE CONSUMPTION OF WILD FOOD ORGANISMS, AND THE POSSIBLE EFFECTS OF LIGHTS ON PREDATION, BY CAGED ATLANTIC SALMON IN BRITISH COLUMBIA

by

D. E. Hay, B. A. Bravender, D. J. Gillis [1],
and E. A. Black [2]

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, B. C. V9T 6N7

[1] RR 22-1170 Flume Road
Roberts Creek, B.C. V0N 2W2

[2] Fisheries and Oceans Canada
Aquaculture Science Branch,
NCR Region,
Ottawa, ON K1A 0E6

Cat. No. Fs 97-4/2662E   ISSN 0706-6473

Correct citation for this publication:

Hay, D. E., B. A. Bravender, D. J. Gillis, and E. A. Black. 2004. An investigation into the consumption of wild food organisms, and the possible effects of lights on predation, by caged Atlantic salmon in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2662: 35 p.

LIST OF TABLES

LIST OF TABLES (cont'd)

LIST OF FIGURES

ABSTRACT

D.E. Hay, B.A. Bravender, D.J. Gillis, and E.A. Black. 2004. An investigation into the consumption of wild food organisms, and the possible effects of lights on predation, by caged Atlantic salmon in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2662: 35 p.

The potential for predation by caged Atlantic salmon on wild food organisms has raised concerns about the possible impacts on local populations of wild fish species in the vicinity of fish farms. The use of bright lights on some sites had raised specific concerns that wild species of fish and zooplankton were being attracted to the lights and were then being consumed by the captive salmon. We collected and examined stomachs from Atlantic salmon reared at four different aquaculture sites on the northern end of Vancouver Island. One site used large lights as a technique to enhance growth. We examined a total of 600 stomachs from all sites collected over a 9-week period. We collected another 134 stomachs from an experimental aquaculture site near the Pacific Biological Station, Nanaimo. Most gut contents were contained within caecae, in various states of digestion. The gut contents varied in time and within and among pens but very little wild feed was taken by salmon at any of the sites. The main wild organisms consumed were caprellids, small crustaceans that are part of the ‘fouling’ community that grows on the webbing of nets on the cages where the fish are held. There were some wild pelagic organisms such as copepods and euphausiids but these were rare. Only one fish was found in the stomachs, a small sand lance (*Ammodytes hexapterus*). No fish larvae were found in the stomachs but very small items, such as larvae of marine fish such as herring (*Clupea pallasi*) or eulachons (*Thaleichthys pacificus*) might have gone undetected because after a short time in the stomachs, the fragile tissue in fish larvae would have been unrecognizable. It is probable, however, that if substantial numbers of fish larvae had been consumed, we would have detected some. There were no obvious differences in the consumption of wild organisms among the sites and lights had no apparent effect on the consumption of wild food.

RÉSUMÉ

D.E. Hay, B.A. Bravender, D.J. Gillis, and E.A. Black. 2004. An investigation into the consumption of wild food organisms, and the possible effects of lights on predation, by caged Atlantic salmon in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2662: 35 p.

La possibilité que le saumon atlantique en cage se nourrisse de proies sauvages soulève des inquiétudes quant aux répercussions possibles de cette prédation sur les populations de poissons sauvages à proximité d'établissements piscicoles. On craint que les lumières vives utilisées dans certains de ces établissements attirent des poissons et du zooplancton sauvages et que ces organismes soient mangés par le saumon d'élevage. Nous avons recueilli et examiné des tubes digestifs de saumons atlantiques élevés dans quatre établissements piscicoles différents à l'extrémité nord de l'île de Vancouver. Un de ces établissements utilisait de grosses lumières pour améliorer la croissance des poissons. Nous avons examiné 600 tubes digestifs recueillis à tous les sites sur une période de neuf semaines. Nous en avons obtenu 134 autres d'un site d'aquaculture expérimentale près de la Station biologique du Pacifique, à Nanaimo. Les contenus des tubes digestifs se trouvaient principalement dans le caecum dans des états de digestion variables. Ces contenus variaient dans le temps ainsi qu'entre saumons d'une même cage ou entre différentes cages, mais les saumons étudiés ont tous consommé très peu d'organismes sauvages. Les principaux organismes consommés étaient des caprellidés, petits crustacés qui font partie des salissures marines croissant sur les filets des cages d'élevage. Quelques rares organismes pélagiques, comme des copépodes et des euphausiacés, ont été trouvés, et un seul poisson, un petit lançon (*Ammodytes hexapterus*), a été observé dans les tubes digestifs. Aucune larve de poisson n'a été trouvée, mais il est possible que de très petits organismes, comme les larves de hareng (*Clupea pallasi*) ou d'eulakane (*Thaleichthys pacificus*), passent inaperçus puisque leurs tissus fragiles deviennent impossibles à identifier après une courte période à l'intérieur d'un estomac. Nous aurions probablement détecté quelques larves si les saumons en avaient consommé de grandes quantités. La consommation d'organismes sauvages était semblable à tous les sites, et les lumières utilisées n'ont eu aucun effet apparent sur cette consommation.

INTRODUCTION

The development of the aquaculture industry in British Columbia has raised concerns about the possible impacts of fish farms on local environments. The potential impact from Atlantic salmon that escape to the wild has been under investigation in British Columbia (Thomson and McKinnell 1994, 1995) and Europe (Hislop and Webb 1992). A subject of general concern is the potential impact of predation, by salmon in cages, on wild fish species and other wild food sources. This concern has increased because of the uncertain ecological effects of large lights that are used on some farms to enhance growth and survival. These lights are used 24 hours a day for considerable periods and this has raised concerns that wild organisms may be attracted to the lighted farm sites and are then at risk of being consumed by the captive salmon. A specific concern in the southern Queen Charlotte Sound area is the possible impact of caged-salmon predation on anadromous eulachons (*Thaleichthys pacificus*) as they migrate seaward from rivers at the head of Knight and Kingcome inlets. Concern about this particular issue has increased since 1994 when the eulachon runs to the Klinaklini River, at the head of Knight Inlet, declined and then remained low in subsequent years.

This report describes an investigation on predation on wild organisms by Atlantic salmon (*Salmo salar)* in cages. The work follows from previous investigations that focused on other farmed species, primarily chinook salmon (Black et al. 1992). Since the previous study, the industry has shifted to growing Atlantic salmon which now is the preferred species at most farms. Often caged salmon are not fed prior to preparation for removal for marketing. It is at this time that their hunger levels may increase and they may be more prone to consume wild organisms, if available. Therefore, some 'starved' salmon were included in these analyses.

The specific objectives of this report are to (1) examine the consumption of wild food, especially juvenile or larval eulachons, by caged Atlantic salmon; (2) compare predation rates between lighted and unlighted farms. This was a cooperative project that was partially funded by the British Columbia Ministry of Agriculture, Food and Fisheries (E. A. Black) in cooperation with the Pacific Biological Station, Fisheries and Oceans, Nanaimo (D.E. Hay and B.A. Bravender). The field study was organized and conducted by D.J. Gillis.

MATERIALS AND METHODS

1. Study Areas and Farm Sites

All samples from commercial farms were collected in the southern Queen Charlotte Strait area. This area contains many salmon farm sites including lighted and unlighted farms. The area is topographically varied with diverse marine habitats and used by migratory and marine species such as salmon (*Oncorhynchus*) juveniles, eulachons and juvenile herring (*Clupea pallasi*). The sampling sites were selected to include farms with, and without lights. Also, the samples were chosen to compare farms that fed the salmon immediately prior to sampling and farms where the salmon were starved, to clear the guts, prior to marketing. The sampling site with lights (Larsen Island, Fig. 1) provided a contrast with an unlighted site (Deep Harbour, Fig. 1). Each of these two farm sites fed salmon prior to sampling. Additional samples were collected to examine samples from farms where salmon were starved prior to sampling, and included farms in the Raynor Group and Shelter Cove (Fig. 1). Fish from these locations were moved to Hardy Bay in ship-board live tanks and were not fed prior to their move. The salmon were held alive in the Hardy Bay holding facility before being brailed out for processing. After brailing they were anaesthetized in a CO_2 bath and killed by a cut to the gill arches. The bleeding fish were then placed in slush ice and transported immediately to the head of the processing line where 40 fish were sampled sequentially in groups of 10.

In 1995, both the Larsen Island and Deep Harbour farms consisted of arrays of 6 square cages measuring 30 m on a side and averaging about 30 m in depth. Farm personnel estimated that there were 15,000 to 20,000 Atlantic salmon in each cage, or about 100,000 at each farm. At Larsen Island usually nine 400-watt lamps and standards were equally spaced around the perimeter of the cages at about 2.5 m above the water surface. Lamps also overhung cages by 2.5 m (Fig. 2). Salmon farms use lights to induce salmon to feed actively through their first winter, a time when feeding is normally reduced to maintenance requirements. All but the last two sets of samples from the Larsen Island farm were sampled under lighted conditions.

2. Salmon and Stomach Samples

When possible, twenty salmon were sampled each week from each farm, from the first week of May to the second week of July (Table 1) but sometimes this schedule was disrupted. At the Larsen Island and Deep Harbour sites, salmon were collected by lowering a dip-net into the water to a depth of 1.5-2.5 m. Food pellets were sprinkled in front of the net to attract salmon. The salmon swam in front of (or into) the net before it was raised quickly to the surface. The fish were immediately removed and killed by a blow to the head. At Hardy Bay**,** fish were taken sequentially from the processing line.

The Larsen Island site had nine operational lights on each pond during the first part of the study (Table 1). For the last 2 sample periods the lights were off. In both cases, the sampling method was the same.

The Hardy Bay fish were returned to the processing line after data and stomach collection. Carcasses from Larsen Island and Deep Harbour were iced on board the sampling vessel, transported to Alert Bay, and frozen/glazed in a licensed plant. The frozen fish were marketed by a Port Hardy-based processor. All revenue realized from the sale of the fish was returned to the farm owners. With all samples, the time of the most recent feeding was noted. Some of the salmon taken at the Hardy Bay processing plant had been starved for about 2 weeks prior to processing.

Another 134 Atlantic salmon stomachs were collected over a five-week period from an experimental facility at the Pacific Biological Station, Nanaimo (Fig. 3). This is a smaller experimental facility located in Departure Bay. These fish were smaller, and the sampling time was later than the other samples. This provided an opportunity to examine a different size range of Atlantic salmon that might have been preying on smaller fish and plankton.

The fork length of each fish from all sources was measured to the nearest millimetre (mm) and weight was recorded to the nearest gram (g). The sex of each fish was also determined. The stomachs, from the esophagus to the intestine, including the pyloric caecae, were removed and placed in a labeled plastic bag containing 3.5% formaldehyde. The stomachs were examined later at the Pacific Biological Station, Nanaimo.

3. Plankton Samples

The plankton community was sampled weekly at both Larsen Island and Deep Harbour using a 0.5 m diameter plankton net with 350 μm mesh. A total of seven tows were made at Larsen Island and six at Deep Harbour. Only one sample was made at Hardy Bay. In each case plankton tows were made outside the anchoring arrays for the farms, usually 60 to 80 m from the cages. For each tow, the net was lowered to 20 m where it was towed for 1 minute. It was then raised to the surface in vertical increments of 4 m and towed for 1 minute at each level (total 6 minutes). An additional minute was required to raise the net between levels, for a total tow time of about 7 minutes. Although a flow meter was used in the net, it malfunctioned and therefore estimated tow volumes are not reliable. The contents of the hauls were fixed in 3.5% sea-water formaldehyde and stored in glass jars for later analysis in the laboratory.

The net-fouling community was sampled twice at Larsen Island and Deep Harbour. The samples were taken by lowering the net inside the cage to a depth of 3 m, then slowly raising it with the rim in contact with the net. The density of the fouling community varied between sites. Both of the Larsen Island samples were taken from nets that had been treated with a copper-based anti-fouling compound. At Deep Harbour, one of the samples was taken from a treated net. The second was taken from an untreated net. The samples were fixed and stored for later laboratory analysis.

4. Laboratory Analyses

In the laboratory the entire gut was weighed to the nearest 0.1 g. The contents were extracted and the empty gut was re-weighed. The difference in the two weights represented the weight of the stomach contents. In some cases, this procedure slightly over-estimated stomach content weight because some fixative fluids (not food), present in the gut, were lost during extraction of the gut contents. Therefore we also used a second method to estimate gut content weight. We weighed (tarred) a small glass jar before adding the stomach contents to the jar and re-weighing. This second method slightly underestimated the contents because there were small food residues, particularly in the large and abundant pyloric caecae that could not be removed.

After the gut contents were placed in a jar we added some new, fresh 3.5% formaldehyde. Many of the stomachs contained residue from pellet food that obscured any obvious natural food. Therefore for nearly all stomachs, the only way to detect wild food was to sort through the pellet residue. For this reason, we found it more efficient to make an initial screening of all stomachs, where we first sorted and removed all wild food. We identified the contents of the gut to major taxonomic categories as follows: caprellids, caprellid eggs, crab zoea, crab megalops, amphipods (gammarids), parasitic copepods, and non-parasitic copepods. All unique occurrences of fish larvae, fish scales, or leaves, etc., were also noted.

The general observation from all farm sites is that there was very little wild food in any of the salmon stomachs. The few food items that were there were small and infrequent. It was not practical to attempt to weigh wild food items individually. Such small particles can loose a large proportion of their wet weight during weighing and the process is slow. Very small particles, such as crab zoea (<0.01 grams) would have required weighing on a microbalance. This level of precision was not warranted in view of the measurement error associated with weighing total gut contents. Therefore instead of weighing the individual wild food items, we classified and counted food particles and then estimated their total weight, by group, with approximations based on data from the literature. We used estimates of wet zooplankton weight in a study that examined feeding by pink salmon on zooplankton (see Table 3 by Parsons and LeBrasseur 1970).

The conversions, shown below, overestimate zooplankton weight, sometimes by an order of magnitude. *The purpose of the conversions, however, is to illustrate that even with error directed at overestimating the wild organism content in the guts, the total consumption was usually very low or negligible*. The food categories are those that were the most common. Under miscellaneous were other items that varied from leaf particles to euphausiids - although there were very few observed.

Category	Estimated weight in grams (and mg)	
(1) Caprellid	0.100	(100 mg)
(2) Caprellid egg (< 200 μm)	0.001	(1 mg)
(3) Crab zoea	0.010	(10 mg)
(4) Amphipod (gammarids)	0.100	(100 mg)
(5) Parasitic copepod	0.100	(100 mg)
(6) Crab megalops	0.010	(10 mg)

Under miscellaneous all items were estimated to be 0.1 g (or 100 mg).

(7) Euphausiid (2 only)	0.100	(100 mg)

(8)	Other amphipods (2 only)	0.100	(100 mg)
(9)	Insect parts (3 only)	0.100	(100 mg)
(10)	Barnacle nauplii (1 instance)	0.010	(1 mg)
(11)	Fish - (1 *Ammodytes* juvenile)	10.000	(10,000 mg)
(12)	Inert particles: scales, leaves etc.	0.100	(100 mg)

RESULTS

1. Atlantic Salmon in Pens - Size and Weights

A plot of the lengths and weights of all salmon, by farm origin, is shown in Fig. 4. This plot shows the approximate size ranges of the salmon from the different sites. The Departure Bay salmon were the smallest in the study.

2. Extraction and Estimation of Stomach Contents

Atlantic salmon stomachs are morphologically different than those of Pacific salmon. The Atlantic salmon that we examined had large pyloric caecae that were tightly bound to the stomach with mesenteric fat. The stomach sac seemed smaller than most Pacific salmon species of similar sizes. The caecae opened into the stomach cavity so it was difficult to get precise estimates of stomach contents without some contamination of contents from the caecae into the lumen of the stomach. The caecae contents appeared to consist mainly of well-digested food. If the caecae are cut away the opening is then a hole for loss of contents from the stomach. Based on the samples we examined, caecae contents could comprise a substantial part of the content weight of some stomachs, particularly those in which the main stomach cavity was nearly empty. The proportion of caecae contents would be much less in full stomachs. The stomach contents, aside from pellet food, are shown for different groups of taxa in Table 2(a-h) as follows:

(1) Caprellids - Table 2a;
(2) Caprellid eggs - Table 2b;
(3) Crab zoea - Table 2c;
(4) Amphipods (gammarids) -Table 2d;
(5) Parasitic copepods - Table 2e;
(6) Crab megalops -Table 2f;
(7) Other or miscellaneous items - Table 2g;
(8) Summary of all wild food items, excluding caprellid eggs, parasites and scales - Table 2h.

There was very little wild food in any of the salmon stomachs, and the few wild food items that were found were small and occurred infrequently. In most instances total weight was only a few milligrams. However, we report the total number of organisms for all stomachs. The most common organism was the caprellid, a small arthropod that is known to inhabit aquaculture nets. It also was the most common wild organism found in previous work that concentrated on Pacific salmon species (Black et al. 1992). The numbers of caprellid eggs appear to be high (Table 2b) but probably are inconsequential as a food source because they are small in size and occurred mainly in the stomachs of a few fish. Individual adult caprellids have egg sacs containing several hundred eggs. These were the most numerous prey item. Probably individual caprellid eggs are too small to be consumed individually. The few instances of high numbers of caprellid eggs in a few stomachs probably resulted after the egg sac from an adult caprellid was broken, with eggs dispelled, after the adult was ingested There was only one fish taken from all the samples, a small (<8 cm) sand lance (*Ammodytes hexapterus*), that is common throughout all coastal waters. There were very few pelagic zooplankton taken in any of the samples with a total of only 2 euphuasiids from all the guts.

The total number of wild food items is small but it is clear that there are some differences among the farm sites. The stomachs from the Larsen Island farm site contained caprellids, but the samples from the Deep Harbour site had none, and there were no caprellid eggs from the Deep Harbour samples (Table 2b). On the other hand, there were more caprellids from the samples from the Raynor Group, even though fewer stomachs were collected there. The Larsen Island samples also contained more crab zoea (Table 2c) and crab megalops (Table 2f) than Larsen Island or the other sites.

In terms of the miscellaneous content (Table 2g) there are few observations from which to draw conclusions. Insect fragments occurred in some of the samples, but we saw no pattern in time or space. Fish scales occurred among a few fish sampled at Port Hardy. The scales all were typical Atlantic salmon scales in size and shape, and probably were ingested during the capture or sampling process.

3. Estimates of Wild Food Consumption

Using the weight approximations estimated above, the total estimated weight (g) of wild food is shown in Table 3. For each sample date and farm site, we show (1) total stomach content weight; (2) estimated total weight of caprellids and their eggs; (3) estimated total weight of organisms and items other than caprellids; and (4) estimated total weight of ‘wild’ food. The separation of caprellid and non-caprellid organisms provide a basis of comparison between consumption of the Larsen Island and Deep Harbour salmon (i.e., the Larsen Island fish ate some caprellids but the Deep Harbour salmon ate none). This difference might reflect differences in the degree of growth in the natural fouling (or vegetative) community of the cages. Caprellids live among the sessile vegetative community on netting. Therefore, new or recently cleaned nets would have fewer caprellids then nets left in the water sufficiently long to grow sessile marine plants.

Tables 4 and 5 show the estimated percentages of wild food as a function of total food consumed. Table 4 shows the estimates for all wild food, including caprellids and Table 5 shows the same data with caprellids excluded. The reader is cautioned that these are only rough estimates. We were not able to actually weigh the wild food contents of each fish as the wild material was too small and occurred too infrequently to provide a practical estimate of wild weights. Instead, Tables 4 and 5 are based on approximate estimates of the weights of individual plankters and other items. In most instances, these estimates probably exceed the actual weight of the zooplankton. Also, we used the smaller of the two estimates of consumed food (i.e. the amount removed and weighed separately in a jar). In this way, the estimated weight of the wild stomach contents is biased to the high side. Even with these procedures, the total estimate of wild food eaten is very low, virtually negligible relative to total food consumed from all sources.

4. Lights Versus No Lights - Effects on Food

There are no obvious differences in food consumption or composition as associated with the lights. The only apparent difference is the slightly higher number of crab zoea and megalops associated with the Larsen Island samples, but these items were found at that site even after the lights were turned off. To further examine this question, all of the ‘wild’ food items were compiled (Table 5) excluding caprellid eggs, parasitic copepods, and salmon scales. A total of 226 items were detected from the entire study, and about 45% of them were taken from the Larsen Island site. This is more than was found in the stomachs from the unlighted Deep Harbour site, but this is not necessarily evidence that lights promote feeding on wild organisms because the other two sites contained relatively higher numbers of wild organisms than either the lighted Larsen Island site or the unlighted Deep Harbour site.

5. Plankton Samples and Larval Fish

The composition of the plankton collections taken in the immediate vicinity of the farms is shown in Tables 6a-c. There were some plankton species that were not seen within the guts of the salmon. Caprellids were only a small part of the plankton community, but were among the most common of wild organisms in the gut.

There were few fish larvae found in wild plankton in the vicinity of the cages, and no fish larvae were found in any of the salmon guts. The only small fish found in any of the guts was an approximately 10 cm. sand lance (*Ammodytes hexapterus*). No juveniles of herring or eulachon (Osmeridae) were found in the plankton samples. This is consistent with results from previous larval fish surveys in the area that found relatively high densities of eulachon larvae in Knight Inlet and Loughborough Inlet, but very few in the outside waters of Queen Charlotte Sound (Hay and McCarter 1997; McCarter and Hay 1999).

DISCUSSION

The results show that the consumption of wild food by the caged Atlantic salmon examined in this investigation was very limited at all locations and in all conditions. The most frequently consumed wild organisms were caprellids that are abundant in the fouling community on the webbing of cages. There were relatively few other organisms and only one fish was found in all of the stomachs that were analyzed. It is possible that some fish larvae were consumed but were not detected. Larval fish are extremely delicate so even minor abrasion, or exposure to digestive juices, would render them to an unrecognizable form, except perhaps for their eyes. In this study, no larval fish ‘parts’ or fragments were observed. If larval or juvenile fish had been consumed regularly, then it is probable that some would have been observed during the analysis of the 734 stomachs that were examined. No fish remains were observed, however, except for the single sand lance (*Ammodytes*) taken from Deep Harbour on DOY 180 or June 29 (Table 2f). Wild fish did occur in the vicinity of the cages, however. Several different larval fish species were captured in the plankton samples, including 11 specimens from 4 taxonomic groups from Larsen Island and 3 different species from Deep Harbour. This indicates that the caged salmon may have ignored very small fish larvae (< 15 mm length). During a visit to the site (by B. Bravender) some small fish, several centimetres in length, were seen swimming *inside* cages and these may have been sand lance. Sand lance spawn early in the year and sand lance juveniles usually are larger (by several orders of magnitude) than the other larval fishes found in the plankton collections during the late spring and early summer.

Although the results provide clear evidence that some wild organisms were consumed at any of the sites, we do not conclude that these results are definitive and further investigation may be required, using different approaches. For instance, we observe that the total stomach contents of all the caged salmon, farm food and wild food, appears to be low relative to the probable requirements for both growth and metabolism of caged salmon. This can be seen in Fig. 5. which shows a scatter plot of the total weight of food contents (maximal estimate) as a percentage of total body weight. Gut contents of most individuals varied from 0-0.5% of the total body weight. The maximal estimate approached 2.0% for a few individuals, mainly from the Larsen Island and Deep Harbour sites. These maximal estimates (Fig. 5) are consistent with the estimate of Thorpe et al. (1990) of a daily food ingestion rate of about 1.45% of total body weight that was made immediately after feeding and used X-ray techniques, so no food was lost. The estimates in this report (Fig. 5) were not made immediately after feeding so we expected our estimate of total food consumed to be lower than the Thorpe et al. (1990) estimate but perhaps not as low as that seen in Fig. 5, especially for the pens where feeding occurred. If the consumption rates are low, the reasons for this are not clear, but we understand that the pellet food fed to these fish is designed for efficient digestion so the food may pass though the stomach and caecae quickly. Also, in some instances, some fish may have regurgitated some stomach contents during capture, but if this happened, probably it was not common and probably would not explain the general low food consumption or the low incidence of wild food in the guts.

A specific objective of this investigation was to compare consumption of wild organisms between lighted and unlighted pens. From the data collected we conclude that there were very few wild organisms consumed at either the lighted or unlighted sites (see Tables 2a-h). The suggestion, however, that lighted sites attract wild organisms to the vicinity of cages might be correct, but we cannot either confirm or refute it from the results presented here. The plankton collections indicate that there were higher numbers of plankton organisms near the Larsen Island site that was lighted. The lights were not used after June so plankton collections in July were made after the lights were no longer in use. Larsen Island plankton abundance was lower in July, but still higher than the Deep Harbour site. Therefore, it is not possible to determine if any differences in plankton density were related to the lights or rather were merely a reflection of normal geographic variation, perhaps related to variation in hydrogaphic conditions. A definitive answer to this question would require a substantial survey. Such a survey would require that samples be taken at different times of the day, and night, with the lights on and off. It also would require having a sufficient number of test sites that would ensure that any differences were not simply due to natural geographic variation in plankton or ichthyoplankton abundance. In the present study, we had only one lighted site.

Some plankton species were taken in plankton nets but not seen within the guts of the salmon. For instance, amphipods were relatively abundant in all the plankton tows at Larsen Island and Deep Harbour but rare in the salmon guts from the same areas (Table 2d). Caprellids were not common in the open-water plankton community, but were the most common when the plankton nets were hauled in contact with the webbing of the cages (Table 6a and 6b). There were differences in the Caprellid numbers between the farm sites. Caprellids were more frequent on the webbing of the (lighted) Larsen Island cages (Table 6a) and more abundant in the guts of the Larsen Island fish (Table 2a) relative to the (unlighted) Deep Harbour cage webbing (Table 6b) and salmon guts from Deep Harbour (Table 2a). The differences in the frequency of caprellids between sites could be related more to the types of anti-fouling agents used, rather than other differences, such as lights.

In general, only small numbers of fish larvae were found in the plankton tows done in the vicinity of the cages and no fish larvae were recovered in any of the salmon guts. If small fish larvae had been consumed by the caged salmon, it is probable that most would soon be unrecognizable following exposure to digestive juices so it is possible that some fish larvae went undetected. It is unlikely, however, that fish larvae were consumed frequently because some would have been found in the guts. Only one fish was found in any of the guts: an 8 cm. sand lance (*Ammodytes*).

Our main conclusion is that the caged Atlantic salmon in this study consumed very few wild food organisms. The most common wild organisms were caprellids, which live on the side of netpen cages. We found no larval fish in the guts but there few fish larvae among the wild plankton in the vicinity of the farms.

ACKNOWLEDGMENTS

Several companies and organizations voluntarily contributed to the sampling program, including Stolt Aquaculture, who provided access to two of their farms and Alpha Processing, who provided access to their processing facility. The Nimpkish Band Council donated freezer space for the samples of salmon. Port Hardy Processors marketed the carcasses without commission or storage charges, and B.C. Packers (Alert Bay) contributed ice each week. Simon Fraser University COOP students Alice Ortmann and Michael Lukach assisted in the analysis of stomachs, with technical assistance from Carol Cooper of AMC Technical Services, Ltd. This firm also conducted the analyses of the plankton samples. Wendell Challenger assisted with the compilation of plankton and ichthyoplankton data. Kristen Daniel assisted with preparation of figures. Constructive reviews were provided by Jim Helfield of the West Vancouver Laboratory and Andy Thomson, Pacific Biological Station.

REFERENCES

Black, E.A., D.J. Gillis, D.E. Hay, C.W. Haegele, and C.D. Levings. 1992. Predation by caged salmon in British Columbia. Bull. Aquacult. Assoc. Can. 92: 58-60.

Hay, D.E. and P.B. McCarter. 1997. Larval retention and stock structure of British Columbia herring. J. Fish. Biol. 51: 155-175.

Hislop, J.R.G. and J.H. Webb. 1992. Escaped farmed Atlantic salmon, *Salmo salar* L., feeding in Scottish coastal waters. Aquacult. Fish. Manage. 23: 721-723.

McCarter, P.B. and D.E. Hay. 1999. Distribution of spawning eulachon stocks in the Central coast of British Columbia as indicated by larval surveys. Can. Stock Assess. Sec. Res. Doc. 99/177. 63 p.

Parsons, T.R. and R.J. LeBrasseur. 1970. The availability of food to different trophic levels in the marine food chain, p. 325-343*.* *In* J.H. Steele [Ed.] Marine Food Chains. Oliver and Boyd, Edinburgh.

Thomson, A.J. and S. McKinnell. 1994. Summary of reported Atlantic salmon (*Salmo salar*) catches and sightings in British Columbia and adjacent waters in 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2246: 35 p.

Thomson, A.J. and S. McKinnell. 1995. Summary of reported Atlantic salmon (*Salmo salar*) catches and sightings in British Columbia and adjacent waters in 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2304: 33 p.

Thorpe, J.E., C. Talbot, M.S. Miles, C. Rawlings and D.S. Keay. 1990. Food consumption in 24 hours by Atlantic salmon (*Salmo salar* L.) in a sea cage. Aquaculture 90: 41-47.

Table 1. The number of stomach samples shown according to the farm site location and by DOY (Day Of Year) of the sample. Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating. The letter 'S' indicates that the fish were not fed or 'starved' for periods of one or more days prior to sampling.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	20 LS	20	-	-	-	40
144	20 L	-	-	-	-	20
145	-	20	-	-	-	20
150	20 L	-	-	-	-	20
152	-	20	-	-	-	20
155	20 L	-	-	-	-	20
157	-	-	40 S	-	-	40
159	-	20	-	-	-	20
164	-	-	40 S	-	-	40
165	20 L	-	-	-	-	20
166	-	20	-	-	-	20
171	-	-	-	40 S	-	40
172	20 L	-	-	-	-	20
173	-	20	-	-	-	20
178	-	-	-	40 S	-	40
179	20 L	-	-	-	-	20
180	-	20 S	-	-	-	20
185	-	-	-	40 S	-	40
186	20	-	-	-	-	20
187	-	20	-	-	-	20
192	-	-	40 S	-	-	40
193	20	-	-	-	-	20
194	-	20	-	-	-	20
208	-	-	-	-	21 S	21
209	-	-	-	-	15 S	15
240	-	-	-	-	43 S	43
262	-	-	-	-	35 S	35
283	-	-	-	-	20 S	20
Total	180	180	120	120	134	734

Table 2a. Sums of the number of caprellids found in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. The numbers indicate the sum of individual caprellids found among the stomachs. Dashes indicate that no samples were taken on the date.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	9	0	-	-	-	9
144	0	-	-	-	-	0
145	-	0	-	-	-	0
150	8	-	-	-	-	8
152	-	0	-	-	-	0
155	8	-	-	-	-	8
157	-	-	18	-	-	18
159	-	0	-	-	-	0
164	-	-	48	-	-	48
165	9	-	-	-	-	9
166	-	0	-	-	-	0
171	-	-	-	7	-	7
172	3	-	-	-	-	3
173	0	-	-	-	-	0
178	-	-	-	4	-	4
179	2	-	-	-	-	2
180	-	0	-	-	-	0
185	-	-	-	1	-	1
186	10	-	-	-	-	10
187	-	0	-	-	-	0
192	-	-	0	-	-	0
193	12	-	-	-	-	12
194	-	0	-	-	-	0
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	-	-	-	0	0
262	-	-	-	-	0	0
283	-	-	-	-	0	0
Total	61	0	66	12	0	139

Table 2b. Sums of the number of caprellid eggs found in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. The numbers indicate the sum of individual caprellid eggs found among the stomachs. Dashes indicate that no samples were taken on the date. The letter ‘L’ indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	0 L	0	-	-	-	0
144	0 L	0	-	-	-	0
145	-	0	-	-	-	0
150	0 L	-	-	-	-	0
152	-	0	-	-	-	0
155	0 L	-	-	-	-	0
157	-	-	57 *2	-	-	57
159	-	0	-	-	-	0
164	-	-	156 *3	-	-	156
165	0 L	-	-	-	-	0
166	-	0	-	-	-	0
171	-	-	-	0	-	0
172	0 L	-	-	-	-	0
173	-	0	-	-	-	0
178	-	-	-	86 *4	-	86
179	0 L	-	-	-	-	0
180	-	0	-	-	-	0
185	-	-	-	0	-	0
186	0	-	-	-	-	0
187	-	0	-	-	-	0
192	-	-	0	-	-	0
193	70 *1	-	-	-	-	70
194	-	0	-	-	-	0
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	-	-	-	0	0
262	-	-	-	-	0	0
283	-	-	-	-	0	0
Total	70	0	213	86	0	369

*1 - all 70 eggs from 2 stomachs (51 + 19)

*2 - all 57 from a single stomach

*3 - 142 of 156 from a single stomach

*4 - all 86 from a single stomach

Table 2c. Sums of the number of crab zoea found in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. The numbers indicate the sum of individual crab zoea found among the stomachs. Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	0 L	0	-	-	-	0
144	0 L	-	-	-	-	0
145	-	0	-	-	-	0
150	0	-	-	-	-	0
152	-	0	-	-	-	0
155	21 L	-	-	-	-	21
157	-	-	4	-	-	4
159	-	1	-	-	-	1
164	-	-	2	-	-	2
165	6 L	-	-	-	-	6
166	-	0	-	-	-	0
171	-	-	-	0	-	0
172	0 L	-	-	-	-	0
173	-	1	-	-	-	1
178	-	-	-	0	-	0
179	0 L	-	-	-	-	0
180	-	1	-	-	-	1
185	-	-	-	0	-	0
186	1	-	-	-	-	1
187	-	0	-	-	-	0
192	-	-	0	-	-	0
193	5	-	-	-	-	5
194	-	0	-	-	-	0
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	-	-	-	1	1
262	-	-	-	-	0	0
283	-	-	-	-	0	0
Total	33	3	6	0	1	43

Table 2d. Sums of the number of amphipods (gammarids) found in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. The numbers indicate the sum of individual gammarids found among the stomachs. Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	0 L	0	-	-	-	0
144	0 L	-	-	-	-	0
145	-	0	-	-	-	0
150	0 L	-	-	-	-	0
152	-	0	-	-	-	0
155	0 L	-	-	-	-	0
157	-	-	1	-	-	1
159	-	0	-	-	-	0
164	-	-	8	-	-	8
165	0 L	-	-	-	-	0
166	-	0	-	-	-	0
171	-	-	-	2	-	2
172	0 L	-	-	-	-	0
173	-	0	-	-	-	0
178	-	-	-	7	-	7
179	1 L	-	-	-	-	1
180	-	0	-	-	-	0
185	-	-	-	0	-	0
186	0	-	-	-	-	0
187	-	0	-	-	-	0
192	-	-	0	-	-	0
193	0	-	-	-	-	0
194	-	0	-	-	-	0
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	-	-	-	0	0
262	-	-	-	-	0	0
283	-	-	-	-	0	0
Total	1	0	9	9	0	19

Table 2e. Sums of the number of parasitic copepods in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. The numbers indicate the sum of individual copepods found among the stomachs. Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	0 L	0	-	-	-	0
144	0 L	-	-	-	-	0
145	-	0	-	-	-	0
150	0 L	-	-	-	-	0
152	-	0	-	-	-	0
155	0 L	-	-	-	-	0
157	-	-	1	-	-	1
159	-	0	-	-	-	0
164	-	-	6	-	-	6
165	0 L	-	-	-	-	0
166	-	0	-	-	-	0
171	-	-	-	2	-	2
172	0 L	-	-	-	-	0
173	-	0	-	-	-	0
178	-	-	-	1	-	1
179	0 L	-	-	-	-	0
180	-	0	-	-	-	0
185	-	-	-	1	-	1
186	0	-	-	-	-	0
187	-	0	-	-	-	0
192	-	--	1	-	-	1
193	0	-	-	-	-	0
194	-	0	-	-	-	0
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	-	-	-	0	0
262	-	-	-	-	0	0
283	-	-	-	-	0	0
Total	0	0	8	4	0	12

Table 2f. Sums of the number of crab megalops in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. Numbers indicate the sum of individual crab megalops found among the stomachs. Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	0 L	0	-	-	-	0
144	0 L	-	-	-	-	0
145	-	0	-	-	-	0
150	0 L	-	-	-	-	0
152	-	0	-	-	-	0
155	2 L	-	-	-	-	2
157	-	-	0	-	-	0
159	-	0	-	-	-	0
164	-	-	0	-	-	0
165	1 L	-	-	-	-	1
166	-	0	-	-	-	0
171	-	-	-	2	-	2
172	0 L	-	-	-	-	0
173	-	0	-	-	-	0
178	-	-	-	2	-	2
179	0 L	-	-	-	-	0
180	-	0	-	-	-	0
185	-	-	-	0	-	0
186	0	-	-	-	-	0
187	-	0	-	-	-	0
192	-	-	0	-	-	0
193	3	-	-	-	-	3
194	-	0	-	-	-	0
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	0	-	-	0	0
262	-	-	-	-	0	0
283	-	-	-	-	0	0
Total	6	0	0	4	0	10

Table 2g. Sums of the number of miscellaneous ingested items found in the stomachs of Atlantic salmon in the 5 test sites, shown by DOY (Day Of Year) of the sample. The numbers of individual items were low. All scales were salmon scales and may have been ingested during the capture process. Dashes indicate that no samples were taken on the date. The single fish was a sand lance (*Ammodytes hexapterus*). The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
129	0 L	0	-	-	-
144	0 L	-	-	-	-
145	-	0	-	-	-
150	0 L	-	-	-	-
152	-	0	-	-	-
155	0 L	-	-	-	-
157	-	-	Euphausiid	-	-
159	-	Amphipod	-	-	-
		Insect	-	-	-
164	-	-	Scales	-	-
165	Nematode L	-	-	-	-
	Leaves	-	-	-	-
166	-	0	-	-	-
171	-	-	-	Scales	-
	-	-	-	Amphipod	-
172	0 L	-	-	-	-
173	-	0	-	-	-
178	-	-	-	-	-
179	0 L	-	-	-	-
180	-	Fish	-	-	-
185	-	-	-	Euphausiid	-
186	-	-	-	-	-
187	0	0	-	-	-
192	-	-	Insect	-	-
193	0	-	-	-	-
194	-	Insect	-	-	-
	-	Barn.nauplii	-	-	-
208	-	-	-	-	-
209	-	-	-	-	-
240	-	-	-	-	-
262	-	-	-	-	-
283	-	-	-	-	-

Table 2h. Summary of all wild food items excluding caprellid eggs, parasitic copepods, and salmon scales. Sums of the number of items are shown by DOY (Day Of Year) of the sample. Dashes indicate that no samples were taken on the date. The letter 'L' indicates the dates when lights were on.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay	All
129	9 L	0	-	-	-	9
144	0 L	-	-	-	-	0
145	-	0	-	-	-	0
150	8 L	-	-	-	-	8
152	-	0	-	-	-	0
155	31 L	-	-	-	-	31
157	-	-	31	-	-	31
159	-	1	-	-	-	1
164	-	-	58	-	-	58
165	17 L	-	-	-	-	17
166	-	0	-	-	-	0
171	-	-	-	12	-	12
172	3 L	-	-	-	-	3
173	-	1	-	-	-	1
178	-	-	-	14	-	14
179	3 L	-	-	-	-	3
180	-	2	-	-	-	2
185	-	-	-	1	-	1
186	11	-	-	-	-	11
187	-	0	-	-	-	0
192	-	-	1	-	-	1
193	20	-	-	-	-	20
194	-	2	-	-	-	2
208	-	-	-	-	0	0
209	-	-	-	-	0	0
240	-	-	-	-	1	1
262	-	-	-	-	-	-
283	-	-	-	-	-	-
Total	102	6	90	27	1	226

Table 3. Estimates of wild food consumption relative to total consumption at each farm site shown by DOY (Day Of Year). The weights (grams) of Caprellids and 'non-Caprellids' (all wild food other than Caprellids) are shown separately. These estimates probably overestimate the wild consumption because the estimated weight of individual items is high and the estimated weight of total gut contents is the lowest of the two possible estimates (See text for explanation). Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Food Category	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
129	Total wt. (g)	24.10 L	209.10	-	-	-
	Caprellid wt. (g)	0.90 L	0.00	-	-	-
	Non Caprellid wt. (g)	0.00 L	0.00	-	-	-
	Total wild	0.90 L	0.00	-	-	-
144	Total wt. (g)	303.60 L	-	-	-	-
	Caprellid wt. (g)	0.00 L	-	-	-	-
	Non Caprellid wt. (g)	0.00 L	-	-	-	-
	Total wild	0.00 L	-	-	-	-
145	Total wt. (g)	-	129.40	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.00	-	-	-
	Total wild	-	0.00	-	-	-
150	Total wt. (g)	36.40 L	-	-	-	-
	Caprellid wt. (g)	0.80 L	-	-	-	-
	Non Caprellid wt. (g)	0.00 L	-	-	-	-
	Total wild	0.80 L	-	-	-	-
152	Total wt. (g)	-	194.30	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.00	-	-	-
	Total wild	-	0.00	-	-	-
155	Total wt. (g)	65.30 L	-	-	-	-
	Caprellid wt. (g)	0.80 L	-	-	-	-
	Non Caprellid wt. (g)	0.23 L	-	-	-	-
	Total wild	1.03 L	-	-	-	-

Table 3 (cont'd).

DOY	Food Category	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
157	Total wt. (g)	-	-	92.40	-	-
	Caprellid wt. (g)	-	-	1.86	-	-
	Non Caprellid wt. (g)	-	-	1.25	-	-
	Total wild	-	-	3.11	-	-
159	Total wt. (g)	-	148.70	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.01	-	-	-
	Total wild	-	0.01	-	-	-
164	Total wt. (g)	-	-	60.90	-	-
	Caprellid wt. (g)	-	-	4.95	-	-
	Non Caprellid wt. (g)	-	-	0.70	-	-
	Total wild	-	-	5.65	-	-
165	Total wt. (g)	54.20 L	-	-	-	-
	Caprellid wt. (g)	0.90 L	-	-	-	-
	Non Caprellid wt. (g)	0.17 L	-	-	-	-
	Total wild	1.07 L	-	-	-	-
166	Total wt. (g)	-	15.80	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.00	-	-	-
	Total wild	-	0.00	-	-	-
171	Total wt. (g)	-	-	-	162.90	-
	Caprellid wt. (g)	-	-	-	0.70	-
	Non Caprellid wt. (g)	-	-	-	0.34	-
	Total wild	-	-	-	1.04	-
172	Total wt. (g)	98.10 L	-	-	-	-
	Caprellid wt. (g)	0.30 L	-	-	-	-
	Non Caprellid wt. (g)	0.00 L	-	-	-	-
	Total wild	0.30 L	-	-	-	-

Table 3 (cont'd).

DOY	Food Category	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
173	Total wt. (g)	-	143.80	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.01	-	-	-
	Total wild	-	0.01	-	-	-
178	Total wt. (g)	-	-	-	90.10	-
	Caprellid wt. (g)	-	-	-	0.48	-
	Non Caprellid wt. (g)	-	-	-	0.89	-
	Total wild	-	-	-	1.37	-
179	Total wt. (g)	49.20 L	-	-	-	-
	Caprellid wt. (g)	0.20 L	-	-	-	-
	Non Caprellid wt. (g)	0.01 L	-	-	-	-
	Total wild	0.21 L	-	-	-	-
180	Total wt. (g)	-	80.10	-	-	-
	Caprellid wt. (g)	-	0.11	-	-	-
	Non Caprellid wt. (g)	-	0.00	-	-	-
	Total wild	-	0.11	-	-	-
185	Total wt. (g)	-	-	-	87.00	-
	Caprellid wt. (g)	-	-	-	0.10	-
	Non Caprellid wt. (g)	-	-	-	0.20	-
	Total wild	-	-	-	0.30	-
186	Total wt. (g)	66.40	-	-	-	-
	Caprellid wt. (g)	1.00	-	-	-	-
	Non Caprellid wt. (g)	0.01	-	-	-	-
	Total wild	1.01	-	-	-	-
187	Total wt. (g)	-	40.10	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.00	-	-	-
	Total wild	-	0.00	-	-	-

Table 3 (cont'd).

DOY	Food Category	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
192	Total wt. (g)	-	-	55.60	-	-
	Caprellid wt. (g)	-	-	0.00	-	-
	Non Caprellid wt. (g)	-	-	0.40	-	-
	Total wild	-	-	0.40	-	-
193	Total wt. (g)	74.20	-	-	-	-
	Caprellid wt. (g)	1.27	-	-	-	-
	Non Caprellid wt. (g)	0.18	-	-	-	-
	Total wild	1.45	-	-	-	-
194	Total wt. (g)	-	32.70	-	-	-
	Caprellid wt. (g)	-	0.00	-	-	-
	Non Caprellid wt. (g)	-	0.10	-	-	-
	Total wild	-	0.10	-	-	-
208	Total wt. (g)	-	-	-	-	5.20
	Caprellid wt. (g)	-	-	-	-	0.00
	Non Caprellid wt. (g)	-	-	-	-	0.00
	Total wild	-	-	-	-	0.00
209	Total wt. (g)	-	-	-	-	3.10
	Caprellid wt. (g)	-	-	-	-	0.00
	Non Caprellid wt. (g)	-	-	-	-	0.00
	Total wild	-	-	-	-	0.00
240	Total wt. (g)	-	-	-	-	8.70
	Caprellid wt. (g)	-	-	-	-	0.00
	Non Caprellid wt. (g)	-	-	-	-	0.01
	Total wild	-	-	-	-	0.01
262	Total wt. (g)	-	-	-	-	18.10
	Caprellid wt. (g)	-	-	-	-	0.00
	Non Caprellid wt. (g)	-	-	-	-	0.00
	Total wild	-	-	-	-	0.00

Table 3 (cont'd).

DOY	Food Category	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
283	Total wt. (g)	-	-	-	-	28.70
	Caprellid wt. (g)	-	-	-	-	0.00
	Non Caprellid wt. (g)	-	-	-	-	0.00
	Total wild	-	-	-	-	0.00
All	Total wt. (g)	771.50	994.00	208.90	340.00	63.80
	Caprellid wt. (g)	6.17	0.00	6.81	1.29	0.00
	Non Caprellid wt. (g)	0.60	0.23	2.35	1.43	0.01
	Total wild	6.77	0.23	9.16	2.72	0.01

Table 4. Estimated percentage of wild food as a proportion of total food consumed, including caprellids shown by DOY (Day Of Year). These estimates, which are derived from generic weights published in the literature (see text for explanation) probably over estimate the wild consumption because the estimated weight of individual items are high and the estimate weight of total gut contents is the lowest of the two estimates (See text for explanation). Dashes indicate that no samples were taken on the date. The letter 'L' indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
129	3.73% L	0.00%	-	-	-
144	0.00% L	-	-	-	-
145	-	0.00%	-	-	-
150	2.20% L	-	-	-	-
152	-	0.00%	-	-	-
155	1.62% L	-	-	-	-
157	-	-	3.36%	-	-
159	-	0.01%	-	-	-
164	-	-	9.03%	-	-
165	1.97% L	-	-	-	-
166	-	0.00%	-	-	-
171	-	-	-	0.78%	-
172	0.31% L	-	-	-	-
173	-	0.01%	-	-	-
178	-	-	-	1.53%	-
179	0.42% L	-	-	-	-
180	-	0.13%	-	0.34%	-
185	-	-	-	-	-
186	1.52%	-	-	-	-
187	-	0.00%	-	-	-
192	-	-	0.72%	-	-
193	1.95%	-	-	-	-
194	-	0.31%	-	-	-
208	-	-	-	-	0.00%
209	-	-	-	-	0.00%
240	-	-	-	-	0.11%
262	-	-	-	-	0.00%
283		-	-	-	0.00%
Total	0.88%	0.02%	4.38%	0.29%	0.02%

Table 5. Estimated percentage of wild food as a proportion of total food consumed, excluding caprellids shown by DOY (Day Of Year). These estimates, which are derived from generic weights published in the literature (see text for explanation) probably over estimate the wild consumption because the estimated weight of individual items is high and the estimate weight of total gut contents is the lowest of the two estimates (See text for explanation). Dashes indicate that no samples were taken on the date. The letter ‘L’ indicates the farm site and dates when lights were operating.

DOY	Larsen Island	Deep Harbour	Raynor Group	Shelter Passage	Departure Bay
129	0.00% L	0.00%	-	-	-
144	0.00% L	-	-	-	-
145	-	0.00%	-	-	-
150	0.00% L	-	-	-	-
152	-	0.00%	-	-	-
155	0.35% L	-	-	-	-
157	-	-	1.35%	-	-
159	-	0.01%	-	-	-
164	-	-	1.15%	-	-
165	0.31% L	-	-	-	-
166	-	0.00%	-	-	-
171	-	-	-	0.20%	-
172	0.00% L	-	-	-	-
173	-	0.01%	-	-	-
178	-	-	-	0.98%	-
179	0.02% L	-	-	-	-
180	-	0.13%	-	0.23%	-
185	-	-	-	-	-
186	0.00%	-	-	-	-
187	-	0.00%	-	-	-
192	-	-	0.72%	-	-
193	0.24%	-	-	-	-
194	-	0.31%	-	-	-
208	-	-	-	-	0.00%
209	-	-	-	-	0.00%
240	-	-	-	-	0.11%
262	-	-	-	-	0.00%
283		-	-	-	0.00%
Total	0.08%	0.02%	1.12%	0.42%	0.02%

Table 6a. Composition of plankton samples from the vicinity of Larsen Island farm. Several splits were sometimes used to make the estimates. The numbers shown below represent the total estimated numbers of organisms of each category in individual samples. Two samples (Web sample) were taken from the fouling community on the inside of the cages.

Date 1995	May 30	June 6	June 14	June 21	June 28	July 5	July 5	July 5	July 12
Time (PST)	12:45 PM	10:20 AM	12:45 PM	12:55 PM	12:20 PM	10:30 AM	10:40 AM	11:40 AM	11:45 AM
						Web sample	Web sample		
Amphipods	260	2048	528	1542	2048	1	64	1282	1
Barnacle exo.	0	0	0	0	1	2	0	0	2
Barnacle nauplii	67840	130048	9472	25600	3584	13760	11360	105728	30720
Calanoid	26881	59392	24064	72192	33536	1856	1184	24320	15360
Caprellids	0	0	14	1	0	3718	786	5	5
Chaetognath	1	0	0	0	0	0	0	0	2
Cladocera	2048	13824	4352	4096	512	192	0	1792	11264
Crab megalops	1	0	512	4	128	0	0	257	8
Crab zoea	784	8432	14608	7900	1332	204	64	867	821
Euphausiid naup.	0	0	0	0	0	0	0	256	0
Cyclopoids	0	0	256	0	128	0	0	256	512
Barnacle cypris	1280	2048	0	512	128	64	32	768	0
Euphausiid juv.	0	32	0	0	0	0	0	0	256
Euphausiid zoea	768	2560	0	0	0	0	0	0	0
Gastropod	1024	5632	1280	7680	640	0	64	1280	2048
Medusa	603	112	80	112	246	18	0	20	12
Octopus juvenile	1	0	0	0	0	0	0	0	0
Oikopleura	6400	0	0	0	1792	0	0	8448	256
Pelecypoda	0	0	0	0	0	0	0	256	0
Polychaete	1	0	0	0	0	0	0	0	0
Shrimp juvenile	0	48	0	0	0	0	0	8	259
Shrimp zoea	5	3072	3072	2	256	0	0	0	1024
Siphonophora	10	0	0	2	5	3	0	0	4
Unid. Fish larva	0	0	1	0	0	0	0	0	0
Herring	1	0	0	0	0	0	0	0	0
Osmeridae	0	0	0	0	0	0	0	0	0
Gadidae	1	0	0	0	0	0	0	0	0
Stich/Pholidae	0	0	0	0	0	0	0	0	0
Ammodytidae	0	1	0	0	0	0	0	0	0
Hexagrammidae	0	0	0	0	0	0	0	0	0
Cottidae	0	2	2	0	0	0	0	2	2
Agonoidae	0	0	0	0	0	0	0	0	0
Pleuronectidae	0	0	0	0	0	0	0	0	0
Bathylagidae	0	0	0	0	0	0	0	0	0
Insect (Diptera)	0	0	1	0	0	0	0	0	0

Table 6b. Composition of plankton samples from the vicinity of Deep Harbour farm. Several splits were sometimes used to make the estimates. Two samples (Web sample) were taken from the fouling community on the inside of the cages.

Date 1995	June 1	June 8	June 22	June 29	July 6	July 6	July 6	July 13
Time (PST)	11:30 AM	10:40 AM	12:45 PM	12:05 PM	10:30 AM	10:30 AM	11:30 AM	11:30 AM
					Web sample	Web sample		
Amphipods	328	1356	360	2080	4	0	8208	3200
Barnacle exo.	0	4	0	0	3	0	272	0
Barnacle nauplii	4864	6080	320	64	6912	28288	25856	9920
Calanoid	768	0	5792	6720	128	1600	0	2944
Caprellids	0	1	0	0	35	2	24	0
Chaetognath	0	0	0	0	0	0	0	0
Cladocera	512	1152	352	64	64	192	2048	1984
Crab megalops	0	0	0	16	0	0	16	0
Crab zoea	5152	2688	1292	6080	3	15	2608	3136
Euphausiid naup.	0	0	0	0	0	0	0	0
Cyclopoids	0	0	32	0	192	64	128	0
Barnacle cypris	128	64	64	0	0	64	128	768
Euphausiid juv.	0	0	0	0	0	0	0	0
Euphausiid zoea	192	0	0	0	0	0	128	0
Gastropod	256	576	0	128	0	0	640	2688
Harpacticoid	0	0	0	0	3008	128	256	0
Medusa	1048	1380	976	1344	2	0	1292	1383
Octopus juvenile	0	0	0	0	0	0	0	0
Oikopleura	128	128	0	0	128	128	512	0
Pelecypoda	0	0	0	0	707	64	0	0
Polychaete	0	0	0	0	3	0	0	0
Shrimp juvenile	0	0	0	16	6	0	0	0
Shrimp zoea	816	272	11	144	0	6	192	832
Siphonophora	48	24	276	208	0	0	1920	2464
Unid. Fish larva	0	1	0	0	0	0	0	0
Herring	1	0	0	0	0	0	0	0
Osmeridae	0	0	0	0	0	0	0	0
Gadidae	0	0	0	0	0	0	0	0
Stich/Pholidae	0	0	0	0	0	0	0	0
Ammodytidae	0	0	0	0	0	0	0	0
Hexagrammidae	0	0	0	0	0	0	0	0
Cottidae	0	0	0	0	0	0	0	0
Agonoidae	0	0	0	0	0	0	0	0
Pleuronectidae	1	0	0	0	0	0	0	0

Table 6c. Composition of plankton samples from the vicinity of Hardy Bay farm. Several splits were sometimes used to make the estimates.

Date 1995	May 31
Time (PST)	10:40 AM
Amphipods	0
Barnacle exoskeleton	2
Barnacle nauplii	18944
Calanoid copepods	14848
Caprellids	1
Chaetognath	0
Cladocera	34816
Crab megalops	32
Crab zoea	26016
Cyclopoids	0
Barnacle cypris	4352
Euphausiid juvenile	0
Euphausiid nauplii	512
Euphausiid zoea	1536
Gastropod	256
Harpacticoid copepod	0
Medusa	310
Octopus juvenile	0
Oikopleura	8704
Pelecypoda	0
Polychaete	0
Shrimp juvenile	4
Shrimp zoea	352
Siphonophora	0
Unidentified Fish larva	2
Herring	0
Osmeridae	0
Gadidae	1
Sticheidae/Pholidae	0
Ammodytidae	0
Hexagrammidae	0
Cottidae	27
Agonoidae	0
Pleuronectidae	0
Bathylagidae	0

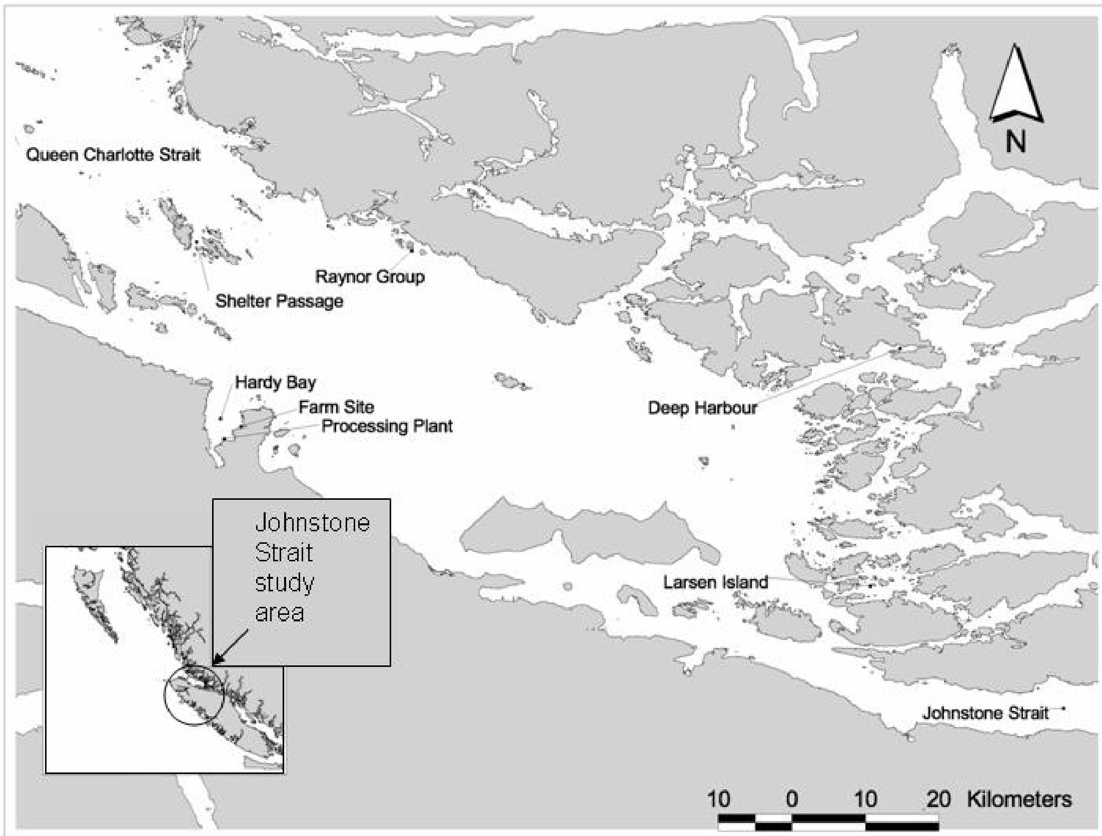

Fig. 1. The study sites in the Queen Charlotte Strait and northern Johnstone Strait.

Fig. 2. Lights on farm cages at Larsen Island.

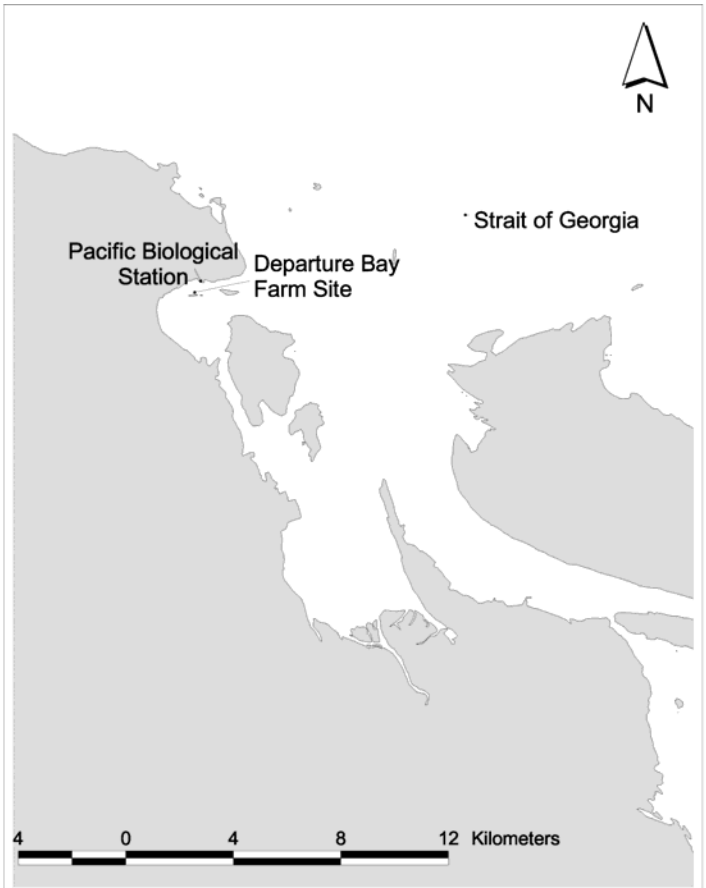

Fig. 3. The experimental farm site in Departure Bay, Nanaimo.

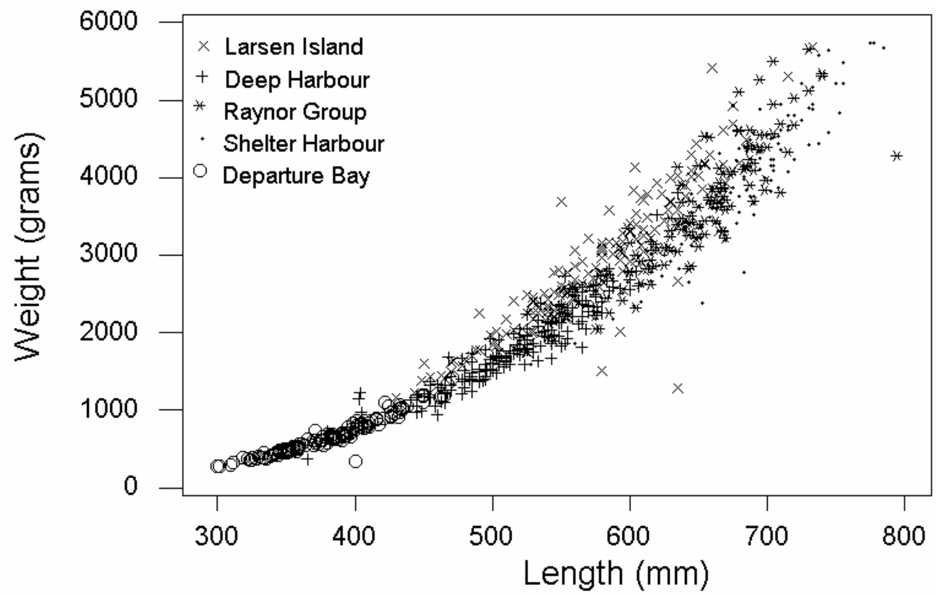

Fig. 4. Lengths (fork) and weights (grams) of 734 Atlantic salmon examined in this study. The Departure Bay fish were the smallest, ranging from 300-500 mm .

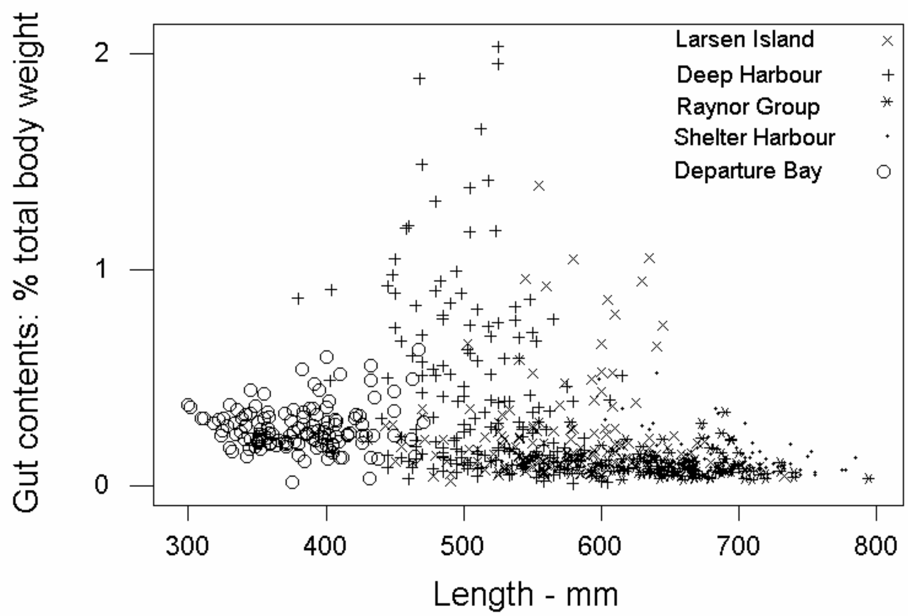

Fig. 5 Scatterplot of the gut contents as a percentage of total body weight. Most fish have gut contents between 0 and 0.5% of their total body weight.