Kitamaat River Oolichan (*Thaleicthys pacificus*) Study: 1996/97

Kitamaat Village Council

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Prepared For:

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1. Introduction

The oolichan (*Thaleicthys pacificus*) is an anadramous species of smelt found only on the west coast of North America, with its distribution centered primarily in British Columbia. Five of the fifteen oolichan runs in British Columbia are found in Haisla Nation Territory; the Kitimat, Kildala, Kemano, Kitlope, and Kowesas rivers (Figure 1). The primary intent of this study is to understand the biology of oolichans in relation to the effects of forest practices, i.e., the impacts of related habitat alterations on the survival and abundance of this species. The Kitimat River, formerly the most important oolichan run to the Haisla, has been impacted by extensive logging, changes to hydrology, and industrial pollution (Karanka 1993; Pedersen et al. 1995; Beak Consultants 1994). Most other oolichan-bearing rivers in this area have logging underway or planned. From the results of this study, the Haisla Nation intends to find ways to conserve, protect, and rehabilitate oolichan stocks.

Studies on the Kitimat River were begun by DFO Habitat Branch in Prince Rupert in 1993 (Pedersen et al. 1995). Studies by the Kitamaat Village Council Oolichan Study have continued this work in 1994/95, 1995/96 and 1996/97 (Kelson, 1995 and 1996). In 1996/97, we further refined our approach for studying the species. We continued to develop a standardized field method for accurately estimating the survival and abundance of oolichan based on adult fecundity and egg/larval outdrift. We attempted to understand more about oolichan distribution and habitat utilization in the Kitimat River and other watersheds within Haisla Nation Territory. Also, we attempted to relate biological findings to habitat alterations from forest practices in the Kitimat as well as in other watersheds.

In order to determine the potential effects of forest practices on oolichan, a more complete understanding of oolichan biology was needed. Limited information on oolichan biology was available at the onset of this study (Lee et al. 1980; Samis 1977; Scott and Crossman 1973; Higgings et al. 1987; Drake et al. 1991). Each year new information on many aspects of oolichan biology has been acquired in this study, and each year the understanding of oolichan biology and our ability to assess the potential impacts of forest practices on oolichan has been improved. In 1996/97, improved methods of taxonomic identification and a novel approach to genetic analysis have expanded our capabilities.

2. Objectives

For the 1996/97 study, the objectives were:

Examination of fecundity, age, sex ratios, and run timing in the Kitimat River through sampling of adults.

Estimation of run size in the Kitimat River by measuring female fecundity and counting out-drifting eggs and larvae.

Preliminary comparison of spawning behaviour, timing and run size in the Kitimat with other rivers using increased sampling of eggdrift during spawning and determination of the hour and dates of spawning activity.

Definition of the areas of spawning within the Kitimat watershed including upstream extent of migration, use of tributaries, contribution of spawning and larval production in the upper watershed compared to contribution in the lower watershed.

Examination of timing of hatching, especially diurnal variation in numbers of outdrifting larvae.

Confirmation of larvae identification captured at various locations and times.

Genetic identification of stocks in selected rivers of the area.

3. Methods

Adult Sampling

From February 8 until May 14, 1996, a 6m x 2m, 3.5cm (stretch from corner to corner) mesh monofilament gill-net ("smelt net" from Redden Nets in Vancouver) was located in Sumgas Slough at the same site as in previous years (Figure 2 and 3). Records were kept of; date, time, sex and number of fish captured. Adult fish were captured to determine: the sex ratio present in the run, weight, length, age, gonad weight and condition, female fecundity, and relative fecundity of spawners. Some of these samples were also sent to UNBC to be used for genetic analysis (see Appendix 1).

Adult oolichans were sampled periodically in a similar fashion in the Kowesas and Kitlope watersheds for genetic analysis (Figure 1).

Ages were estimated using otoliths. Aging was done by AMC Technical Services in Lantzville, B.C.. The same lab has done aging work for Triton on the Kemano River and was used by this study to ensure comparability of results between rivers.

Egg and Larvae Sampling

From February 13 until September 10, 1996, a 1m diameter plankton net with General Oceanics 2031 digital flow meter was used to catch drifting eggs and larvae (Figure 3). The net was adjusted down until there was no bow wave to insure an even laminar flow. Samples were collected routinely at the same selected location(s) within the river, as well as at a variety of other locations to determine upstream distribution, timing, and other objectives.

In the Kitimat River all samples were taken at a depth of 1m to 2m so that the net was at or very near the bottom. Similarly, samples in the Kitlope, Kowesas and Kemano were taken at a depth of less than 2m to ensure that it was unlikely that eggs or larvae were missed. Eggs and larvae were sorted on a light table in Pyrex trays and preserved in ethanol. All samples were retained.

As in 1995, a 3 point index of distance across the river was used to test for uniform egg and larval distribution across a transect of the river. In 1995, no significant difference was found, however this was tested again. Three samples also increased the sample size to improve the confidence intervals in egg and larval production estimates.

Samples were taken at the Eurocan intake, and upstream to determine extent of use of the watershed, and the contribution of upstream spawning to the total egg and larval production.

Spawning activity was monitored using plankton net sampling in the Kowesas, Kitlope and Kemano rivers, but at a much lower intensity than in the Kitimat River.

Eggs were identified by size and shape and also, occassionally, by attached material indicating their adhesiveness (Figure 4). Oolichan eggs are strongly adhesive when fertilized (Hart and McHugh 1944; Kelson 1995). Osmerid eggs are generally 0.8 to 1.1mm (Matarese et al. 1989). Other species with which oolichan eggs could be confused are Longfin and Rainbow smelt, whose eggs are 1.2mm (Wang 1989) and sculpins (cottidae - cottid eggs are 1.6mm (Wang et al. 1989; D. Kent, pers. comm.).

Oolichan larvae were identified by comparison with drawings using a dissecting scope based on previous experience (Kelson 1995,1996) and information provided by DFO (Pedersen et al. 1995). Collected larvae were also sent to the Vancouver Aquarium for further confirmation of taxonomic identification.

Physical Environment

River temperature, salinity, and conductivity were measured with a YSI Model 33 S-C-T meter. Kitimat River temperatures were also obtained from the DFO Salmonid Enhancement Hatchery, although they may be inaccurate because they are taken just below the warm water discharge from the hatchery. Tide tables from Hydrographic Survey of Canada were used to examine tidal influence on run timing.

Population Estimate

In 1993, DFO Habitat Branch estimated Kitimat River run size as did this study in 1994 and 1995. An estimation of total numbers of outdrifting eggs and larvae and calculation of adult fecundity were used to determine the number of spawning fish in the run (see Pedersen et al. 1995; Kelson 1995, 1996). In 1996 methods were essentially repeated to ensure comparability of results except for some improvements. Efforts were made to improve fecundity estimates. Gonads were weighed from 47 mature and unspawned female oolichans. Eggs were frozen and stored. Thawed eggs were reweighed, and a 2g sample from 25 randomly selected gonads was counted. The difference between the fresh and frozen weights were then included in the estimation of total number of eggs in each female. The number of eggs per gram of gonad was used to estimate the number of eggs in the remaining females. The differing weights of male and females and the ratio present in the run was used to calculate the relative fecundity of the run.

1995 Recommendations for Future Studies and 1996 Improvements

The following are recommendations made following last year's work Kelson 1995) and work done in 1996 in response to them.

1. Egg Sampling

In 1995, egg and larval sampling did not begin for two days after spawners arrived in the river. At this time there was a high density of egg outdrift, however, an undetected pulse of drifting eggs may have occurred during this unsampled time. Another source of potential error was thought to be eggs missed if spawning occurred at night during the main part of the run because sampling for eggs was not done until the next day. Therefore, in 1996, egg sampling began in the Kitimat River on February 23, as soon as ice conditions in the river permitted. Night sampling was also conducted during this period because oolichans are thought to spawn at night consistent with other smelt species (A. Lewis pers. comm.).

In previous years, detected egg outdrift peaked four or five days after each peak of spawners entered the river. Peaks of egg outdrift appear to coincide with peaks of spawning activity based on capture of adults in past work (Kelson 1995, 1996) and observations in Kemano where the water is clear. However, in previous years, egg sampling did not begin until spawners were already obvious in the river. In 1996, egg and larval sampling began prior to the arrival of spawners in the river in an attempt to ensure that no eggs were missed. This was intended to improve the accuracy of the run size estimate and better pinpoint the relationship between the arrival of spawners and the beginning of spawning.

2. Diurnal Variation in Egg and Larval Density: Sample during the night

From analysis of the daily variation in larval density captured in 1995 it was found that in the early morning (6:00am to 8:00am), 7 samples were needed whereas in the evening (4:00pm to 10:00pm) 60 samples were needed to achieve the same level of statistical confidence. Therefore, based on 1995 data, this year's sampling focused on morning abundance.

Because night sampling was not conducted in previous years, it was necessary to determine if more or less outdrift occurred during the night. In 1996, a large effort was made to examine this question. Sampling was done every few hours for a 24 hour period in the Kitimat River on; March 18, April 18, May 6, 7, 8, 13, 14, 15, 21, 22, 23, 27, 28, and 29. In the Kemano River, sampling was done around the clock on March 22 and 23, and similarly in the Kowesas. We attempted to confine all other sampling to the early morning period (before 8:00am).

3. Upstream Distribution of Spawning

In order to develop a more definitive picture of where larvae are and where spawning is occurring, sampling was undertaken at an upstream location above where the majority of oolichans are thought to spawn. Some upstream spawning is suspected from past work, and intensive sampling was used in an attempt to quantify it. Sampling was done every few hours for a 24 hour period at the Eurocan Intake (Figure 2) on June 4, 6, 11, and 12.

In 1996 efforts were made to establish an upstream point at which no larvae were present in the Kitimat River. Presence in a number of tributaries was also investigated.

4. Genetic Stock Identity

Stock identity is an important question for which the Kitimat area is an ideal study site. There are two approaches to answering the question of genetic stock identity in oolichans. Previous genetic differentiation studies on oolichan (Taylor, 1996) investigated broad scale differences of some coastal stocks using mitochondrial DNA restriction fragment length polymorphisms. In our study, localized differencesin the five oolichan bearing rivers of the Kitimat area were investigated using a highly sensitive polymerase chain reaction of microsatellite markers, more suited to genetic analysis of closely related populations (see Appendix 1).

Understanding of genetic stock identity is essential when considering whether river populations are ecologically and genetically unique or part of one large population, as well as for management and rehabilitation of impacted stocks. For example, for the Kildala River run, which has nearly disappeared for 10 years, enhancement may be an option if stocks are found to be genetically homogenous. However, if the various runs are genetically and/or ecologically distinct, each run must be managed and considered as an important element of the diversity of the species. This has implications for forestry and other development which may impact oolichans.

5. Comparison of Kitimat River Stock with Other Stocks

In 1996, spawning behaviour in the Kemano, Kitlope and Kowesas was studied during March and April. In addition to the value of studying spawning in these other rivers, this effort laid the groundwork for future efforts. Work on these rivers is logistically very challenging, and it was important to begin some work to assist in planning future study objectives.

4. Results

Run Timing

The majority of adults were captured between March 11 and 18 (Figure 5). The last adult was captured on May 13, one day before sampling was ceased due to high water and debris. The first returning adult oolichans caught were males on February 21. In the Kitimat River 70% of eggs were caught between March 11 - 18 (Figure 6). Egg outdrift density was high on March 13 and 14, however a higher peak occurred on March 18 and 19 (Figure 7). This coincided with the capture of 98% of adults from March 7 to 19. There may have been an even closer relationship but this was not detected because one day of sampling for eggs was missed, eggs being captured only after the first day of spawning.

The majority of spawning in the Kitimat River between March 11 and 18 occurred during a peak of river discharge (Figure 8). In the Kemano, the peak of egg outdrift density (Figure 6) was used to gauge peak of spawning activity. This occurred during a low flow period approximately two weeks before the spring freshet in April (Figure 9).

Tidal influence during the main part of the Kitimat River run was not relatively large (Figure 10). Oolichans moved into the river during the nighttime rising tide in both the Kitimat and Kemano. In Kemano, the peak of egg discharge occurred during large tides, and the run began, again based on egg capture, during even larger tides.

Daily temperature in the Kitimat River could not be reliably determined throughout this period becausethe SCT meter was not functioning correctly before March 15, and only monthly averages could be obtained from the DFO Hatchery (Figure 11).

Spawning Activity

Sampling for eggs was done throughout the day on March 18 and 19 in the Kitimat River and March 21, 22, 23, 26 and 29 in the Kemano. Variation in eggs captured was greatest between days, such as in the Kemano between March 26 to April 2 as compared to March 22 or 23. Diurnal variation was evident in Kitimat, Kemano and Wahoo (an upstream tributary of the Kemano), with density of eggs increasing in the late evening, and peaking by early morning (Figures 12, 13 and 14).

Between river variation in egg density was also great. The highest density of eggs captured was in the Wahoo (103.9 eggs/m^3), followed by the Kemano (86.2 eggs/m^3), the Kildala (11.3 eggs/m^3) and the Kitimat (3.5 eggs/m^3) (Table 1). The species of eggs found in Bish, and Giltoyees is being reexamined.

Fecundity

A total of 1546 adult oolichans were captured in the Kitimat River of which there were 509 females and 1037 males. Of those females, 47 mature and unspawned fish were used in fecundity calculations. The mean weight of female gonads was 42.8g. Fecundity was calculated two ways; both by counting eggs in a 2g subsample from 25 females, and by applying the mean egg weight of 0.4363mg as has been done in previous years (Pedersen et al. 1995). By these means, a mean relative fecundity (males and females corrected for body weight and sex ratio in the run) of 79.6 (by counting) and 136.2 eggs (egg weight method) per gram of spawners was calculated (Table 2).

Fecundity of females was not significantly related to age (r=0.55), but was significantly related to weight (r=0.75) (Figure 15). Similarly, male fecundity was not related to age, but was related to size (Figure 16).

Age

Oolichans caught in the Kitimat River were from 2 to 6 years old with an average age of 3.73 years (n=300) (Figure 17). 3.33% were 2 years, 40.3% were 3 years, 34.7% were 4 years, 18.3% were 5 years, and 2.3% were 6 years. Most males were 3 years (50%) and 4 years (26%). Most females were 4 years (40%) and 3 years (36%).

Sex ratios

A few male oolichans arrived before the main body of spawners in late February, and before any spawning activity was detected through egg capture. Between March 11 - 18, a period of the majority of spawner presence, males outnumbered females by a ratio of 1.4 to 1, but on the 15th to 18th females dropped off sharply and the male to female ratio was 6.1 to 1 (Figure 5). The last female was caught on March 29. A few more fish were captured, all male, until the last one on May 13th. Considering the entire run, males outnumbered females by a ratio of 2.04:1.

Larval Outdrift

Larvae were first captured on May 6 and 7, and continued in large numbers and with numerous peaks until mid August. An abrupt decrease in larval outdrift occurred after mid-August with the last larvae being captured on August 26. The peak of egg capture in the Kitimat River was March 14. Based on accumulated thermal units of 190^{o}C, the peak of larval hatching would have been expected on April 23. However a mixture of species of larvae in the samples was found which has so far prevented determination of the timing of oolichan larval outdrift.

Oolichan larvae have a standard length of about 5.5mm, have an elongate body shape, snout to anus length is 75% of standard length, subterminal mouth, and a myomere count of 65 to 72 (Hearn 1984; Matarese et al. 1989) (Figure 4). Other larvae identified in the river were cottids (*Cottus asper* and one other) (D. Kent, pers. comm.). *Cottus asper* or sculpin larvae have a standard length of about 5.2mm, a snout to anus length of 35-40% of standard length and a myomere count of about 30 to 35 (Matarese et al.

1989). Another unidentified species of cottid was identified as distinguished by a myomere count of 17 or 18. The most useful distinguishing characteristic between these larvae is the myomere count which remains evident even in partially decomposed larvae.

Location of Spawning

In 1995, larvae were captured in small numbers up to approximately 20 km upstream, approximately 18.5 km above the upstream extent of tidal influence. We did not achieve a nil result, so in 1996 we continued to investigate further upriver. Larvae were captured approximately 40 km above the estuary and in a number of tributaries, however, these samples have not been reviewed since the presence of cottids in the samples was found. While this earlier finding could change our understanding of oolichan utilization and distribution in the Kitimat River, we cannot make this conclusion at this time until the taxonomy of these larvae samples is reviewed during the summer of 1997.

Genetic Identification of Oolichan Stocks

In 1995, appropriate methods of genetic analysis were researched and preliminary plans were made to work with geneticists at UNBC to analyze for localized genetic differentiation. We also supplied samples for coastwide broad scale genetic differences done at UBC in cooperation with DFO.

In 1996, this study organized a meeting which occurred in late April which brought together Doug Hay (DFO), Don McPhail and Ric Taylor (UBC), Dan Heath (UNBC), Michael Gordon and John Kelson (Haisla Oolichan Study). This group represented those interested in, or currently working on the oolichan stock ID question. Sharing of information, division of labour, and sample collection were discussed. Samples were collected during the 1996 run in the Kitimat area.

During early 1997, UNBC developed microsatellite markers which were then used to examine adults and larvae from Kitimat area rivers. The markers were developed from adult oolichan and subsequently used to identify larvae. These markers now form part of a genetic library available to other researchers. The novel approach of using larvae for genetic identification allows this approach to be very rapid and cost effective. Preliminary results of the analysis also confirmed that other species of larvae were present in outdrift samples. Answers to the stock ID question will be available during summer1997 (Appendix 1).

Discussion

Run Timing and Spawning Activity

The majority of adults were captured between March 11 and 18. The last adult was captured on May 13, one day before sampling was ceased due to high water and debris. The first oolichans were caught were males on February 21. In the Kitimat River 70% of eggs were caught between March 11 - 18. Egg outdrift density was high on March 13 and 14, however a higher peak occurred on March 18 and 19. This coincided with the capture of 98% of adults from March 7 to 19. There may have been an even closer relationship but this was not detected because one day of sampling for eggs was missed, eggs being captured only after the first day of spawning. Comparison of differences in run timing, flows and river temperature in Kitimat vs. Kemano might provide some insight into the ecological distinctions of stocks or the effects of forest practices on oolichan runs within Haisla territory. Multi-variant analyses of all existing data on run timing and river temperature, discharge and tides will determine which of these three factors is important.River discharge seems to be a key factor in initiating the run. In 1995 the peak of spawner inmigration was at the lowest point just before the spring freshet (Kelson 1996). However, during the March 11 to 18 period in the Kitimat, flows were large. Natural variation in river discharge may account for this. However, if oolichans are adapted to select the low flow before the freshet, destabilization of the flow regime of the watershed due to extensive logging could interfere with successful spawning. Further analysis and comparisons of these factors in the Kitimat and Kemano rivers is planned for 1997/98.

Spawner Characteristics

Work done on the Kemano in 1997 showed that gill net selectivity is probably misrepresenting the Kitimat River run. Several buckets of oolichans were collected from drag seined oolichans and tested to see if any could pass through the gillnet. A small percentage did pass through, all of which were female, but this was not quantified. Since size is related to both sex and age (Table 3) female and younger fish are probably being missed. This would tend to reduce the observed size difference between males and females, and also to affect fecundity estimates. A better estimate of fecundity will be produced by analysis of the Kemano oolichans planned for collection in 1997/98.

Fecundity

A different fecundity was calculated using the two methods in this study. The results from counting a 2g subsample are quite inconsistent with fecundities calculated elsewhere, probably due to counting error. The fecundity calculated using the egg weight from Pedersen (1995) is more credible. Average gonad weights in the Kitimat increased from 4.0g in 1995 to 5.8g in 1996, however because female weight also increased relative fecundity decreased.

Age

Oolichans caught in the Kitimat River in 1996 averaged 3.7 years, as opposed to 4.4 in 1995 and 1994 (Table 4). The significance of these shifts in age are not known. Comparison between rivers and years might shed light on the cause of this variation.

Sex Ratio

The sex ratio found in 1996 of 2.04 males:1 female is comparable with that found in the past several years. For instance, in 1995 the ratio of males to females in the Kitimat River was 2.33:1. The bias towards higher numbers of males probably reflects the requirements for milt production in a broadcast spawner which spawns in moving water. However, the ratio of males to females found in all other studies had many more males. Ratios of 3.3:1, 3.4:1, and 4.5:1 have been found in the Kemano, Fraser, and Columbia rivers, respectively (Triton 1992; Hart and McHugh 1944; Smith and Saalfield 1955). Because gill-net selectivity was a factor in the Kitimat River, it would have tended to increase the proportion of males because they are slightly larger than females. Therefore this ratio of males to females may be biased towards a slightly higher number of males.

Various possibilities exist for the lower ratio of males to females found in the Kitimat River. Something may behaviourally affect oolichans which discourages males. Some toxicant in pollution from Eurocan or the municipal discharge may be causing male specific genotoxicity or organ toxicity. More likely, the lower ratio of males to females might be a function of the generally reduced abundance of oolichans in the Kitimat River.

Egg Outdrift

It is not known if the amount of eggs drifting out of the river during spawning is related to run size or spawning conditions. For instance, a very large run might have a small egg drift if spawning conditions were favourable for egg deposition and most eggs managed to settle successfully on the substrate. Converserly, a small run under unfavourable conditions might produce a large egg drift if a large proportion of eggs did not manage to adhere to the substrate. Conditions which affect the eggs adherence to the substrate might be key to the success of the run for the season.

Some eggs were captured in the Kitimat with material attached, indicating they adhered to something but washed away. Most eggs captured (70%) were alive, and fertilized but without material attached. These eggs failed to adhere to the substrate. Comparison with Kemano suggests that large numbers of fertlized eggs drift out of the river during spawning. In Kemano, where the water is clear and spawners can be seen, large numbers of eggs were captured coinciding with the arrival of large numbers of spawning oolichans. However in the Kitimat, no relationship can be observed between presence of spawners and egg outdrift because of the turbid water. Most likely, the amount of egg outdrift reflects the timing and size of the run affected by spawning conditions.

Confusion of oolichan eggs with Cottids or other non-smelt species was not thought to be a problem because the other smelts have eggs which are distinctly smaller. Some possibiltiy exists that Longfin smelt or Rainbow smelt eggs and larvae were caught. However, if they were present, adults would likely have been captured on the gill nets sometime during the past several years of study, or reported anecdotally from Haisla fishermen. Fertilized eggs which have a nearly formed embryo could be identified to species through genetic analysis using the newly developed markers, but this has not yet been done.

Larval Outdrift

Numbers of larvae captured must reflect numbers of larvae drifting down the river. Unfortunately, recent findings from taxonomic identification of larvae will require that we review and re-analyze all samples.Therefore, earlier conclusions about upstream extent of use of the watershed, use of other small watersheds, timing of larval hatching, and run size estimates will need to be reviewed and revised after reanalysis of the samples from all previous years.

Run Size Estimate in the Kitimat River

All elements needed to produce a run size estimate by the egg and larval production method were acquired assuming that the larvae were only oolichan. The accuracy of estimates of total numbers of eggs and adult fecundityhave benefitted from several years of improvements, however, run size cannot be estimated until the larval samples are re-examined. The presence of cottids in the samples will require that run size estimates be revised.

Some approximation of run size may be inferred from the egg production during spawning. More than 100 tonnes of oolichans were caught in the Kemano and Wahoo during the 1996 fishery. It is not known what proportion of the run this constitutes, but it is probably about 50%, more or less. Kitimat egg production was found to be about 10% of that from the Kemano/Wahoo (Figure 7) and so the Kitimat run size may be a similar fraction of the Kemano/Wahoo.

Genetic Identification of Stocks

Genetic markers developed for oolichans by UNBC (see appendix 1) will be used to investigate stock structure. Larvae and adult oolichans from Kitimat, Kildala, Kowesas and Kemano are currently being analysed for variation within and between populations.

Recommendations for Future Studies

1. Gill-net Selectivity

Use a combination of mesh sizes to try and capture smaller adult oolichans.

2. Correct Identification of Larvae

Improved accuracy of larval identification is necessary for many aspects of this study. All larvae must be identified and sorted using a microscope.

3. Comparison of Abundance, Timing and Age Structure of Kitimat River vs. Kemano River Oolichan Stocks

The comparison of these two stocks will enable us to confirm the quantitative reliability of egg and larval outdrift estimates of abundance for the Kitimat River because the Kemano is not impacted by logging, has water that is not turbid and therefore allows direct counts of spawners in the river, and has a fishery from which data on catch is available for tracking abundance. Differences in yearly abundance, run timing, and age structure would also provide insight into ecological differences between stocks and/or effects of habitat alterations due to forest practices.

4. Continuation of Data Collection to Account for Generational Effects on Variation

The current study has documented variation in stock abundance for the past three years. In order to understand the implications of this variation, the study would need to account for adult returns of progeny produced and sampled in years one, two and three of the study. Thus, years with higher abundance would be expected to result in larger returns when that generation of progeny returned. Disparities in abundance between one generation and the next could be indicative of oceanic impacts. Since the life cycle of oolichan may be 5-7 years, it would be necessary to continue the study for a minimum of 4-5 years to have a more precise understanding of this approach for measuring effects of logging practices, differentiating ecological differences between stocks and differentiating watershed impacts from oceanic effects.

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DAY VERSUS NIGHT

Night(00:00-6:00))	night

Average of larv/vol

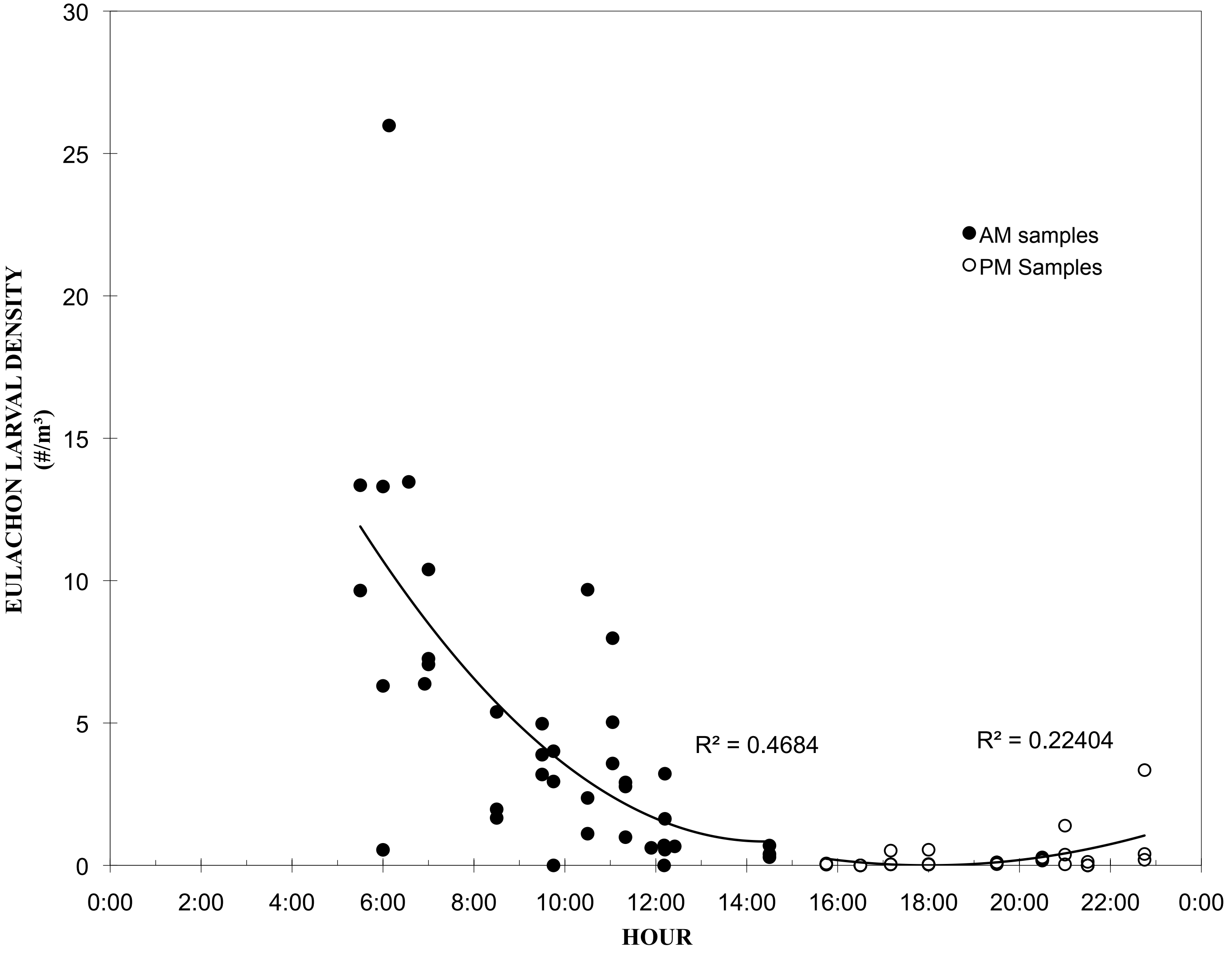
week	SITE	DATE	time	Total		
20	1B	5/15/95	11:54:00 AM	0.616755991	11:54	0.616755991
		5/17/95	12:11:00 PM	0	12:11	0
	1C	5/15/95	12:11:00 PM	0.702106129	12:11	0.702106129
		5/17/95	12:25:00 PM	0.668344681	12:25	0.668344681
21	1A	5/23/95	6:08:00 AM	25.98143608	6:08	25.98143608
		5/24/95	5:30:00 AM	9.651530947	5:30	9.651530947
		5/25/95	6:00:00 AM	6.303462549	6:00	6.303462549
		5/26/95	7:00:00 AM	7.058212436	7:00	7.058212436
	1B	5/23/95	6:34:00 AM	13.46738325	6:34	13.46738325
		5/25/95	6:00:00 AM	13.30570276	6:00	13.30570276
		5/26/95	7:00:00 AM	10.39046928	7:00	10.39046928
	1C	5/23/95	6:55:00 AM	6.376001206	6:55	6.376001206
		5/24/95	5:30:00 AM	13.34981804	5:30	13.34981804
		5/25/95	6:00:00 AM	0.54630231	6:00	0.54630231
		5/26/95	7:00:00 AM	7.25833886	7:00	7.25833886
22	1A	5/29/95	8:30:00 AM	5.390376059	8:30	5.390376059
		5/30/95	9:30:00 AM	3.887116967	9:30	3.887116967
		5/31/95	9:45:00 AM	4.009685371	9:45	4.009685371
		6/1/95	10:30:00 AM	9.681857831	10:30	9.681857831
		6/2/95	11:20:00 AM	2.770746901	11:20	2.770746901
	1B	5/29/95	8:30:00 AM	1.969538151	8:30	1.969538151
		5/30/95	9:30:00 AM	3.192237591	9:30	3.192237591
		5/31/95	9:45:00 AM	2.946169388	9:45	2.946169388
		6/1/95	10:30:00 AM	2.368040509	10:30	2.368040509
		6/2/95	11:20:00 AM	0.990958799	11:20	0.990958799
	1C	5/29/95	8:30:00 AM	1.667308371	8:30	1.667308371
		5/30/95	9:30:00 AM	4.975239237	9:30	4.975239237
		5/31/95	9:45:00 AM	0	9:45	0
		6/1/95	10:30:00 AM	1.11342021	10:30	1.11342021
		6/2/95	11:20:00 AM	2.913486945	11:20	2.913486945
23	1A	6/5/95	12:12:00 PM	3.219659161	12:12	3.219659161
		6/7/95	2:30:00 PM	0.697188903	14:30	0.697188903
	1B	6/5/95	12:12:00 PM	0.552566914	12:12	0.552566914
		6/7/95	2:30:00 PM	0.39536168	14:30	0.39536168
	1C	6/5/95	12:12:00 PM	1.635518405	12:12	1.635518405
		6/7/95	2:30:00 PM	0.289106722	14:30	0.289106722
24	1A	6/15/95	11:03:00 AM	7.979071009	11:03	7.979071009
	1B	6/15/95	11:03:00 AM	5.028721692	11:03	5.028721692
	1C	6/15/95	11:03:00 AM	3.578325379	11:03	3.578325379

DAY VERSUS NIGHT

Night(00:00-6:0	day

Average of larv/vol						
week	SITE	DATE	time	Total		
21	1A	5/23/95	3:45:00 PM	0.067768214	15:45	0.067768214
		5/24/95	6:00:00 PM	0.549530392	18:00	0.549530392
		5/25/95	5:10:00 PM	0.039855276	17:10	0.039855276
		5/26/95	7:30:00 PM	0.04436072	19:30	0.04436072
	1B	5/23/95	3:45:00 PM	0.02757642	15:45	0.02757642
		5/24/95	6:00:00 PM	0.027168653	18:00	0.027168653
		5/25/95	5:10:00 PM	0.03426125	17:10	0.03426125
		5/26/95	7:30:00 PM	0.099829136	19:30	0.099829136
	1C	5/24/95	6:00:00 PM	0.046381161	18:00	0.046381161
		5/25/95	5:10:00 PM	0.519352128	17:10	0.519352128
		5/26/95	7:30:00 PM	0.10652554	19:30	0.10652554
22	1A	5/29/95	8:30:00 PM	0.226271434	20:30	0.226271434
		5/30/95	9:00:00 PM	1.395051956	21:00	1.395051956
		5/31/95	9:30:00 PM	0.125100918	21:30	0.125100918
		6/2/95	10:45:00 PM	3.34654892	22:45	3.34654892
	1B	5/29/95	8:30:00 PM	0.169744087	20:30	0.169744087
		5/30/95	9:00:00 PM	0.378360694	21:00	0.378360694
		5/31/95	9:30:00 PM	0	21:30	0
		6/2/95	10:45:00 PM	0.401407508	22:45	0.401407508
	1C	5/29/95	8:30:00 PM	0.280330369	20:30	0.280330369
		5/30/95	9:00:00 PM	0.038031101	21:00	0.038031101
		5/31/95	9:30:00 PM	0	21:30	0
		6/2/95	10:45:00 PM	0.19802492	22:45	0.19802492
23	1B	6/9/95	4:30:00 PM	0	16:30	0
	1C	6/9/95	4:30:00 PM	0	16:30	0

Figure. Diurnal pattern of eulachon larvae migration in the Kitimat River from May 15 to June 15, 1995.



Night(00:00	night				
Average of larv/vol					
week	time	Total			
11	10:30:00 AM	0			
12	8:45:00 AM	0			
	9:10:00 AM	0			
	11:47:00 AM	0			
	11:50:00 AM	0			
13	9:10:00 AM	0			
14	9:10:00 AM	0			
	10:00:00 AM	0			
	11:00:00 AM	0			
16	10:41:00 AM	0.043414109			
	10:56:00 AM	0			
	11:10:00 AM	0			
18	11:00:00 AM	0.023106929			
	11:15:00 AM	0			
20	11:54:00 AM	0.616755991			
21	5:30:00 AM	11.50067449		5:30	11.500674
	6:00:00 AM	6.718489207		6:00	6.7184892
	6:08:00 AM	25.98143608		6:08	25.981436
	6:34:00 AM	13.46738325		6:34	13.467383
	6:55:00 AM	6.376001206		6:55	6.3760012
	7:00:00 AM	8.235673525		7:00	8.2356735
22	8:30:00 AM	3.009074194		8:30	3.0090742
	9:30:00 AM	4.018197932		9:30	4.0181979
	9:45:00 AM	2.318618253		9:45	2.3186183
	10:30:00 AM	4.38777285		10:30	4.3877729
	11:20:00 AM	2.225064215		11:20	2.2250642
24	11:03:00 AM	5.528706027		11:03	5.528706
26	8:30:00 AM	17.11354673		8:30	17.113547
	9:30:00 AM	3.980123739		9:30	3.9801237
28	9:30:00 AM	7.741928648		9:30	7.7419286
	9:45:00 AM	0.01754291		9:45	0.0175429
	10:00:00 AM	2.265792525		10:00	2.2657925
29	10:45:00 AM	2.559658167		10:45	2.5596582
	11:00:00 AM	2.97673772		11:00	2.9767377
	11:05:00 AM	3.171711098		11:05	3.1717111
	11:30:00 AM	1.718326143		11:30	1.7183261
Grand Total		4.203694227			

Kitimat River eulachon larvae catch during 1995: mean, standard deviation, and confidence limits.

Time Period	Start Time	End Time	Duration (H)	Average (#/m^3)	S.D.	n	CI	LCL	UCL
Early	5:00	8:00	3.00	10.34	6.49	11	3.83	6.50	14.17
Mid-morning	8:00	10:30	2.50	3.43	2.52	12	1.42	1.42	4.86
Mid-day	10:30	15:00	4.50	1.41	1.16	10	0.72	0.72	2.12
Afternoon	15:00	18:00	3.00	0.21	0.25	13	0.14	0.14	0.34
Evening	18:00	23:00	5.00	0.45	0.87	15	0.44	0.44	0.89
Night	23:00	5:00	6.00	5.39	3.68	13	2.00	0.44	7.39
Summary			24	3.54	2.49	21			

Guidelines for future eulachon sampling effort of eulachon larvae

Time Period	Start Time	End Time	% of Total Larvae Hours	Samples needed for +_50% of period mean	Suggested optimal sampling allocation‘	Minimum sampling allocation[2]
Early	5:00	8:00	38%	7	4	1
Mid-morning	8:00	10:30	11%	9	1	0
Mid-day	10:30	15:00	8%	11	1	0
Afternoon	15:00	18:00	1%	50	0	0
Evening	18:00	23:00	3%	24	0	0
Night	23:00	5:00	40%	7-24	4	1
Total			100%		10	2

Notes: Raw data obtained from John Kelson, Biologist, Haisla Fisheries Commission.

Samples are to be taken within a single 24-hour period twice per week during the eulachon run on consecutive days. There are three replicate sites, therefore the optimal design will result in sixty samples per week, while the minimum design will result in 12 samples per week.

Figure. Larval eulachon volume: confidence interval versus sample size.

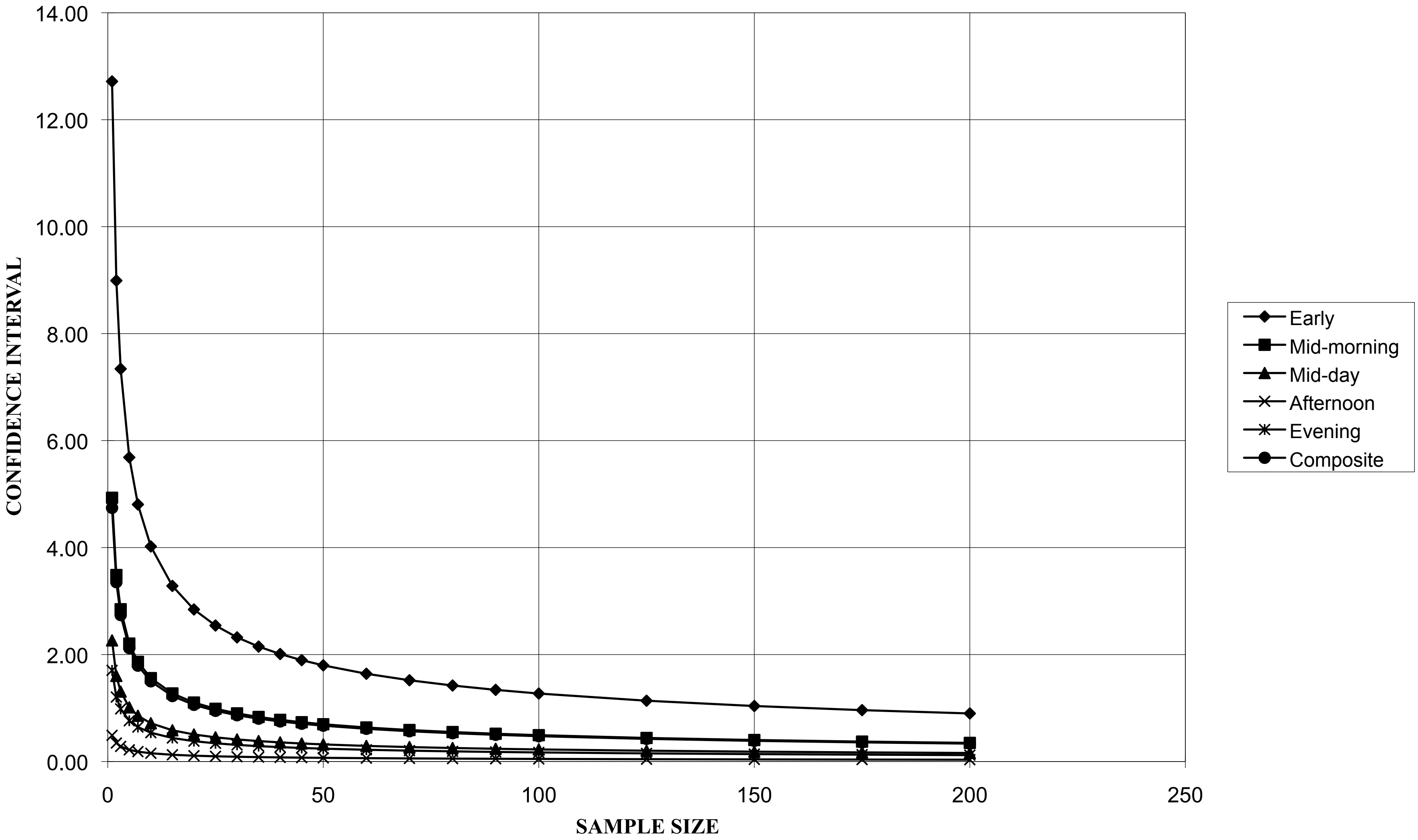


Figure. Larval eulachon volume: confidence interval versus sample size.

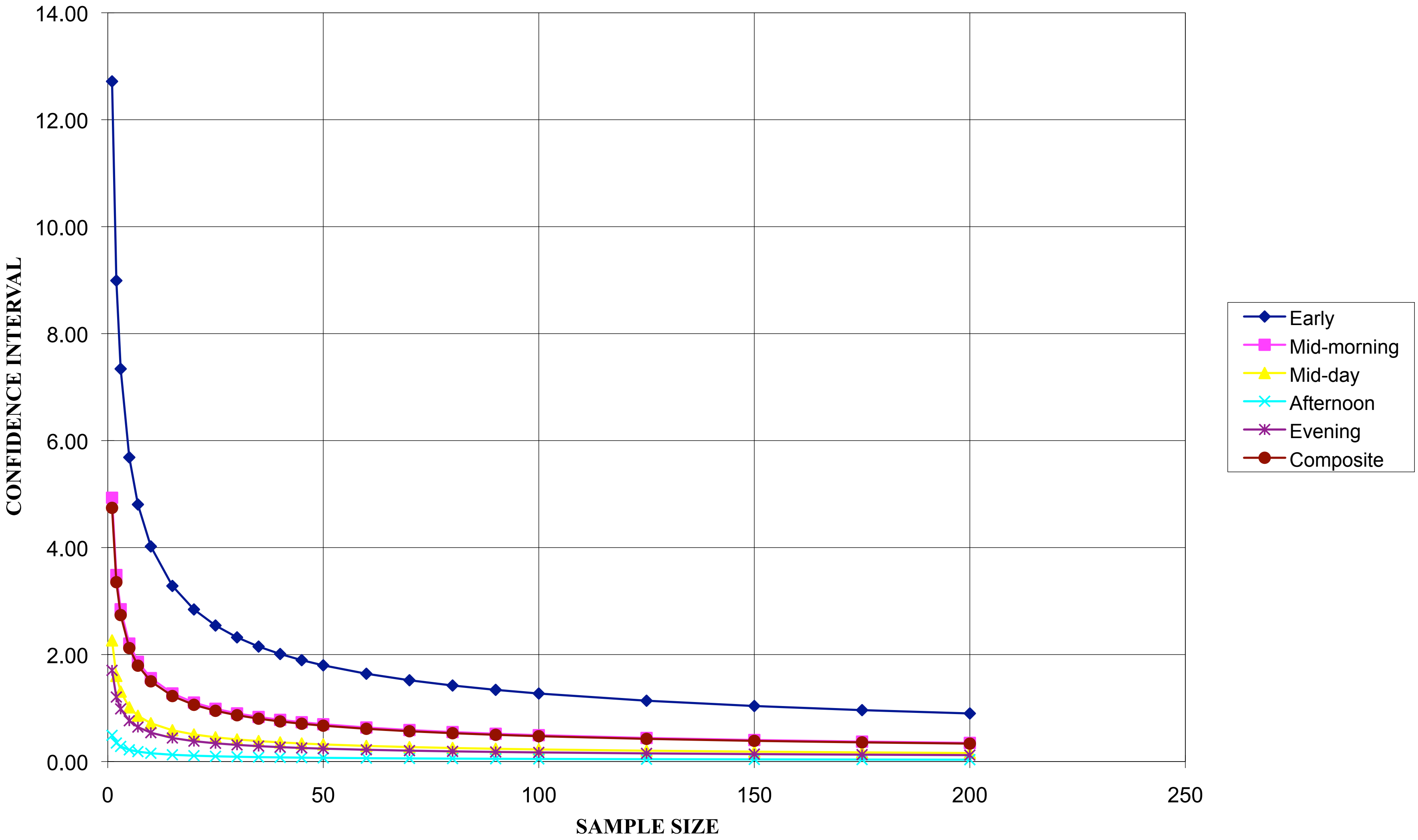


Figure. Larval eulachon volume: confidence interval as a percent of mean versus sample size.

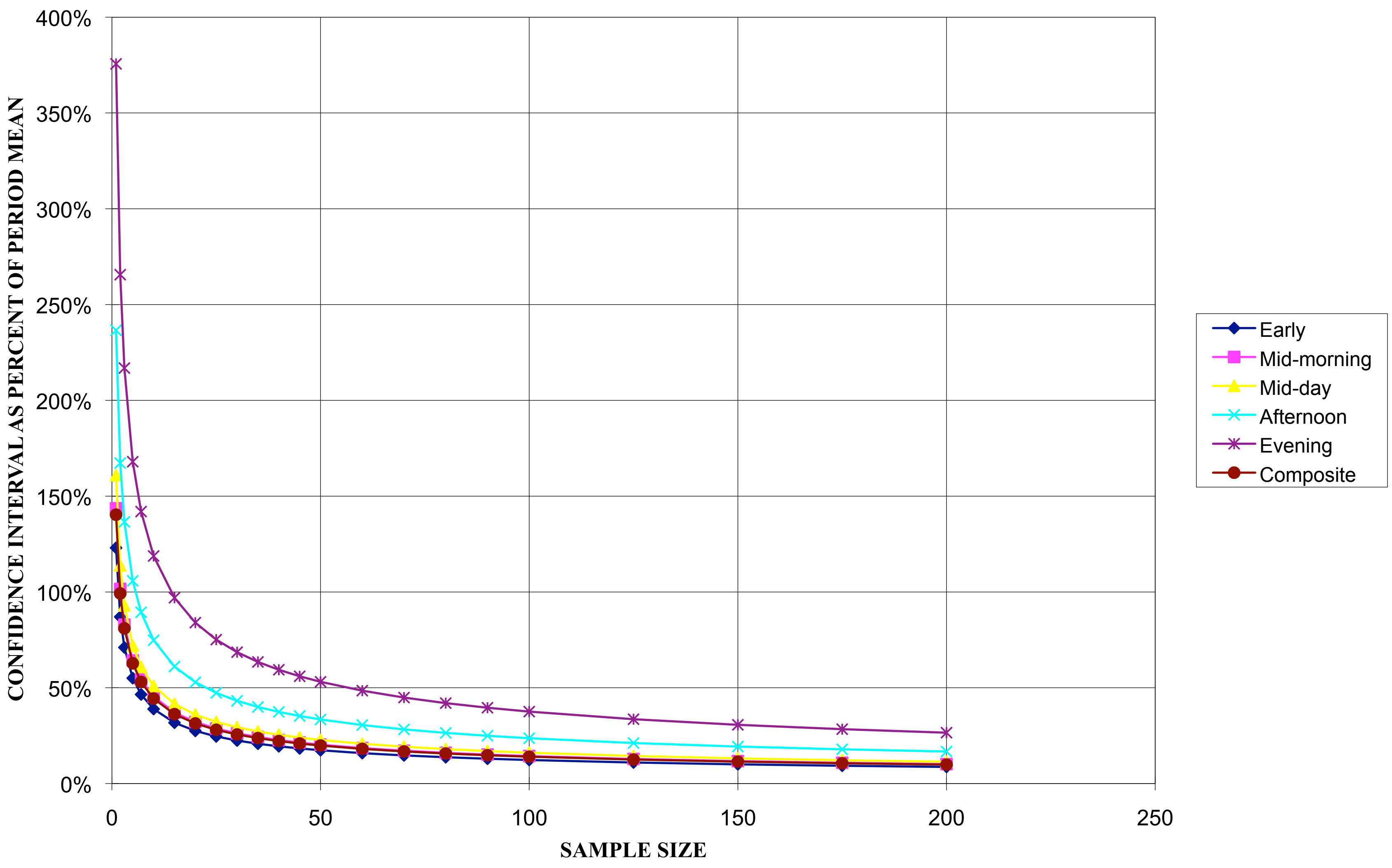


Table. Diurnal variation in eulachon larval density in the Kitimat River (May 15 to June 15), and the effect on confidence interval.

Time Period	Start Time	End Time	Duration (H)	Average	Larvae Hours	% of Total Larvae Hours	S.D.	n	C.I.	C.I. as % of average
Early	5:00	8:00	3.00	10.34	31.01	64%	6.49	11	3.83	37%
Mid-morning	8:00	10:30	2.50	3.43	8.58	18%	2.52	12	1.42	41%
Mid-day	10:30	15:00	4.50	1.41	6.33	13%	1.16	10	0.72	51%
Afternoon	15:00	18:00	3.00	0.21	0.62	1%	0.25	13	0.14	66%
Evening	18:00	23:00	5.00	0.45	2.27	5%	0.87	15	0.44	97%

Table. Weekly variation in eulachon larval density in the Kitimat River (May 15 to June 15), and the on confidence interval.

Week	Average	S.D.	n	C.I.	C.I. as % of average
Mid-morning					
22	3.43	2.52	12	1.42	41%
26	10.55	8.14	6	6.51	62%
28	3.07	3.77	4	3.70	120%
Mid-day					
16	0.02	0.03	6	0.02	129%
18	0.01	0.02	2	0.02	196%
20	0.50	0.33	4	0.33	66%
22	3.31	3.23	6	2.58	78%
23	1.13	1.13	6	0.90	80%
24	5.53	2.24	3	2.54	46%
25	0.56	0.36	6	0.29	52%
27	0.96	0.17	3	0.19	20%
29	1.83	1.31	6	1.05	57%

Distribution of sampling effort and catch during eulachon larvae program on the Kitimat River during 1995.

Lack of sampling effort in this period reduces our confidence in the estimate beyond that calculated statisticallyl with the data. We are forced to assume that early morning and evening density was constant thorughout the migration.