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Eulachon (Thaleichthys pacificus) studies related to Lower Columbia River channel deepening operations.

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INTRODUCTION

The anadromous eulachon, *Thaleichthys pacificus,* is a smelt of the Pacific coast of North America, found from the Pribilof Islands (Bering Sea) to the Klamath River in California (Wydoski and Whitney 1979). Within this range spawning occurs in approximately 70 rivers, all of which experience pronounced spring freshets. In the Lower Columbia Basin major spawning runs occur in the Columbia mainstem and Cowlitz River with smaller, periodic runs occurring in several other tributaries (Grays, Skamokawa, Elochoman, Kalama, Lewis, Sandy)(Figure 1). Adult migration usually begins in December, peaks in February and continues through May (Figure 2). Water temperature has a direct influence on migration with adults only entering freshwater when temperatures are between 4.4°C and 9.0°C (WDFW 2000). Peak spawning time varies among rivers – February in the Columbia and March in most British Columbia rivers except the Fraser where it occurs in April/May.

Eulachon spawn at 3 – 5 years of age and then die; though there is some evidence to suggest some individuals survive and return to the sea (Hart 1973). Adults deposit eggs in areas where the substrate consists of coarse sand/fine gravel, and where water flows are “moderate” in velocity (Hart and McHugh 1944; Smith and Saalfeld, 1955). Eggs are spherical, approximately 1 mm in diameter and at maturity have a double membrane that, upon fertilization, peels back to form an adhesive peduncle (Hart and McHugh 1944). Eggs adhere to the surface of the substrate and incubate over a period of about 30-40 days, depending on temperature. Upon hatching the larvae become part of the drift as (presumably) passive plankters and are rapidly transported out to sea (Hart and McHugh, 1944; Hart 1973) where they rear in near-shore marine areas at moderate to shallow depths (Barraclough 1964). Larval distribution in the water column during out migration is not known though Smith and Saalfield (1955) reported catches of larvae in intermediate and deep-water plankton net hauls conducted in the springs of 1946 and 1947 at various locations downstream from the Cowlitz River.

The largest eulachon runs are found in the Columbia, Fraser and Nass rivers and are associated with historically important commercial and sport fisheries. Annual returns, based on commercial landings, were relatively stable until 1994 when a sharp decline occurred simultaneously in these rivers - a trend that continued through 1999 (Figure 2). Although the 2000 run was apparently stronger in the Lower Columbia its relative magnitude is difficult to quantify as restrictive fishery management strategies imposed in response to the recent decline in returns severely reduced commercial effort. Test fisheries also proved inadequate for assessing run size. The lack of developed methods for determining eulachon stock status led the National Marine Fisheries Service (NMFS) to reject a recent petition to list eulachon as threatened under the Endangered Species Act (EPA 1999).

The low returns of the 1990s followed by a relatively strong run in 2000 correlates well with a return of favorable marine conditions after the disappearance of the severe El Niño climatic patterns of the past decade. However, mechanisms controlling eulachon recruitment and survival are poorly understood. Conditions in the freshwater environment, where eulachon spawn, may also influence productivity. Musick et al (2000) maintain the Columbia River eulachon should be listed as a threatened distinct population segment and cite anthropogenic disturbance in freshwater habitats as risk factors contributing to the recent decline. Critical physical habitat for spawning eulachon has only been generally described and there is little understanding as to how variation in habitat conditions affects spawning and egg survival.

Of particular concern is the impact of dredging such as the U.S. Army Corps of Engineers (USACE) proposed channel-deepening operations on Columbia River (USACE 1999). Dredging activity has the potential to impact eulachon spawning areas (through smothering of developing eggs by increased turbidity and suspended sediment in the vicinity of operations) as well as to entrain developing eggs and larvae.

The goal of the study is to minimize impacts of channel deepening operations on eulachon eggs and larvae. Objectives structured to reach this goal are 1) to determine the presence or absence of egg deposition and larval migrants within proposed channel deepening areas, and 2) use information acquired to schedule channel deepening so that impacts to smelt are minimized.

METHODS AND MATERIALS

Field Methods

Field sampling methods consisted of: 1) using plankton nets to collect eggs and larvae and 2) using a grab sampler and artificial substrates to collect eggs.

Plankton Net Sampling

Sampling took place from March 7 through May 26, 2000. Staff of Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) used plankton nets deployed from stationary vessels to capture eulachon larvae and eggs in the Columbia River, between river miles 30 and 85 (Figure 1). The plankton net was a non-closeable, tapered nylon sock with a length of 335cm and mesh size of 300 µm. A stainless steel circular frame measuring 61cm (diameter) with a cross bar and towing eye was attached to the mouth of the net. A 7.9 cm, two piece, sample collection cup was attached at the base of the net. Water flow was measured by a General Oceanics mechanical flow meter, which was attached inside the frame at the mouth of the net. Vessels were equipped with a hydraulic hauler and davit arm system for net retrieval. Spherical lead weights (2.54 kg, 9.07 kg or both) were attached to the frame base.

The study area was divided into 55 sections (corresponding to Columbia River Miles (CRM) 30 to 85) and sampling was conducted in every section that contained a proposed dredging area (as defined on maps in the USACE environmental impact statement; USACE 1999). Approximately 20 sections (of a potential 46) were sampled each week.

We attempted to distribute weekly effort throughout the reach. (Table 1). Each section was sampled such that the whole reach was fully sampled four times during the three-month season. No attempt was made to sample in the exact same location within a section on successive visits.

Sampling within each section consisted of choosing two-sample points along an approximate cross-river transect - one inside and one outside (but in close proximity to) the dredge areas. At each point, samples were taken from both bottom and mid-water depths. Sampling was conducted during daylight hours on ebb tides. Vessels were anchored in the current at each site. Differential Global Positioning System coordinates, water temperature, depth and turbidity readings were recorded. The plankton nets were lowered to the desired depth and a start time was recorded. Nets were fished for sixty seconds and then immediately retrieved. Stop time was taken to be the moment the flow meter emerged from the water. Contents of the collection cup were rinsed into storage jars with a dilute solution of ethyl alcohol.

To provide information on inter-annual variation in run-size and timing further sampling was conducted in the vicinities of Clifton Channel (CRM 35) and Price Island (CRM 34) – larval index sites monitored by WDFW since 1994 (WDFW 2000). Each index site consisted of a cross-river transect containing three sampling points. Each sampling point consisted of three net sets – bottom, mid-water, and surface. Each site was sampled a total of 6 times over the sampling period (approximately once every two weeks.)

Artificial Substrates

Artificial substrates have been successfully employed to describe spawning areas for white sturgeon, *Acipenser transmontanus,* in the Columbia River (McCabe 1990). The eggs of the white sturgeon are similar to those of the eulachon in that they are demersal and adhesive. Consequently an attempt was made to utilize this gear for identification of mainstem eulachon spawning. The advantage of artificial substrates over plankton nets is that they can be fished for extended periods, thereby increasing the chance of detecting spawning in an area. Several artificial substrates were fabricated according to specifications outlined by McCabe (1990). In addition to the cited "latex covered animal hair" collection material, various types of carpeting were also experimentally deployed. Unfortunately, deployment of substrates at historic index sites (where eggs/larvae had previously been captured with plankton nets) was unsuccessful due to high sedimentation rates on ebb tides – substrates were found inundated with sand after short periods of fishing (a few hours at most). No eggs were found adhered to any of the substrates. Sampling with this gear type was subsequently abandoned.

Ponar Grab Sampler

Sampling with this gear was curtailed after the loss of the grab sampler early in the study.

Laboratory Methods

Laboratory analysis consisted of: 1) egg and larvae counts for each sample and 2) assessment of larval development from random sub-samples.

Larvae and Egg Counts

Preliminary attempts at sample counts of larvae and eggs proved time consuming. Given the large number of samples taken and limited time available, we decided to employ a representative sub-sampling methodology for stratified samples. Index site samples were counted in total.

Representative sub-sampling was performed as follows: Samples were emptied into an Erlenmeyer flask and total sample volume was recorded. In order to thoroughly mix the sample the flask was swirled to produce a random mixing of its contents. Approximately 20% of the total sample volume was poured off in to a graduated cylinder. This sub-sample was in turn poured in to a Petrie dish and counts of any larvae or eggs present were made with the aid of a stereomicroscope. Larvae and eggs present in the sub-sample were retained separately from the main sample for subsequent larval development analysis. Total sample counts were extrapolated based on the volume of subsamples.

Larval Development

Every fifth sub-sample was randomly chosen to characterize stages of larval development. Chosen samples were mixed and poured into a Petrie dish. The larvae in one pre-selected quadrant were then examined and characterized by developmental stage.

Three characteristics of eulachon larvae assumed to be related to development were examined: yolk-sac depletion, pigmentation, and length. Yolk-sac depletion and pigmentation were described qualitatively while length was described quantitatively. Developmental criteria were as follows:

Yolk sac

Full. A yolk sac without transparencies that would indicate no utilization of nutrients (i.e. a recently hatched larva).

Partially depleted. A yolk sac with some transparency indicating some degree of nutrient utilization.

Empty. An empty yolk sac.

Absorbed. The yolk sac is no longer apparent. Digestive tract may be visible.

Non-Existent Larvae damaged/decomposed. No description of yolk sac was possible.

Pigmentation.

Characterized as present or absent on the yolk sac and/or the body.

Length.

Total length of larvae was measured to the nearest millimeter.

Data Analysis

We calculated the total volume of water sampled for each set from the General Oceanics flow-meter algorithm:

$$\text{Volume Sampled } (\mathrm{m}^3) = \left(\frac{\pi \mathrm{d}^2}{4}\right)\left(\frac{R.\delta C}{999999}\right)$$

where d = diameter of net,

δC = start count – stop count,

R = Rotor Constant (26,873).

Catch rate for larvae and eggs was then estimated as catch per cubic meter in each sample.

We examined the catch frequency of eggs and larvae to describe the form of the catch distribution and tested for significant differences ($p \leq 0.05$) in larval catch rate between depth strata and between channel strata using non-parametric statistical analyses (Kruskall-Wallace ANOVA).

Mean catch rates and frequency distribution characteristics for larvae amongst both sampling weeks and five-mile river increments were evaluated. Mean larvae and egg catch rates were also calculated for depth and channel strata by week and river mile increments. These data were also examined by analyzing the proportion of sets in which one or more larvae were captured (Proportion of Positive Tows – PPT; Bannerot and Austin 1983, Counihan and Miller 1999) and tested for significant differences ($p \leq 0.05$) using Chi-square analysis (SAS 1990).

RESULTS

A total of 716 samples were taken as part of the stratified sampling. Water depths averaged 15.6 m for “inside channel” and 10 m for “outside channel” sites.

Catch frequency distributions were highly skewed, exhibiting properties of a negative binomial distribution (Figure 4). Attempts to normalize the error terms by transforming as *log (catch rate + 1)* failed with data remaining highly skewed. Consequently we considered that analysis of these data by parametric statistics was likely to be inappropriate. Instead we tested for significant differences ($p \leq 0.05$) in larval catch rate between depth strata and between channel strata using a Kruskall-Wallace test.

Nonparametric analyses showed that mean larval catch rates were not significantly different between depth or channel strata (Figure 5). Chi-square analysis of PPT data revealed no significant differences among strata. Figures 6 and 7 summarize catch characteristics by week and river mile increment.

Average catch rates for larvae declined from March – May (Figure 8a) and were variable among river mile increments (Figure 9a). Highest catches were observed downstream of the Cowlitz R. (CRM 68) and Eagle Cliff (CRM 50). Figures 8b and 9b show how PPT data reflect these trends.

108 samples were taken from the Price Island and Clifton Channel index sites over the course of the sampling period. Mean catch rates were seen to decline over time (Figure 10) consistent with data obtained from stratified sampling.

Of the three characteristics we postulated could be used as descriptors of larval development only yolk sac stage was determined to be a useful indicator of larval age. Neither pigmentation nor length measurements displayed sufficient variability to be of use.

Figure 11a shows the geographic distribution of full yolk sac larvae expressed as a percentage of all larvae collected in each area. Figure 11b compares mean egg catches by river mile.

DISCUSSION

Stratified Sampling

Plankton nets efficiently captured migrating smelt larvae and established their distribution within and outside proposed channel deepening areas. Gross spatial and temporal trends were observed. The late initiation of this years field sampling probably resulted in missing the peak of larval outmigration and our data likely describe the descending limb of the outmigration curve. The highest catch rates were observed in close proximity to previously documented spawning sites - the Cowlitz River and Eagle Cliff (Figure 9a).

Although out of channel samples did show a slightly higher average catch rate (Figure 5), we did not observe statistically significant differences in abundance between sampling strata. Comparisons of catch rate between depth strata were suspect since plankton nets were not closeable, and therefore continued to fish while being retrieved (Table 2).

Closeable plankton nets would be required to ascertain whether distribution is depth related.

The lack of statistically significant differences between channel strata is puzzling given the apparent heterogeneous distribution of larvae in several areas of the river (Figure 7). Intuitively, such differences would be expected in areas in close downstream proximity to spawning areas where cross-river dispersion of the larval "plume" is limited. The dichotomy probably arises from the nature of sampling design. In the design, the location and spatial relationship of paired sample points within a sampling section was randomly selected on each subsequent visit (e.g. the "out channel" site could be taken either side of the "in channel" site). Any area that was, in reality, heterogeneous in its larval distribution would not show a statistically significant relationship between channel strata because of the high variance in out-channel catch rates.

Further work is required to estimate the relative importance of the channel to migrating smelt larvae in various areas of the river. Reducing the number of sites sampled and increasing the intensity of sampling at each site could achieve this. Reduction in the number of sampling sites may also allow sampling to be conducted across diel and tidal cycles in order to identify related changes in the spatial distribution of larvae.

Spawning Site Location

Recently emerged larvae should be indicative of spawning distribution. If larvae with full yolk sacs are assumed recently emerged, and collections of them are clustered geographically it is likely that these areas are in close proximity to spawning areas. The results of the larval development analysis (Figure 11a) appear to show some clustering but we are not confident that our sample size was large enough to identify spawning areas. For example, it is notable that our results do not show high proportions of full yolk sac larvae in close proximity to the mouth of the Cowlitz R. (CRM 67) or Eagle Cliff (CRM 50) – known sites of spawning. This method might be more successfully employed in FY2001 if we could validate the timing of larval developmental stages and refine our knowledge of the development process. This could be achieved by rearing eggs and larvae. Knowledge of the time required to reach certain developmental stages at various temperatures will allow us to estimate the ages of larvae collected, and therefore aid in determining time and locating of spawning.

Increased catch rates of eggs might also indicate the close proximity of spawning areas. Plankton nets caught eggs in the majority of river miles below the confluence of the Cowlitz River (figure 11b). No strong clustering patterns are apparent but CRM 67 (mouth of Cowlitz R.) and CRM 52 (Eagle Cliff area) show higher catch rates indicating proximal spawning areas. Sampling with the artificial substrates and grab sampler was limited but will be attempted again next year by developing a systematic egg sampling protocol to be implemented when catches in plankton nets indicate nearby spawning areas. If egg deposition areas are located, we will characterize the associated physical habitat.

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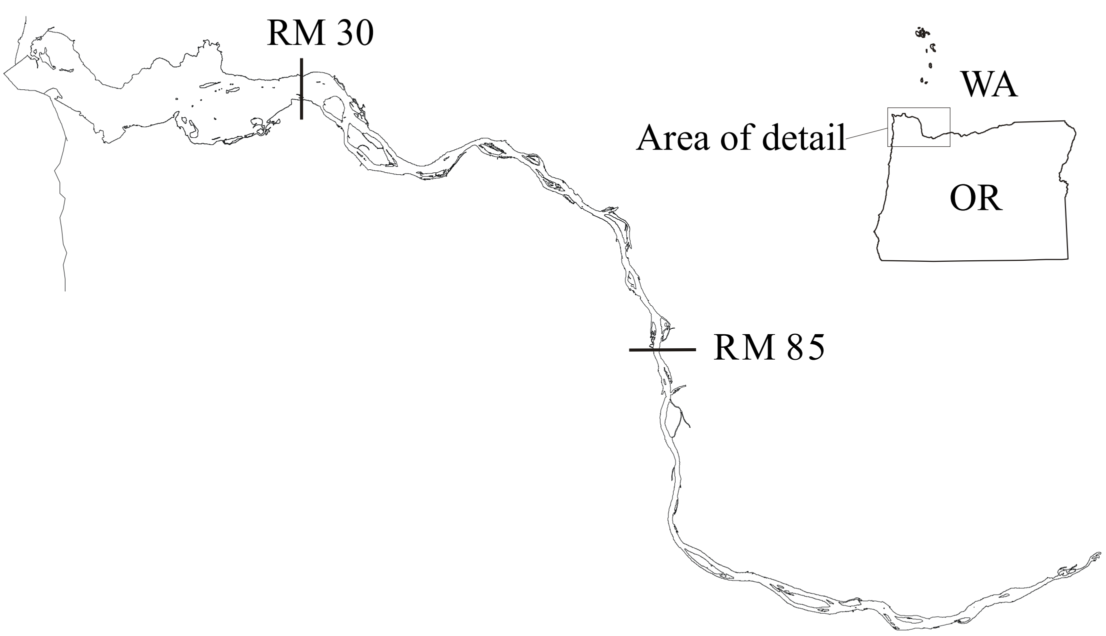


Figure 1. Lower Columbia River smelt study area extends from river mile (RM) 30 to 85.

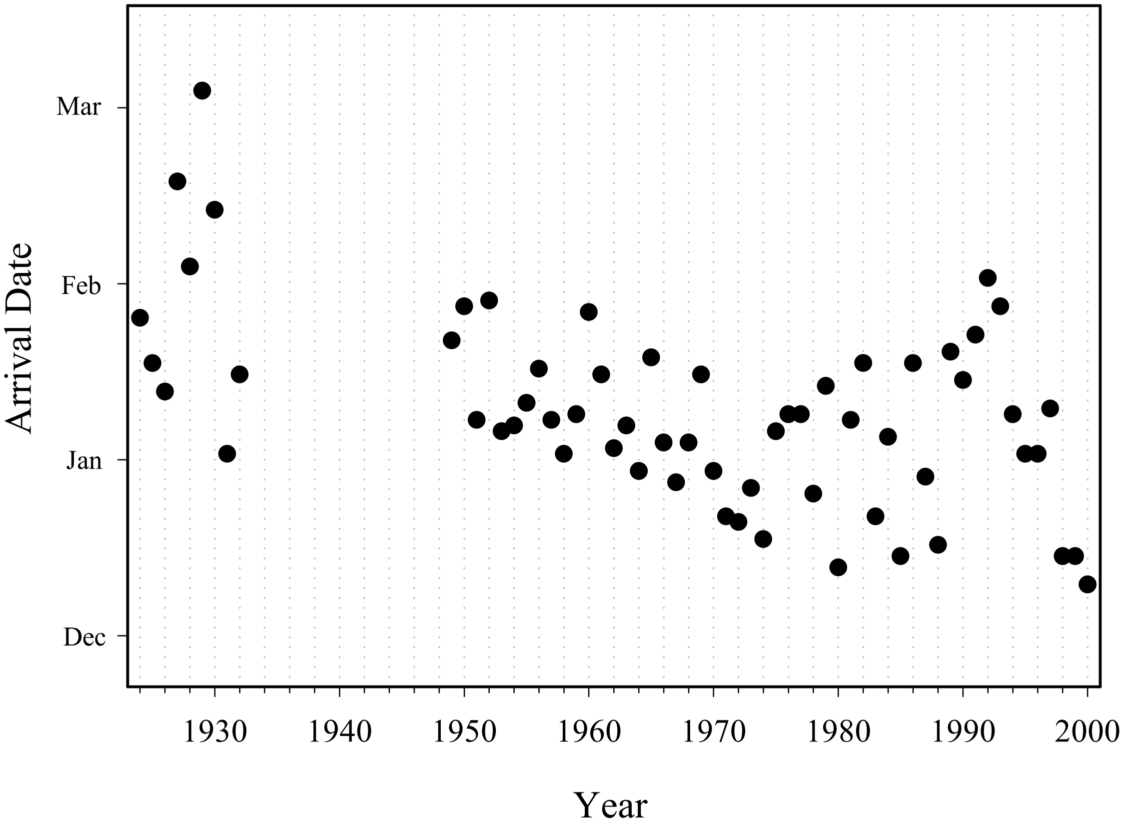


Figure 2. Eulachon arrivals in the Columbia River 1934-2000 based on commercial landings.

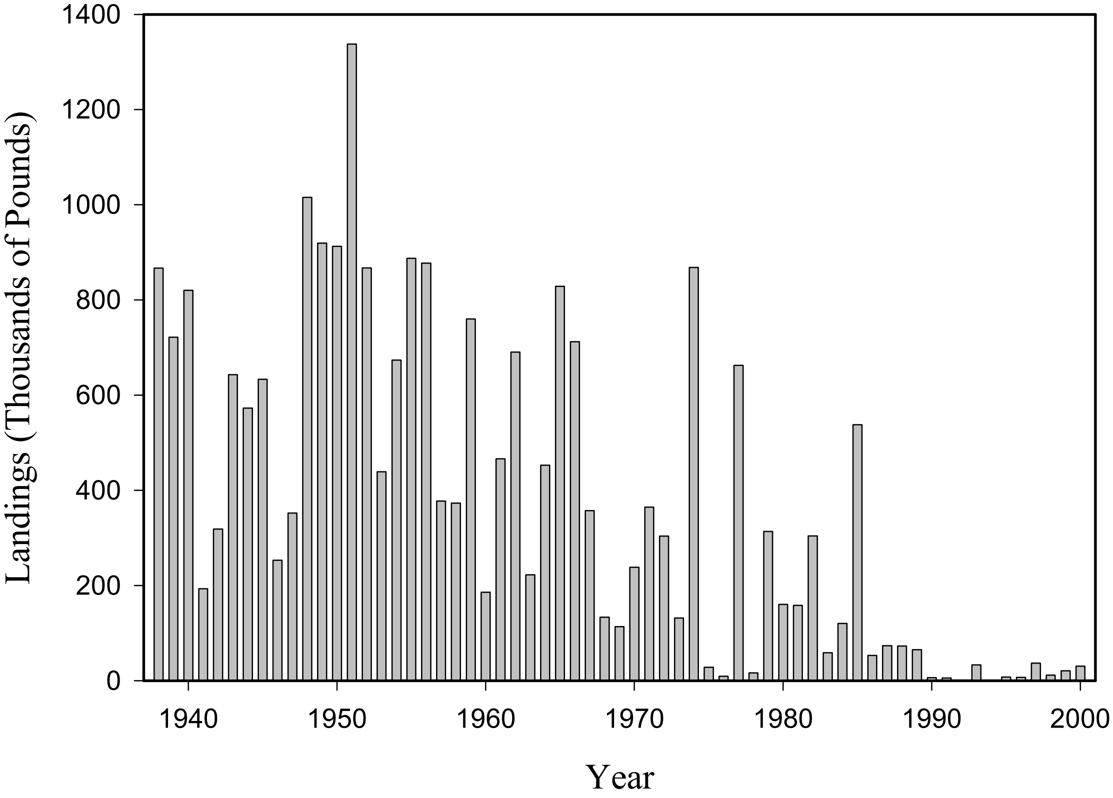


Figure 3. Eulachon landings in Columbia River commercial fisheries, 1938-2000.

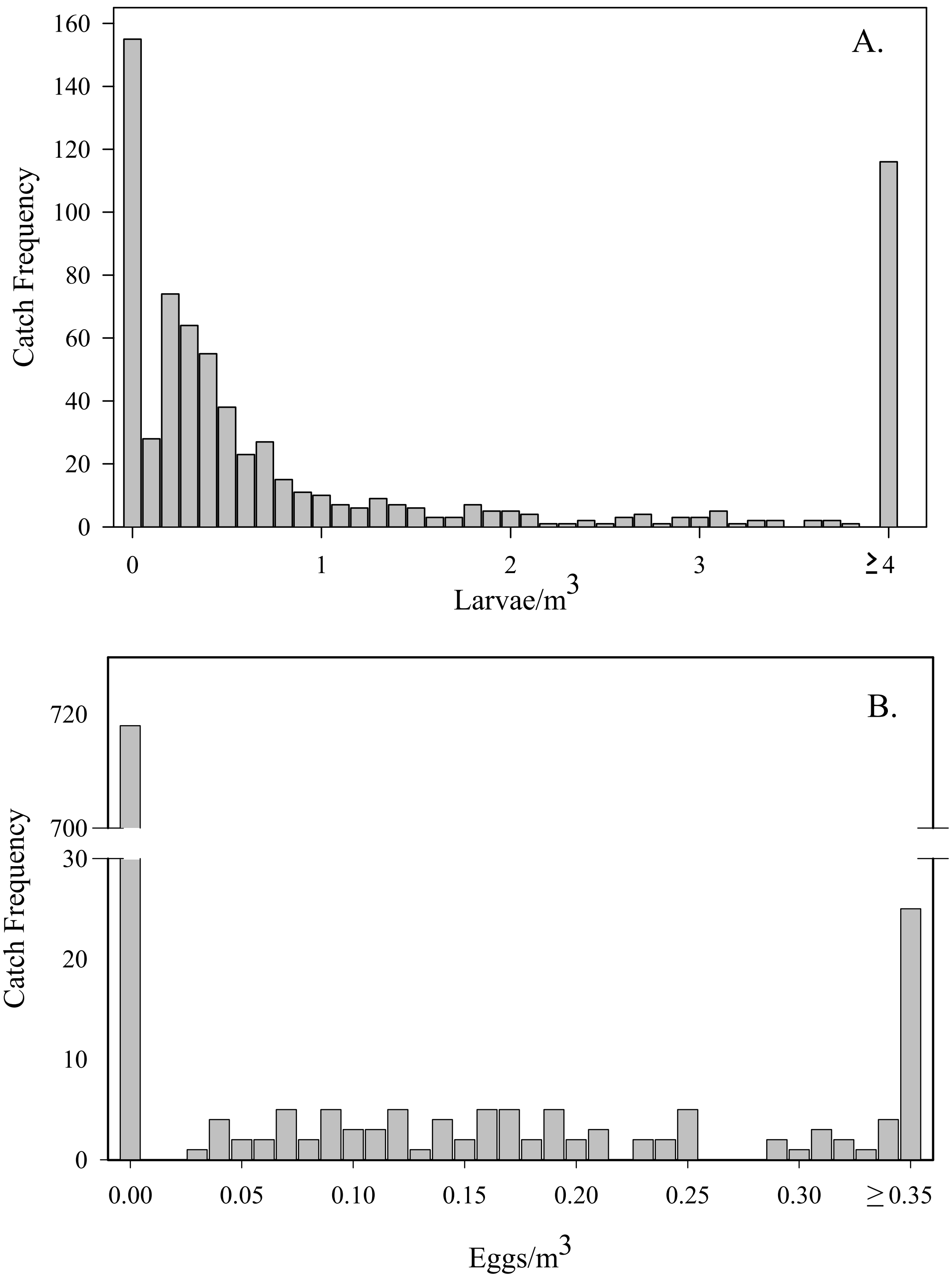


Figure 4. Catch frequencies of eulachon larvae and eggs.

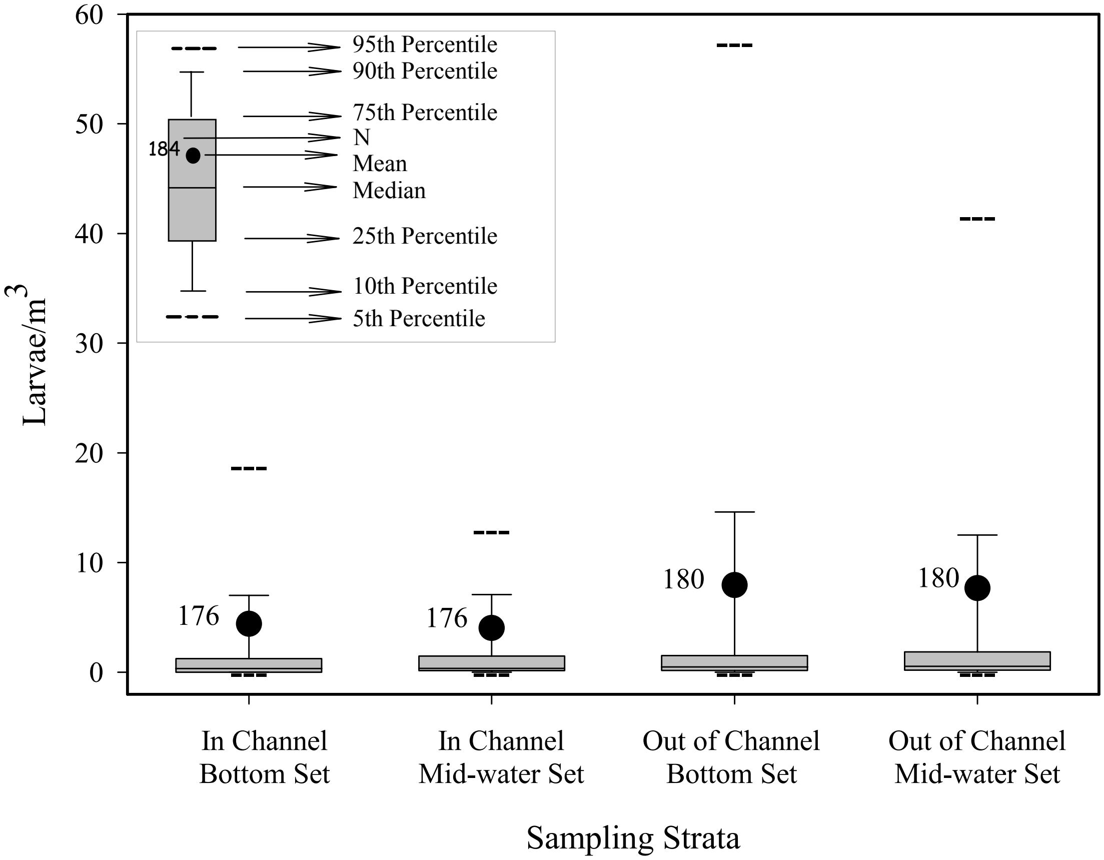


Figure 5. Characteristics of larval catches by sampling strata.

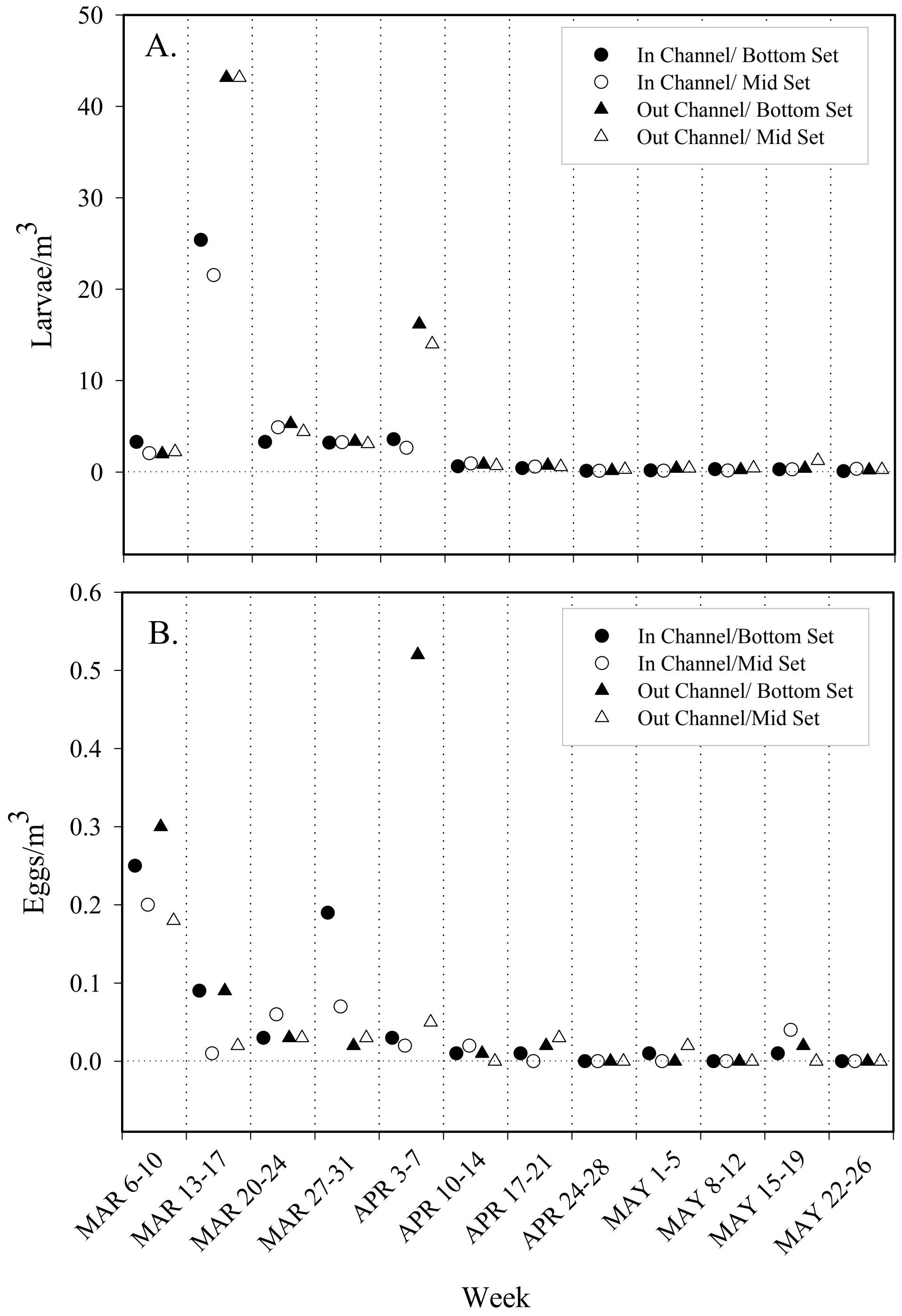


Figure 6. Mean stratal catches of eulachon larvae and eggs by week.

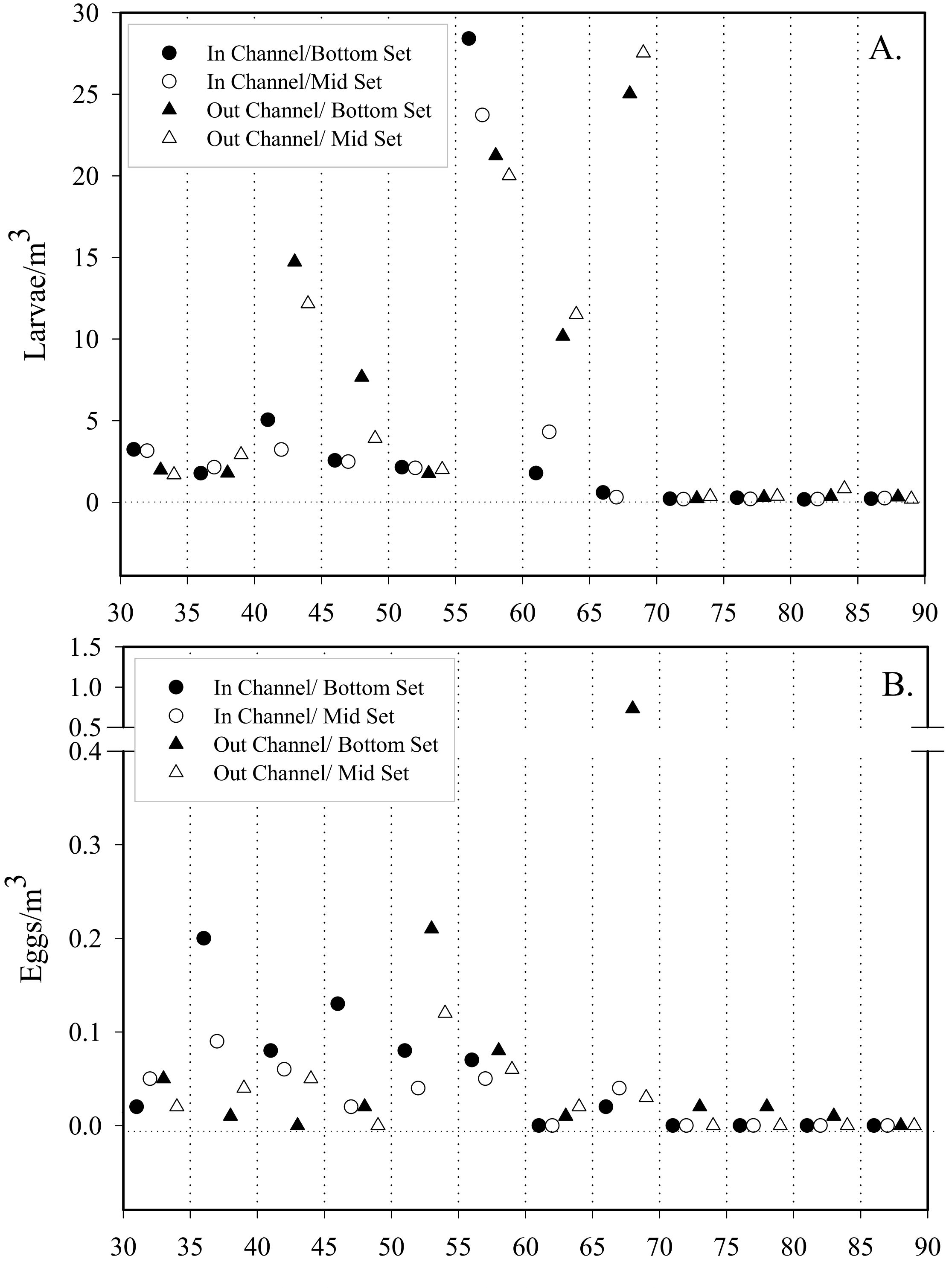


Figure 7. Mean stratal catches of eulachon larvae and eggs by river mile increment.

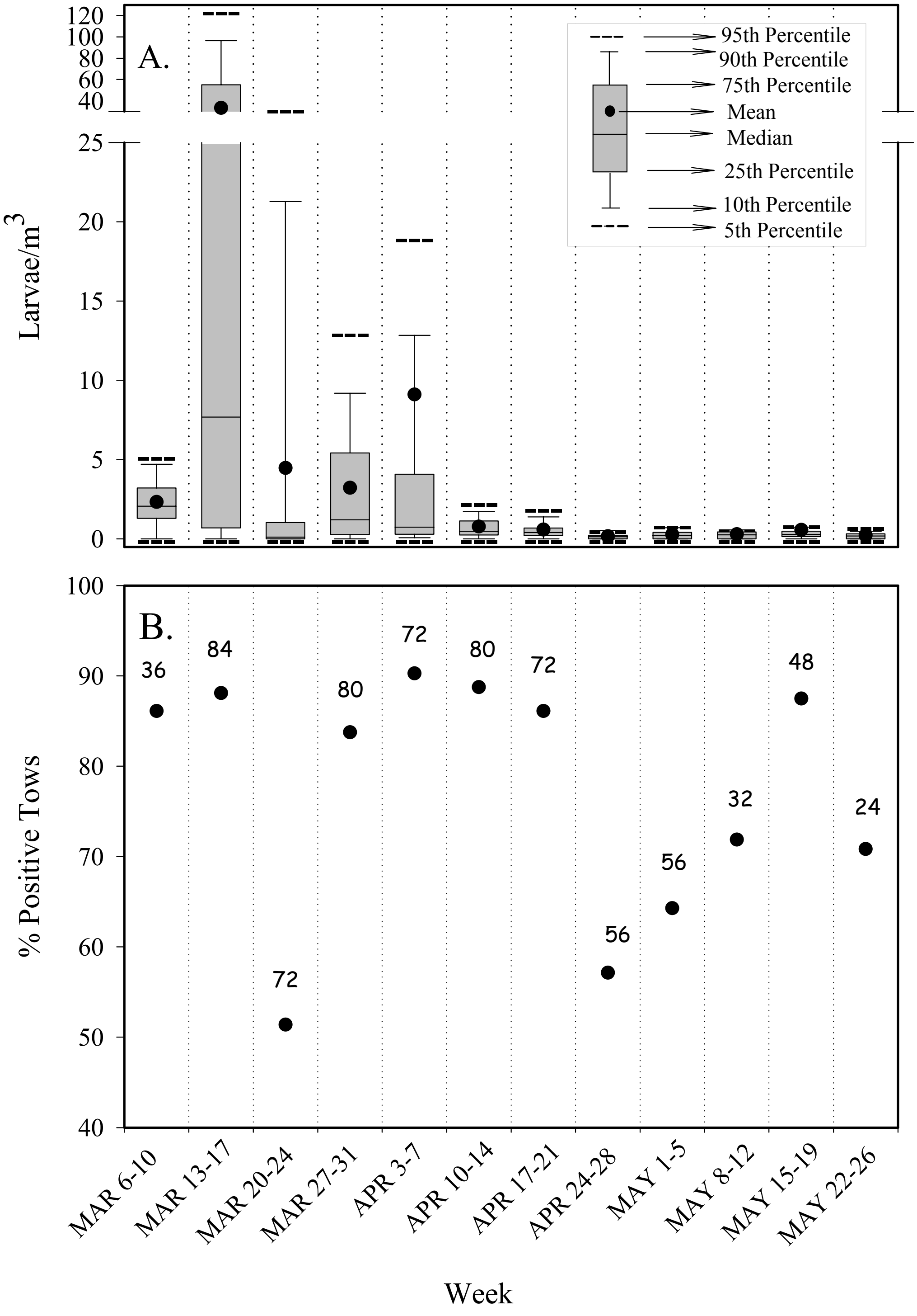


Figure 8. Larval catch by week.

A. Catch characteristics.

B. Proportion of samples containing at least one larva. Numbers associated with each data point denote sample size.

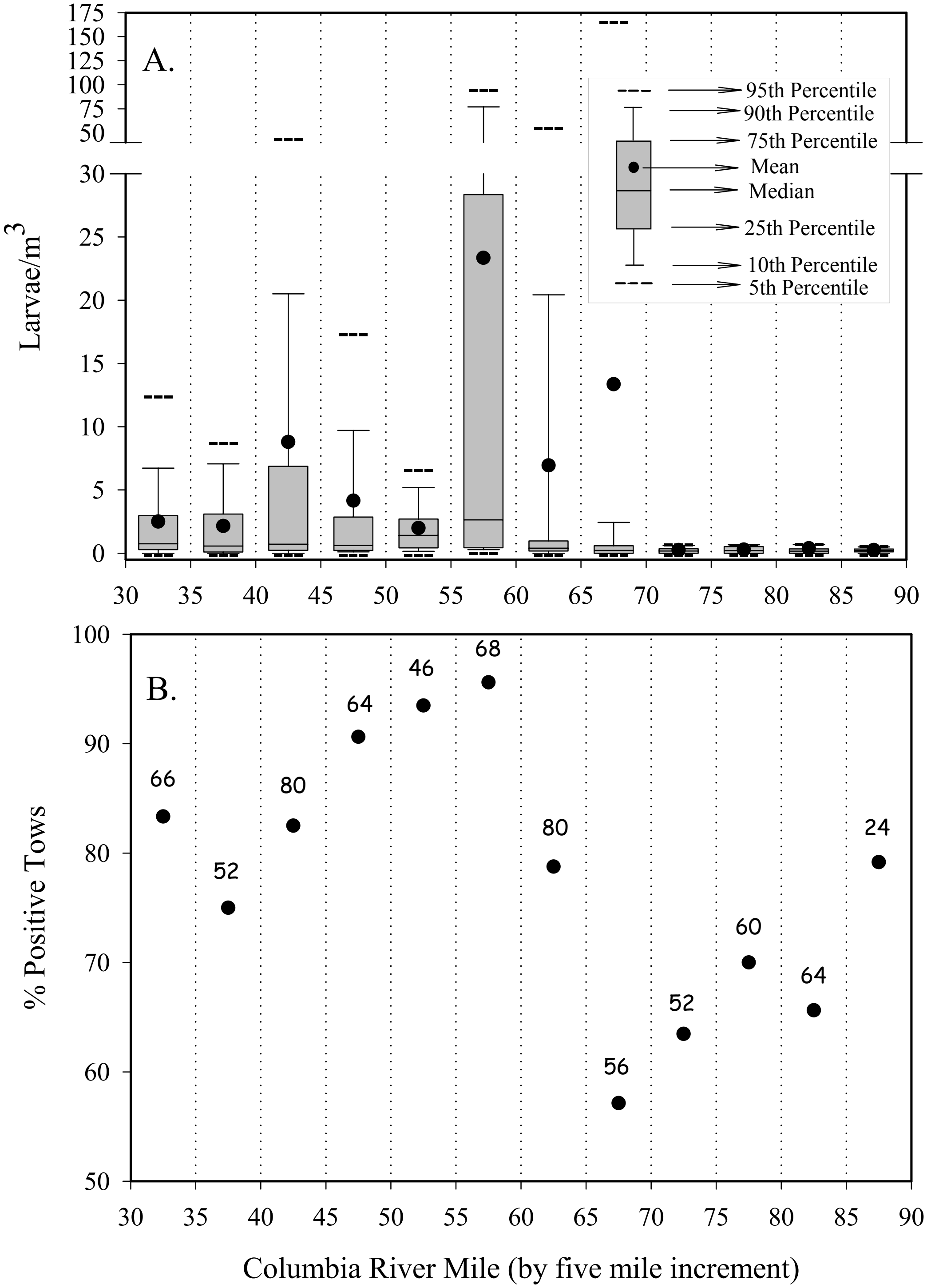


Figure 9. Larval catch by five mile river increment.
A. Catch characteristics.
B. Proportion of samples containing at least one larva. Numbers associated with each data point denote sample size.

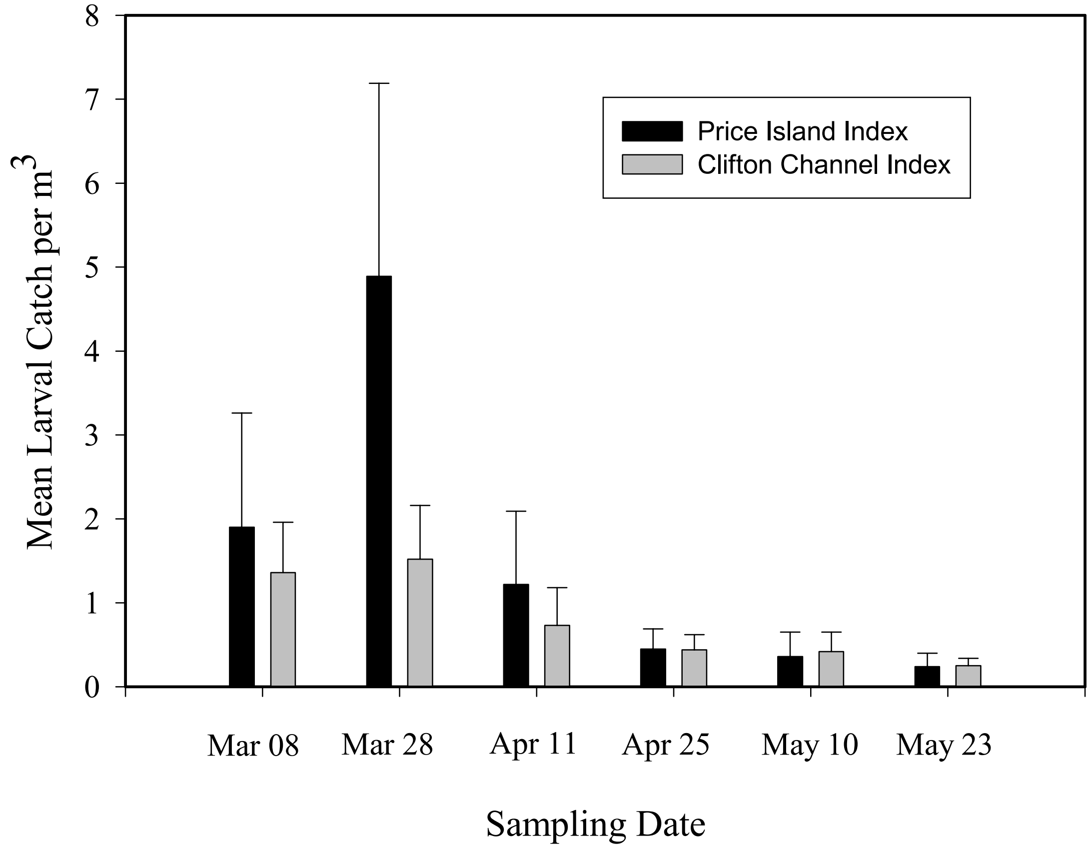
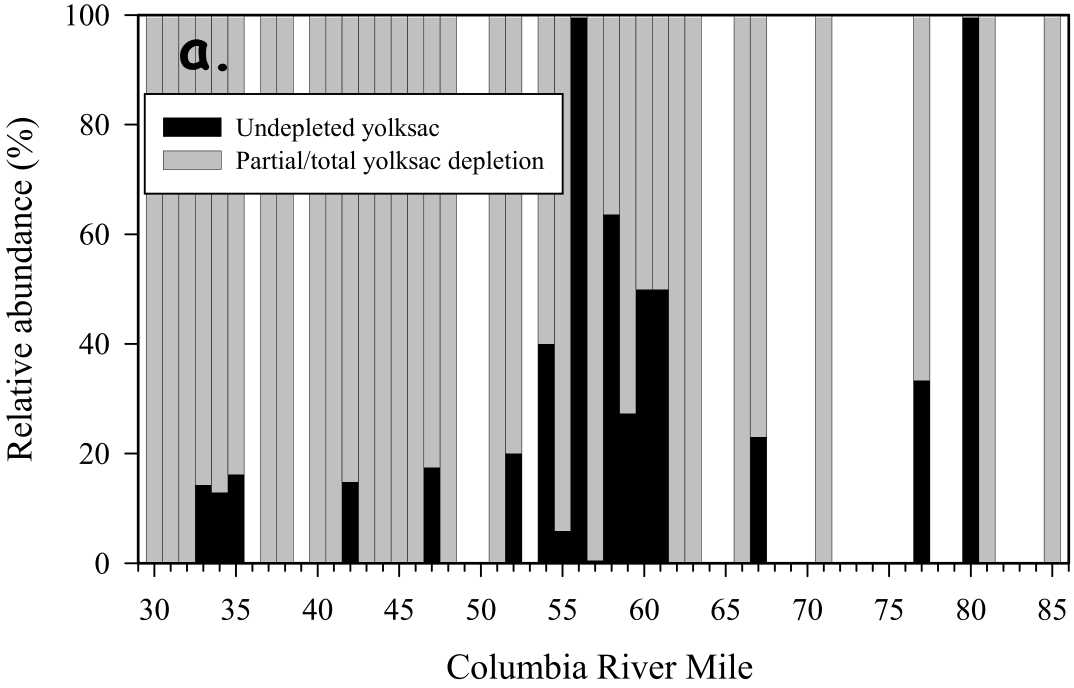


Figure 10. Mean catch rates of larval eulachon at Price Island and Clifton Channel Index sites during spring 2000 field sampling. Each bar represents 9 samples. Error bars are 1 standard deviation.



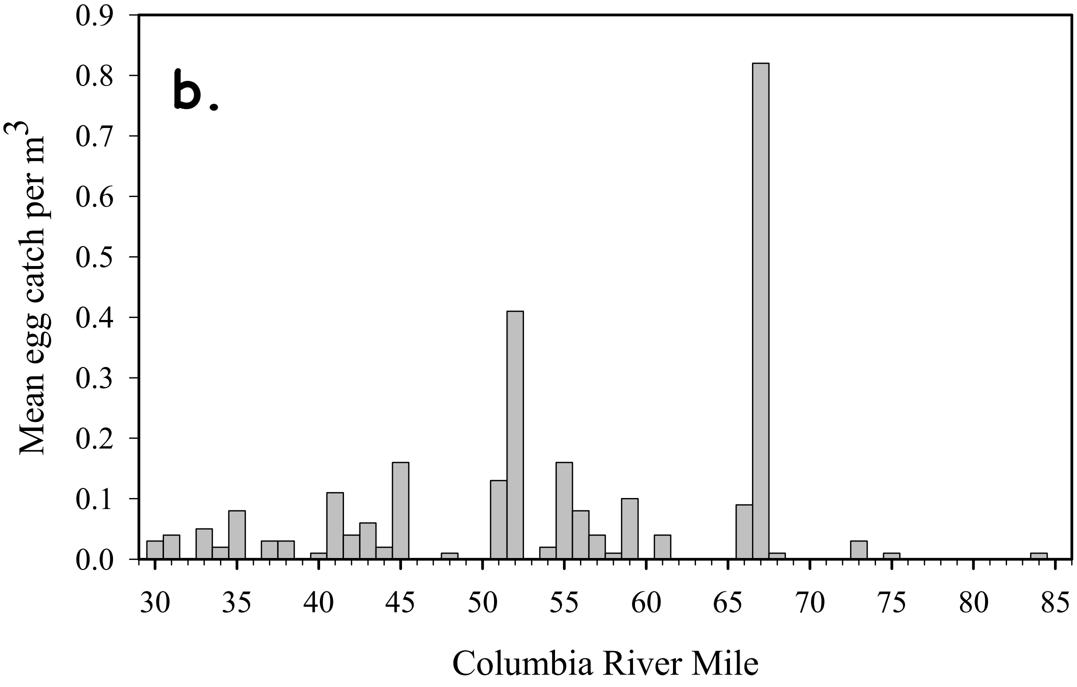


Figure 11. Comparison of relative abundance of newly hatched larvae (a) with egg catches throughout the study area (b).