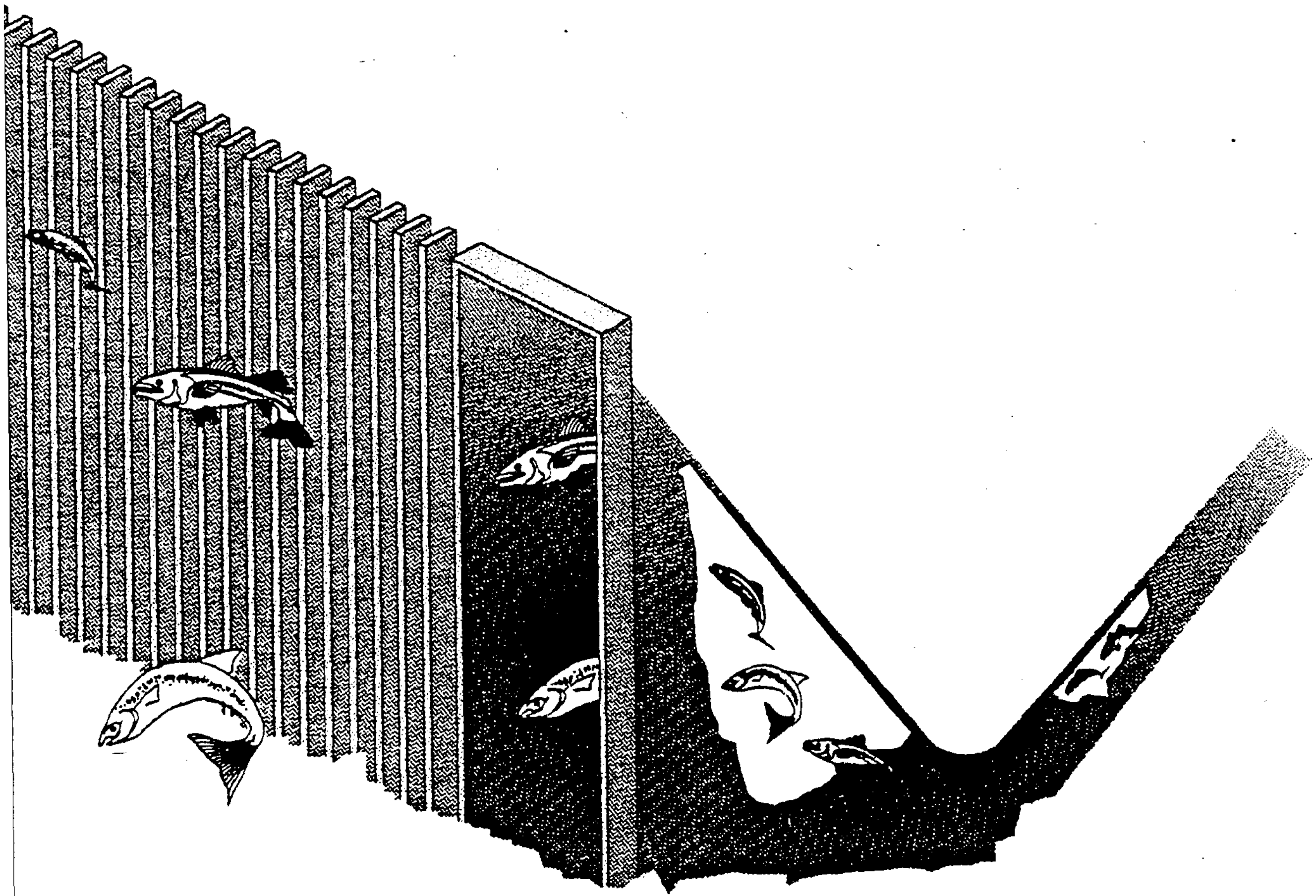

TRACY FISH COLLECTION FACILITY STUDIES

CALIFORNIA

Volume 2

Continuous Monitoring of Fish Eggs and Larvae

1991 - 1992

United States Department of the Interior
Bureau of Reclamation
Mid - Pacific Region and Denver Office

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Continuous Monitoring of Fish Eggs and Larvae During 1991 and 1992

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TRACY FISH COLLECTION FACILITY STUDIES
CALIFORNIA, VOLUME 2

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
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AND
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PREFACE

The central valley of California contains two major drainages, the Sacramento River system to the north and the San Joaquin River system to the south. These systems converge in central California (Delta) and flow westward through San Francisco Bay to the Pacific Ocean. The Central Valley Project (CVP) was authorized in the mid-1930's to regulate these river systems and the Delta to provide water for irrigation. Additional purposes now include flood control, domestic and industrial water sources, power generation, improved Sacramento River navigation, conservation of fish and wildlife, recreation opportunities, and enhanced water quality.

The CVP was developed over several decades and includes nine divisions. The Delta Division (completed in the mid-1950's) transports water through the central portion of the valley and includes the Tracy Pumping Plant (TPP), the Tracy Fish Collection Facility (TFCF), and the Delta-Mendota Canal (DMC) system. Water is drawn in from the Old River channel by the TPP and passes through TFCF en route to being lifted into the DMC.

The TFCF is located at the head of the intake channel connecting the Old River channel with the pumping plant and the DMC. The multilouver facility was designed and built in the 1950's to divert young fish, particularly young chinook salmon and striped bass, from the flow before it is lifted into the DMC, and to return the salvaged fish to the Delta. Although the TFCF annually salvages about 2 to 14 million fish, recent evaluations have concluded that TFCF is not salvaging fish at the efficiencies originally designed and expected. This is particularly true during periods of low tides and high irrigation demands. Other problems include fish predation within the facility; inability to maintain preferred primary and secondary channel velocities and bypass ratios; outdated water measuring devices; high velocities and debris in holding tanks; frequency of fish hauls; louver cleaning operations; predation at stocking sites; and, inability to separate fish by species or size prior to transport and stocking activities (Liston et al., 1993). Problems are compounded by the recent increased concern for native species, and the listing of two species as endangered or threatened (i.e., Delta smelt and "winter-run" chinook salmon). Two other species, the Sacramento splittail and longfin smelt, have been proposed for listing. Recent concerns over egg and larval fish losses from the Delta further complicate TFCF considerations.

An agreement between the Bureau of Reclamation (Reclamation) and California Department of Fish and Game concerning the modification and improvement of TFCF to reduce and offset direct fish losses was executed July 17, 1992, following negotiations that had begun in the late 1980's. In association with these negotiations and agreement, an aggressive program was initiated to implement studies and improvements intended to assist present salvage efforts as well as provide for future recommendations for long-term solutions. These studies are addressing all the TFCF concerns listed above.

Although earlier reports on the present TFCF evaluation program have been prepared and distributed (Kubitschek and Johnson, 1993 and Liston et al., 1992 and 1993), the present report is the second volume of a larger series being developed by Reclamation's Research and Laboratory Services Division, Denver Office. Each report will contain the primary title "Tracy Fish Collection Facility Studies, California," but each will be identified further by a subtitle. Volume 1 focused on predator removal activities (Liston et al., 1994). The focus of volume 2 is on the design, operation, and results of continuous fish egg and larval collection equipment used during 1991 and 1992.

INTRODUCTION

The fish communities and ecological conditions of the San Francisco Bay Delta-Estuary have undergone dramatic changes over the past century (Stevens et al., 1985). The fishery has been affected by numerous events including introduced species and a growing human population with its consequent increased use of water. An Interagency Ecological Study Program was formed in 1970 to plan, coordinate, and execute environmental studies addressing the ecological changes within the Estuary associated with water development. Included in present studies is a monitoring program targeting several declining species of fish, among them the striped bass (*Morone saxatilis*) and, more recently, Delta smelt (Hypomesus transpacificus) and various salmon stocks.

Striped bass investigations have indicated strong relationships between declines in striped bass and water diversions from the Delta by State and Federal water project export facilities. Most scientists evaluating the fishery decline agree that larval striped bass survival could be enhanced if the larvae were transported, with sufficient outflow, through the Delta to nursery areas in Suisun Bay (Arthur et al., 1990). In 1989, the Reclamation's Mid-Pacific Regional Office and Denver Office began methodology development for monitoring densities of striped bass eggs and larvae continuously during the spring spawning period in the Sacramento River near Sacramento, California. It has been demonstrated that data from continuous monitoring of bass eggs and larvae passing a specific point above the estuary can be used to enact protective operational measures that help move the eggs and larvae out of the Delta, where they are subject to the water projects and some 1,800 unscreened diversions, downstream to suitable nursery sites. Reclamation continued to develop the continuous fish egg and larval sampler during spring 1990 at San Andreas Point, San Joaquin River (Hiebert and Liston, 1992).

Prior to Reclamation's egg and larval collecting, California Departments of Fish and Game and Water Resources had been cooperatively sampling eggs and larvae throughout the Delta with eight of the sample locations (i.e., South Delta Striped Bass-Egg and Larvae Sampling Stations) near the State and Federal Export Facilities. Surveys at these stations were conducted every other day from April to mid-July by making a 10-minute oblique tow with a 505-micron mesh net mounted on a towing frame with skids. Following enumeration of eggs and larvae in samples, entrainment of striped bass eggs and larvae were derived from daily export volumes at each facility. For days when no samples were taken, densities from the previous day were used to calculate entrainment. Entrainment estimates from large data gaps (2 days or more) used the estimate from the nearest sampling day and interpolation between sampling days. The routine egg and larvae surveys were made at about the same time of day and there had been some question as to whether taking one sample at each station was representative of actual egg and larvae densities.

In 1990 Reclamation's egg and larval monitoring was extended to include the TFCF on Old River near Byron, California (Hess et al., 1993). Because of the high variability (patchiness) of eggs and larvae, past practices of sampling every other day or less to determine entrainment upstream of the TFCF did not provide enough data on fish egg and larvae entrainment. A floating pump-based system was built to sample eggs and larvae with the idea that it lent itself to operation within the Delta's tidal changes and consequent fluctuating velocities and flow directions. With the design and installation of the continuous pump sampler, an improved relative abundance index and potentially more accurate estimates of numbers of organisms entrained over time can be determined. This report represents sampling results in 1991 and 1992 at the TFCF and the development of an improved fish egg and larvae monitoring device.

Striped Bass - Background

Striped bass were successfully introduced into the San Francisco Bay area in the late 1880's (Scofield, 1930) and supported a commercial fishery until the 1930's. Since the 1930's, the decreasing population has gained considerable attention. Significant declines were documented by California Department of Fish and Game (DFG) since the mid-1970's (Stevens et al., 1985). Striped bass spawning commences as water temperatures reach 58 °F, usually sometime in April, and typically continues through June at temperatures to about 69 °F (Moyle, 1976). Distinct spawning peaks can occur several times during the spawning season, possibly triggered by increasing water temperatures. Fertilized eggs develop into yolk sac larvae in 70 to 74 hours at 58 to 60 °F and in 48 hours at 64 to 67 °F. It takes about 50 to 60 days for the larvae to reach 1.5 inches. Early larvae are essentially planktonic and are largely distributed with water currents.

Delta Smelt - Background

Delta smelt monitoring studies conducted by DFG and the University of California, Davis, have shown a large population decline from about 2 million 20 years ago to an estimated 200,000 in 1990 (Moyle and Herbold, 1991; Stevens et al., 1990). Delta smelt has been listed as endangered and is protected under the Endangered Species Act. Diversions of freshwater from preferred estuarine habitat coupled with recent drought conditions and a high percent of the freshwater inflow diverted, are considered major factors influencing the decline of this species. Other factors that may be contributing to the decline of Delta smelt include high toxin levels, displacement of native zooplankton food organisms by exotic zooplankton, and competition and predation on larval zooplankton by the exotic species of clam *(Potamocorbula amurensis)* (Kimmerer, 1990).

Other Native Species

Other native Delta fish species such as the Sacramento splittail (Pogonichthys macrolepidotus) and longfin smelt (Spirinchus thaleichthys) are declining and are potential candidates for threatened status. Introduced species interactions, water diversions, and increased use of water are contributing to the native fish declines. Generally, protective measures designed for one native species should have some carryover in protection of other natives (i.e., reduction of Delta smelt entrainment at export facilities will also reduce entrainment of other species).

TRACY FISH COLLECTION FACILITY DESCRIPTION

The TFCF was built in the mid-1950's to intercept and salvage juvenile salmon and striped bass over 25 mm (1 inch) entering the Delta-Mendota Canal (DMC). The facility consists of two sets of louver arrays (primary and secondary) in series that divert fish to holding tanks (figure 1). The primary louver array is positioned in the channel at about a 15° angle with the direction of the flow (Bureau of Reclamation, 1957) and has four bypasses that allow fish to pass to the secondary louver array and then into the holding tanks. Fish are removed from the holding tanks and trucked and released daily into the Sacramento/San Joaquin River Delta. Flows through the facility result from pumping activities at the TPP located 2.5 miles downstream. TPP flows can range from less than 1000 ft^3/s to a maximum capacity of 5000 ft^3/s. Tides are attenuated at the TFCF because of distance from the ocean and localized flows at diversions and Old River. Localized high tide occurs about 8.0 hours after those recorded at the Golden Gate Bridge and is reduced to about 68 percent of tide height at the same (Tidelog, 1992). Pumping rates at the TPP vary and consequently tidal highs and lows are affected and sometimes difficult to pinpoint. The depth of the water behind the trashrack in the primary louver bay at the TFCF varies between 13 and 21 feet. In addition, trashrack clogging by detritus and plants (i.e., *Elodea*) can cause head differences between the primary louver bay and the river, adding more variables to the hydraulics and entrainment of eggs and larvae.

METHODS AND MATERIALS FOR FISH EGG AND LARVAE SAMPLING

Continuous Pump Sampling System

Avoidance and patchiness are the two major problems with ichthyoplankton sampling (Marcy and Dahlburg, 1980). In order to get as representative sample as possible, a pumpbased system was incorporated into the design to reduce the avoidance problem by continuously pumping at an intake velocity faster than the canal flow and to reduce the inaccuracy of patchiness by continuously pumping relatively large volumes.

This sampling system was designed with the following additional criteria in mind: quantifiable continuous sampling, automation (to reduce staff), and frequent preservation of samples. The sampler operated by pumping, concentrating, separating, and preserving samples for a specific period of time and/or volume. A patent for the continuous fish egg and larval sampler was applied for in 1991 and granted in January 1993 to the author with the Department of the Interior.

The sampling system was moored behind the trashracks on a floating pontoon deck. Figure 1 shows the sampler location relative to the intake channel to the TFCF and figure 2 presents a top and side view of the continuous sampler with arrows indicating flow of water and sampled material. The mixing processes that occur as intake canal water passes through the TFCF trashracks tend to break up potential stratification of particles in the water column, including eggs and larvae. The sampler intake was positioned behind the trashracks to reduce sampling error associated with the vertical patchiness of planktonic organisms. Operation of the continuous sampler is described as follows: a submersible centrifugal pump lifts water containing fish eggs and larvae, and detritus up into a headbox/energy dissipator; water and material move by gravity from the headbox over and through an inclined 250-micron opening wedge wire screen; water flowing through the screen (including most particles less than 250 microns) is discharged back into the canal (95 to 99 percent of the original pumped flow); 1 to 5 percent of the original pumped flow, containing all particles greater than 250 microns from the original pumped flow, is collected at the lower end of the screen into a rotating diverter arm; water and materials flow through the diverter arm into screened collection buckets located at predetermined points in a circle (the diverter arm rotates to a new collection bucket on a preset time interval such as each hour). A small amount of formalin solution is delivered automatically to each collection bucket following sampling via a peristaltic pump to preserve samples and reduce predation on larvae by amphipods.

The centrifugal pump intake was structured to withdraw water parallel to the channel flow and was suspended 10 feet below the water surface; distance from the bottom varied with the tide. An interchangeable PVC pipe intake nozzle was constructed to allow changes in diameter in order to vary the intake velocities to match channel flows as closely as possible as recommended for optimum sampling effectiveness (Bowles et al., 1978). All internal plumbing surfaces were smoothed and junctions tapered to reduce abrasion on pumped organisms. An inline flowmeter was installed within the inflow plumbing from the pump and was connected to an electronic data logger that recorded the volumes of water per sample. The continuous sampler was able to collect 10 to 24 samples a day representing a complete diel cycle. The 1991 sampler was programmed to take 90-minute samples; in 1992, 60-minute samples were taken. Further modifications in 1992 included use of conical nets placed inside collection buckets, and increased volume of formalin solution injected into each collection bucket to reduce sample degradation. The continuous sampler was unloaded and reset by hand at least twice a day.

Sampled material in the collection buckets was transferred to 1 liter sample bottles, preserved and stained with 5 percent formalin to which a Rose Bengal dye solution was added. Samples were labeled in numerical sequence for laboratory analysis. Sample number, sample duration, time of day, and total water volume filtered were recorded in a field notebook each time the sampling device was unloaded and reset. Daily total number of fish passing through the TFCF was extrapolated using daily canal flow summaries provided by operators at the Tracy Pumping Plant (appendix A). The continuous pump sampler was operated from March 28 to June 12, 1991, with brief periods of downtime due to power outages and system improvement installations, and virtually uninterrupted from February 20 to June 3, 1992.

Sample sorting was performed under illumination and magnification in white enamel trays, using extremely flexible forceps and pipettes to hand separate eggs and larvae from detritus. Eggs and larvae were identified under a 10 to 40X-power binocular microscope by Reclamation's contractor, National Environmental Services, Concord, California. Random samples were repicked and identified to ensure quality control. Because of the high number of samples collected in 1992 (1500+), time and money did not permit all samples to be examined and alternating samples were analyzed on collections early and late in the season. Hourly and daily density (fish eggs and larvae per cubic meter) was calculated for all species collected. Data management and analysis were performed using computer-based spreadsheets and database software. Because of the improvements in the sampler in 1992 and the longer timeframe of operation, the 1992 data were analyzed in greater detail and used in more species trend comparisons. Appendix B contains calculations and factors used in data reduction from continuous flowmeter readings.

Evaluation of Egg and Larval Collection Efficiency by the Continuous Pump Sampling System

The continuous pump sampler was evaluated in 1991 to determine the condition of pumped eggs and larvae and to examine the accuracy of estimating the abundance of eggs and larvae in the channel. Thirty evaluation tests were performed using striped bass eggs and larvae of known numbers and age obtained from the striped bass hatchery in Elk Grove, California. Determination of pump damage to eggs and larvae was performed by injecting eggs and larvae into the intake of the pump while it was suspended in the river inside a plankton net, which isolated the pump from eggs and larvae in the river. Fifty eggs and/or 50 larvae were injected in each test. During short-term tests, eggs and larvae were removed from the collection bucket within 5 minutes. Longer term evaluations for 90 minutes were also run with eggs and larvae to determine effects of holding time within the collection buckets. Eggs and larvae were also introduced into the headbox to separate pump and screen plumbing effects on fish.

Plankton Net Sampling

Plankton nets were fished during the same times as selected continuous pump samples to provide data for quantitative comparison between gears and also to provide more data for estimating egg and larval abundances over time. Nets were 0.5-meter diameter with 250-micron mesh Nitex. A Kahl Scientific Flowmeter was positioned off-center in the mouth to determine water volume sampled. Flowmeters were calibrated in test flumes at the Reclamation Hydraulics Laboratory in Denver, and regressions were generated unique to each meter and were used in analysis for greatest accuracy of sample volume (appendix C). Paired or duplicate net tows were performed during daylight hours and fished behind the trashracks. All samples were taken when the continuous pump sampler was operating, with some nets fished at surface, middepth, and bottom and some nets fished at the same depth as the sampler intake. Duration of net samples varied between 5 and 20 minutes, primarily as a function of canal flow and the associated degree of net fouling. Net samples taken for comparison with the continuous pumped sampler were not fished the entire time as the associated pumped sample but were taken for a brief period of the entire 60- or 90-minute pumping period. Calculations used to obtain egg and larvae density are in appendix B.

Water Quality Monitoring

Water temperatures and specific conductance were measured hourly from March to June in 1991 with an electronic, in-situ data logger and intermittently over the same months in 1992. Water temperatures were also recorded by a circular paper recorder in the secondary portion of the TFCF and hand extracted for comparison with data logger temperatures in the primary section.

RESULTS

Continuous Sampler Evaluation

The 1991 evaluation of the continuous sampler using known numbers of striped bass eggs indicated that about 81 percent of the eggs that are entrained by the sample pump were recovered in the collection buckets. Ninety percent of the eggs introduced into the headbox were recovered from the collection buckets. Appendix D contains results from the recovered number of eggs and larvae from each test.

Numbers of larvae recovered after injection into the sample pump varied considerably, ranging from 0 to 56 percent. Larvae introduced into the headbox and not passing though the pump resulted in 60- to 72-percent recovery. The difference between the pump and headbox recovery rates appears to be due to larval damage in the pump and impeller. Mutilation by the pump and delayed stress factors probably killed many larvae. Rapid decomposition may reduce the larvae to pieces smaller than 250 microns. Preserved larvae were also introduced into the pump and recovered 90 minutes later; this resulted in 42- to 60-percent recovery rates. This indicated that preserved larvae are tougher and last longer in the collection buckets. Factors contributing to the variability in the live larvae tests may include the amount of detritus pumped, wedgewire screen and pump abrasion, and varying water velocities over clogged wedgewire screen slots. Also the elapsed time in collection buckets before preservation is probably a factor as indicated by lowest numbers of recovered larvae coming from the 90-minute tests.

Results from these tests led to attempted improvements in sample collection operations in 1992 including the purchase of a special low speed, helical impeller, delicate solids pump designed and made in Peru, South America (figure 3). This pump was ordered to specifications of: 250 gal/min against a 20-foot total dynamic head at 850 RPM with a 3.3-hp 3-phase, 460-volt, immersible motor. Because of the extensive shipping time, the pump was not obtained in time to use in 1992. Extensive data were collected in 1993 and are preliminarily analyzed in the following "1993 Continuous Pump System Efficiency Factors" section.

From the 1991 tests a "weighted efficiency factor" was determined by averaging the percentage results from all tests performed with striped bass eggs and larvae injected into the pump. This provided an average percentage that takes into account eggs and larvae that were in the sample at minute 1 to those collected at minute 89. The efficiency factors calculated were: 81 percent for striped bass eggs and 27 percent for striped bass larvae and are indicative of how many eggs or larvae out of 100 percent were recovered from each sample collected. Correction factors for striped bass eggs and larvae based on these efficiencies were 1.2 and 3.6, respectively, and were used in the final analysis when data were extrapolated to daily entrainment through the TFCF. Data with no fish collected in samples were left at zero with no factoring.

1993 Continuous Pump System Efficiency Factors

In 1993, 24 tests were performed with known numbers of carp eggs and striped bass larvae in the continuous collector and the delicate solids pump with the helical impeller. The striped bass larvae were approximately 24 hours old. The pump was operating at about 220 gal/min, the wedge-wire screen was inspected but not cleaned between each test, and the pump was only shut off between test types (eggs, larvae, headbox only). Appendix J presents the results of each test. It should be noted that the headbox partition on the continuous pumped sampler was resealed after test L and percent recoveries increased. Also, larvae were still collected in the exhaust water (test P), indicating the headbox was still not sealed completely. A "weighted efficiency factor" was determined by averaging all the percentage results for eggs and larvae through the pump, similar to the 1991 factor. The efficiency factors calculated are: 98 percent for eggs and 44 percent (SD = 18.6 percent) for larvae, combining both pre- and post-headbox reseal samples. These factors approach a 100-percent recovery for eggs and a near double increase from 1991 efficiencies in percent larvae recovered. Larval efficiencies should be even higher if a seamless headbox design was incorporated.

Continuous Pump Sampling Data - 1991

A list of common and scientific names of all fish species collected throughout this egg and larval study is given in Table 1. A total of 622 samples were collected from April 27 though June 12, 1991, with the continuous sampler.

Table 2 presents the percent composition by species for the continuously collected data. Striped bass were the dominant species collected with large numbers of eggs making up the major constituent. Striped bass eggs initially appeared in samples on April 30 and the first striped bass larvae were collected May 1. Figure 4 presents the 1991 striped bass egg and larvae total number from May 1 to June 12. The peak number of striped bass eggs were collected on May 23 between 11:00 pm and midnight and peak larvae occurred on June 10 between 2:30 a.m. and 4:00 a.m. Since each sample has a known time, duration, and density, a diel pattern (and possibly tidal) of striped bass egg and larval entrainment was determined. Sixty-five percent of the striped bass eggs sampled were collected from 8 p.m. to midnight with another 25 percent collected from midnight to 6 a.m. Fifty-six percent of the striped bass larvae were collected from midnight to 6 a.m. The day and night percentage of total striped bass and the other species of fish collected is presented in appendix E. Figure 5 presents an example of diel collection results of striped bass eggs over a 5-day "window" from May 6 through May 10, 1991.

Delta smelt larvae were sparse with a total of three collected in 1991 in continuous collected samples and net samples. Table 3 presents individual information on each of the 1991 collected Delta smelt.

Plankton Net Sampling - 1991

A total of 193 samples were collected with ichthyoplankton nets during February 27 through July 18, 1991. Samples were comprised mainly of prickly sculpin and chameleon gobies. Table 2 shows percent composition of the net samples. Prickly sculpin made up 48 percent of the fish sampled and were present in most samples until April 1. Chameleon goby larvae were found in samples starting April 23 and were the major species in samples through July 17 when the sampling ended. Striped bass eggs were present from April 4 to June 2 with most eggs collected from April 26 to May 26. Approximately 49 times more striped bass eggs than larvae were collected. The relatively fewer striped bass larvae were collected from May 11 to June 11.

Table 4 presents the numbers of striped bass eggs and larvae extrapolated from averaged daily densities, calculated using the weighted efficiency factor, totaled over a 15-day increment similar to the method used by Sparr (1992). In a comparison of the two samplers, trends over time were similar but the continuous sampler estimates were at least 10 times higher than the net sampler. A caveat on this comparison is that a continuous record is being compared to a one or two sample per day average. This comparison demonstrates the difference that can occur between the two sampling methods and the extrapolation to total numbers entrained. Also net data are from daytime only (continuous data indicate greater numbers of bass eggs and larvae at night).

Continuous Pump Sampling Data - 1992

In 1992, 1,512 samples were collected from February 23 through June 3 with the continuous sampler, all representing 60-minute samples with an average sample volume of 42 m^3 of water. Table 5 presents percent composition of the total collected by species. Forty-three percent of the eggs and larvae collected were prickly sculpin. Prickly sculpin larvae were present in virtually every sample from March 2 through April 6 with the last sculpin larvae found on May 27. Striped bass eggs were first collected April 2 (2 a.m.) and larvae first collected April 8 (10 a.m.). Figure 6 presents estimated average daily number of striped bass eggs and larvae entrained into the TFCF. The peak of striped bass eggs collected occurred May 11 and the peak of striped bass larvae occurred on May 13. Ninety percent of the striped bass larvae passed through the TFCF in May 1992. An estimated 3,188,119 striped bass eggs and 13,029,997 larvae were entrained at the TFCF from March 1 to June 3 using data collected by the continuous sampler.

The densities of striped bass eggs and larvae varied considerably over the day, and generally at least one sample each day contained no striped bass. Figure 7 presents the striped bass larvae daily average, maximum and minimum densities from April 1 to May 31. The average was calculated from 2 to 22 samples taken per day and the maximum and minimum represent the single highest or lowest density from the same 2 to 22 samples. The average density numbers were used in extrapolation calculations to arrive at total numbers.

With the continuous sampler data, analysis of diel trends is possible. Seventy-one percent of the striped bass eggs were collected from samples taken from midnight to 6 a.m. with another 8 percent collected from samples bracketing the evening/night period (8 p.m. to midnight). Striped bass larvae did not show as strong a diel difference as eggs; 46 percent were collected during the day (6 a.m. to 8 p.m.) and 54 percent collected more equally between the morning and evening dark periods. Other species showed strong diel entrainment tendencies. For example, 90 percent and 77 percent of the prickly sculpin eggs and larvae, respectively, were collected during the daylight period. Appendix F presents the percentage of each species that was collected from three periods covering exclusive dark and light periods.

Plankton Net sampling - 1992

A total of 227 ichthyoplankton net samples were taken during February 17 through June 1, 1992. Prickly sculpin (primarily larvae) made up 75 percent of all the fish and was present in most (91 percent) of the samples until April 15. Table 5 presents percent composition by species in the net samples. Striped bass were uncommon with only 16 larvae and 49 eggs collected. This represented only 0.1 percent of the total organisms collected. Striped bass eggs were first collected on April 3 and were absent after May 6. Chameleon gobies were the dominant species in samples starting April 3 and continuing through the end of the sampling season (June 1).

Table 6 presents comparison of 1992 netted and continuous sampled striped bass egg and larvae extrapolated totals, summed in 15-day increments similar to Spaar (1992). Striped bass eggs occurred during the same timeframe but extrapolation of netted eggs was less than extrapolated continuous sampled totals by a factor of 5.5. Results of netted striped bass larvae were considerably different than the continuous sampler results with larval estimates 175 times lower in the grand total and by even wider margins during the incremental time periods. These inequities are probably related to the low numbers of netted eggs and larvae collected in 1992. Again the caveat that this is a continuous record compared to a one to three sample per day average.

Delta smelt larvae were sparse with eight collected in continuous samples and net samples (Table 7).

Water Quality Monitoring

Water temperatures were monitored behind the trashrack at the continuous sampler from February 28 to May 16, 1991, and from March 30 to June 6, 1992. Figures in appendixG present a comparison of hand-extracted temperature data from the TFCF circular paper recorder with the electronic data logger temperatures. During both years, both water temperature recorders showed increasing temperature over the spring with the paper recorder consistently showing lower overall temperatures. During spring 1991, the paper recorder was 2 to 3 °C lower than the data logger; in 1992 the paper recorder was only about 0.3 °C lower. A check with a portable water quality monitor with a temperature probe in April and December 1991, confirmed that the paper thermograph needed recalibration and that there was a negligible difference between temperatures at the continuous sampler location and temperatures 200 feet away in the secondary where the paper chart recorder was installed.

Figure 8 presents the average daily water temperatures taken with the electronic logger for spring 1991 and 1992. In 1991, water temperatures from April 1 to May 15 averaged 3.0 °C (SD = 0.76) cooler than in 1992 over the same time period. Hourly conductance measured from March 1 to May 15, 1991, is presented in figure 9. Conductance varied from 320 to 1480 µS/cm from April 1 to May 1, 1991, with some days exhibiting a 1000 µS/cm change twice in 24 hours. The variable oscillations in conductance are tidal related and a "snapshot" of diel readings from May 1 to May 6, superimposed on tides levels, is presented in figure 10. The tidal levels were taken from the Tidelog (1991) and offset 8 hours from the San Francisco Golden Gate tides and were vertically scaled to fit the graph. Conductance was inversely related to tide height with the highest conductance water going through the TFCF during the lowest tide. This is probably a result of the source water quality differences with Sacramento River water having a lower conductance than the San Joaquin River. There is some degree of dampening of the tidal highs by the operation of nearby Clifton Court Forebay (G. Collins, pers com.) and further investigation could show more precise relationships of variation in conductance during the high tides. Days and times of highest conductivities corresponded with days of highest flood tide.

DISCUSSION

Continuous Pump and Net Sampling

Concentrations of fish eggs and larvae sampled by the automated continuous collection device were highly variable over a diel cycle. During both years of sampling, the majority of striped bass eggs passed into the TFCF during the dark, and more precisely, during the early morning hours. Observations by R. Wydoski (pers comm.) indicated that a population of striped bass spawn very near the TFCF trashracks during the early mornings and eggs are immediately entrained. Larvae of other species such as gobies, sculpins, logperch, and cyprinids, and life stages such as juvenile striped bass, were collected most frequently in daytime samples. Although tidal variations were not examined intensively in this study, there is indication that the diel cycle overrides the tidal influences as evidenced by the constant collection of some species during specific light or dark periods. Lunar phase has been inferred as a determinate for striped bass spawning. In 1992 the two largest peaks of striped bass eggs, indicative of spawning no more than 2 days prior, occurred on a full moon and a waxing moon (5 days prior to full). The three highest 1991 striped bass egg peaks all occurred during the waxing phase of the moon. Though preliminary, it could be speculated that there is some lunar (hence tidal) relationship with striped bass spawning.

Water temperatures were warmer earlier in 1992 and were probably responsible for the earlier collection of striped bass eggs and may account for the higher numbers of threadfin shad, catfish, and cyprinids compared to 1991. The peaks of striped bass eggs occurred during mid-May in both years when average daily water temperatures were within the 16 to 20 °C optimum spawning range. Timing and proportional relationships between peaks of striped bass eggs and larvae were not obvious with peaks of larvae not always following peaks of eggs. This is possibly due to local spawning producing eggs peaks, while larvae are imported with the water from the San Joaquin, Old, and Middle Rivers which is subject to timing variables caused by tides and operation of Clifton Court. Higher numbers of striped bass larvae in 1992 could be related to improved collection buckets and more frequent collections providing higher quality samples.

Sampling Gear Comparison

In order to relate continuous sampling with established net sampling surveys some degree of comparability is desirable between the two. There are many factors, biological and mechanical, that make the comparison difficult and relating either to the aquatic community confounds the analysis. The perfect sampler does not exist (Marcy and Dahlberg, 1980) since no specific type of gear can be used in all habitats and objectives. Comparisons between the net and continuous sampler were done on data collected over the same timeframes. The 1991 data comparison period was from May 1 to June 12 and the 1992 comparison was performed on data collected from March 1 to May 31 with both samplers. The first data comparison was a relatively gross look at species composition. Figures 11 and 12 present illustrations of composition of the samples collected over the respected sample periods. The charts compare combined eggs and larvae of the species. Striped bass made up a considerable portion of the 1991 nets and continuous samples. The 1992 continuous samples were mixed with predominantly sculpins and relatively even proportions of shad, striped bass, and gobies, with the net collecting relatively few striped bass and very high percentage of sculpins and gobies. This suggests that the continuous sampler could be more selective toward striped bass and that the smaller sized sculpin and chameleon goby larvae are more effectively collected by the nets. The depth of sample and the fixed location of intake is probably another reason for this species differences. Hess (1993) found a difference in depth distribution of striped bass in front of the trashracks at TFCF in 1990. If there is a persistent stratification of striped bass (or any other species) despite the trashrack hydraulic mixing, then a fixed location intake would collect a disproportionate high number of fish in that strata. An integrated, full water column sample intake would remedy that situation.

Table 8 presents the gross average of all samples from February 23 to June 3, 1992. As discussed earlier, there are large differences in sampler averages with the continuous sampler showing greater densities of striped bass eggs and larvae and the nets showing greater densities of sculpin larvae, chameleon goby larvae, and threadfin shad. Striped bass eggs, striped bass larvae, prickly sculpin larvae, and chameleon goby larvae were used for paired simultaneous tests between the continuous sampler and the net. Appendix H figures present the 1991 and 1992 data comparisons of the paired samples. These paired tests do not show any obvious proportional changes that could lead to a correlation factor between the two sample gears. In these tests virtually no chameleon gobies were in continuous samples, again indicating that the continuous sampler was not collecting representative samples of that species probably due to the smaller size of the goby larvae and potential passage of small larvae through the 250-micron wedgewire screen.

General seasonal trends of abundance were both indicated in the prickly sculpin larvae net and continuous collections but no proportional relationship can be seen. A regression equation was calculated using these 1992 paired sculpin larvae data, with the continuous pump sampler data as the y (dependent) variable. An R squared value of 0.13 resulted, indicating only 13 percent of the variability could be explained by the regression. All other species sets had similarly weak mathematical relationships. Striped bass larvae data were difficult to relate because of the few collected in the nets compared to the continuous sampler, particularly in 1992. Also difficult to compare were striped bass egg data, primarily because of the number of zero egg samples.

Comparisons between the continuous sampler and the net samples is very difficult, probably because of the nature of the sampling and non-normal distribution of fish eggs and larvae. Specific reasons for lack of proportional relationship at the TFCF could be: (1) Time of day of sampling (nets were primarily fished during the day when eggs and larvae of some species are lower and net avoidance could be high; (2) nets were only fished for 10 to 15 minutes whereas continuous samples represent a 1-hour period (egg and larvae patchiness probably makes this time frame incomparable); and (3) differing ages of larvae vary in susceptibility to mutilation, and therefore collection efficiency.

Time and space variability in egg and larvae samples is probably related to tidal effects, the State Water Project operations, and the patchy nature of larvae in the river, as reported by the California State Division of Water Resources in studies done near the State Water Project intake (about 1/2 mile north of the TFCF) (Spaar, 1990). Where multispecies sampling was involved, similar to what this study encountered, Taggart and Leggett (1984) observe nets were more efficient at low densities, while pumps excelled at higher densities. This was probably due to the pumps low volume at low densities and tendency of nets to clog at higher volume and densities.

From these data, no comparison provides any correlation factor that can be applied to the data to interchange nets with continuously collected data. Furthermore, comparisons are nearly impossible when one of the comparing data sets is always zero. The continuous collection system does provide an index, with accuracy increasing with the 1993 delicate solids pump installation, and any extrapolation to "cover" non-sample periods is unnecessary. For species of fish whose numbers are low, the continuous sampler should increase the chances of collecting their larvae because the system is on all the time and concentrations of fish passing the sampler are subsampled.

Preliminary Comparisons of 1993 Sampling Gear Results

Sampling gear comparison tests were performed over the spring 1993 season. Extra effort was put in these tests to reduce the variability by collecting truly simultaneous samples with both the sample methods operated for the exact same time and the depth. The continuous pumped sampler was only operated during the same time as the net was fished and both samplers results are treated as a paired sample. Figure 13 presents a graph of combining all species densities per sample in a 23-pair comparison. The netted samples have a predominantly lower density than the continuous sampler with varying magnitude of difference. In this preliminary analysis a consistent relationship is not apparent even under the "tighter" 1993 testing methods. In the future 1993 egg and larval report, analysis will be performed using individual species, statistical pattern recognition, and transformation tools trying to determine mathematical relationships.

Comparison with California Department of Water Resources Data (DWR)

A tabular comparison between Reclamation's continuous pumped sampler striped bass entrainment totals with DWR calculated totals from net samples from 1991 (Spaar, 1992) and 1992 (Spaar, 1993) is presented in appendix I. A caveat on these tables is that they are comparisons between continuous records and one-per-day net samples extrapolated over nonsampled days, and the purpose of this comparison is to generally demonstrate differences between the two methods. The 1991 comparison shows the continuous sampled egg results (total entrainment at TFCF) about 5 times larger and the continuous sampler larvae results about 8 times less than the DWR estimates. In 1992 the two compare more closely with DWR estimates about 4 million higher for eggs and the continuous pumped sampler about 3 million higher for larvae.

CONCLUSIONS

1. Depicting trends obtained by the continuous pump collection system for species abundance is possible and probably more accurate than using single daily, daytime, net collection data.

2. A mathematical "correction " or correlation factor is probably impossible to accurately relate continuous collected and net data, with these data sets. (Particularly a general one for all species of eggs and larvae).

3. There appears to be strong diel trends in striped bass eggs and larvae, prickly sculpin larvae, cyprinid larvae, and bigscale logperch.

4. The continuous pumped sampler collected more striped bass than the nets. Smaller eggs and larvae (such as gobies) are probably underestimated because they possibly can pass through the 250-micron wedgewire screen to some degree.

5. Higher numbers of striped bass eggs were collected by the continuous sampler in 1991 than 1992 and higher numbers of striped bass larvae were collected in 1992 than 1991. This is probably due in part to improvements in the sampler in 1992 increasing the quality of larval samples collected.

6. More striped bass larvae were estimated entrained in 1992 than 1991 from the continuous sampler results.

FUTURE PLANS AND RECOMMENDATIONS

Since the target fish species to be monitored have changed from primarily striped bass to most all species, the sampler operation and collections need to change to optimize the ability to collect any eggs and larvae present in the water column. The term continuous ichthyoplankton sampler could be interpreted to mean "continuously being improved." Future improvements include a sample integration winch that will permit a top to bottom sample integration by moving the intake continuously up and down through the water column, similar to what an oblique net tow provides. Powlik et al., (1991) suggest that the shape of the intake field and not the shape of the intake is key to efficient sampling. This was performed to some degree in designing the intake to match or slightly exceed the canal flow but future design of a variable intake nozzle could improve the collector. Also visual and acoustic avoidance could be reduced by having the intake at some distance from the pump. An improved seamless headbox/dewatering box has been designed and will be installed in the future. It will incorporate stainless steel sheet-metal construction with flow diverters built in to assure all water crosses the wedgewire screen and not partially flow down the solid screen frame perimeter. Night netting is needed to continue investigating diel trends of different species and to determine any relationship between the continuous system and nets results.

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Table 1. List of common and scientific names of fish eggs and larvae collected during both the 1991 and 1992 sample periods

Common Name	Scientific Name
Herrings	Clupeidae
Threadfin Shad	*Dorosoma petenense*
Catfishes	Ictalaridae
White Catfish	*Ictalurus catus*
Channel catfish	*Ictalurus punctatus*
Bullheads	*Ictalurus sp.*
Silversides	Atherinidae
Inland silverside	*Menidia beryllina*
Sea Bass	Percichthyidae
Striped bass	*Morone saxitilis*
Gobies	Gobiidae
Yellowfin Goby	*Acanthogobius flavimanus*
Chameleon Goby	*Tridentiger trigonocephalus*
Minnows	Cyprinidae
Carp	*Cyprinus carpio*
Sacramento splittail	*Pogonichthys macrolepidotus*
Goldfish	*Carassius auratus*
Golden shiner	*Notemigonus crysoleucas*
Red Shiner	*Cyprinella lutrensis*
Perches	Percidae
Bigscale logperch	*Percina macrolepida*
Sculpins	Cottidae
Prickly sculpin	*Cottus asper*
Smelt	Osmeridae
Delta smelt	*Hypomesus transpacificus*
Longfin smelt	*Spirinchus thaleichthys*
Suckers	Catostomidae
Sacramento sucker	*Catostomus occidentalis*
Sunfish and Black Basses	Centrarchidae
Bluegill	*Lepomis machrochirus*
Largemouth bass	*Micropterus salmoides*
Trout	Salmonidae
Rainbow trout	*Onchorhynchus mykiss*

Neomycid shrimp and amphipods (*Lagunagammarus* sp.) were also collected.

Table 2. Percent composition of fish eggs and larvae collected by nets and the continuous sampler at the Tracy Fish Collection Facility from February 27 to July 18, 1991 (nets) and April 27 through June 12 (continuous pump sampler).

Fish Species (eggs and larvae combined)	Percent composition in continuous samples	Percent composition in net samples
Striped bass	94.3	17.2
Chameleon goby	1.64	31.6
Bigscale logperch	0.07	0.5
Prickly sculpin	1.02	48.5
Threadfin shad	0.05	0.5
Delta smelt	0.02	0.1
Sacramento sucker	0.0	0.1
White catfish	0.05	0.1
Rainbow trout	0.0	0.1
Cyprinidae	3.07	1.4
Centarchidae	0.05	0.1
Longfin smelt	0.0	0.1

Table 3. Delta smelt larvae collected in 1991 by continuous pumping and net methods at Tracy Fish Collection Facility.

Date of collection	Time of collection	Total length
March 3, 1991	11:30 a.m.	7.3 mm
March 5, 1991	10:00 a.m.	9.5 mm
May 5, 1991	5:00 p.m.	15.4 mm

Table 4. Striped bass eggs and larvae numbers passing through the Tracy Fish Collection Facility in 1991 estimated from continuous egg and larvae collection device and ichthyoplankton net samples.

DATE	Continuous sampled STRIPED BASS EGGS Total	Netted STRIPED BASS EGGS Total	Continuous sampled STRIPED BASS LARVAE Total	Netted STRIPED BASS LARVAE Total
May 1-15, 1991	1,544,700	7,880,219	304,624	35,697
May 16-31, 1991	22,331,835	1,844,795	889,808	124,418
June 1-12, 1991	75,982	13,903	1,149,113	78,261
Grand Totals	23,952,517	9,738,917	2,343,545	238,376

Table 5. Percent composition of fish eggs and larvae collected by nets and the continuous pump sampler at the Tracy Fish Collection Facility, 1992.

Fish Species (eggs and larvae combined)	Percent composition in continuous samples	Percent composition in net samples
Striped Bass	17.2	0.1
Chameleon Goby	15.7	24.3
Bigscale Logperch	0.9	0.3
Prickly Sculpin	43.1	75.1
Threadfin Shad	11.3	0.07
Delta Smelt	0.02	0.02
Sacramento sucker	0.1	0.03
White Catfish	1.0	0.01
Splittail	0.0	0.01
Cyprinidae	1.5	0.01
Centarchidae	3.0	0.01
Inland silverside	3.3	0.22

Table 6. Total numbers of striped bass eggs and larvae passing through the Tracy Fish Collection Facility in 1992.

DATE	Netted STRIPED BASS EGGS Total	Continuous sampled STRIPED BASS EGGS Total	Netted STRIPED BASS LARVAE Total	Continuous sampled STRIPED BASS LARVAE Total
Feb 20-29, 1992		0		0
March 1-15, 1992	0	0	0	0
March 16-31, 1992	0	0	0	0
April 1-15, 1992	88,059	118,528	34,977	110,224
April 16-30, 1992	436,842	1,181,956	0	195,061
May 1-15, 1992	58,437	1,887,635	39,449	5,916,141
May 16-31, 1992	0	0	0	6,666,070
June 1-3, 1992		0		142,481
Grand Totals	583,338	3,188,119	74,426	13,029,997

Table 7. Delta Smelt collected in 1992 with continuous and net samples at the Tracy Fish Collection Facility.

Date of collection	Time of collection	Total length
March 9, 1992	9:45 a.m.	5.5 mm
March 9, 1992	9:45 a.m.	6.1 mm
March 23, 1992	9:20 a.m.	7.2 mm
March 25, 1992	2:00 p.m.	5.9 mm
March 26, 1992	10:20 a.m.	6.0 mm
April 25, 1992	5:50 p.m.	7.5 mm
March 11, 1992 *	12.20 p.m.	5.2 mm
March 11, 1992 *	5:20 p.m.	6.8 mm

* Net Collected

Table 8. Total average densities of fish eggs and larvae from February 23 through June 3, 1992, at the Tracy Fish Collection Facility. Average density is in fish per cubic meter of water.

Species/Life Stage	Continuous sampler Average fish/m3	Net sampler Average fish/m3
Striped Bass EGGS	.0135	.0009
Striped Bass LARVAE	.0186	.0001
Prickly Sculpin EGGS	.0028	.0000
Prickly Sculpin LARVAE	.0780	.1345
Chameleon Goby EGGS	.0000	.0015
Chameleon Goby EGGS	.0250	.3924
Centrarchidae LARVAE	.0047	.0002
Bigscale Logperch EGGS	.0000	.0003
Bigscale Logperch LARVAE	.0018	.0005
Inland Silverside LARVAE	.0000	.0000
Splittail LARVAE	.0000	.0005
Delta Smelt LARVAE	.0001	.0000
Threadfin Shad LARVAE	.0140	.0673
Sacramento Sucker LARVAE	.0004	.0000

Figure 1. Diagram of the Tracy Fish Facility showing the location of tthe continuous sampling device behind the trash rack

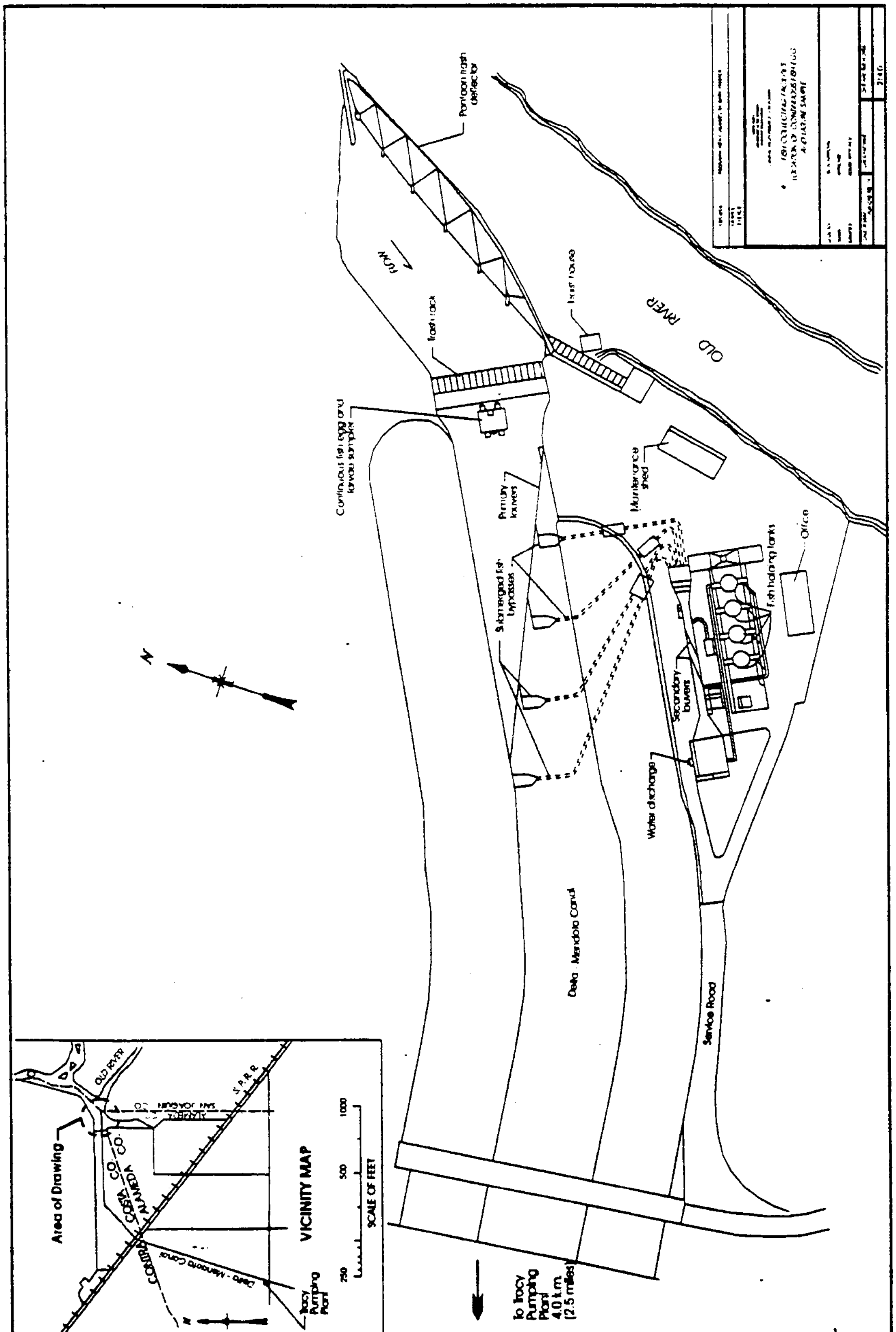


Figure 2. Views of the continuous sampler used at Tracy Fish Collection Facility, 1991-1992

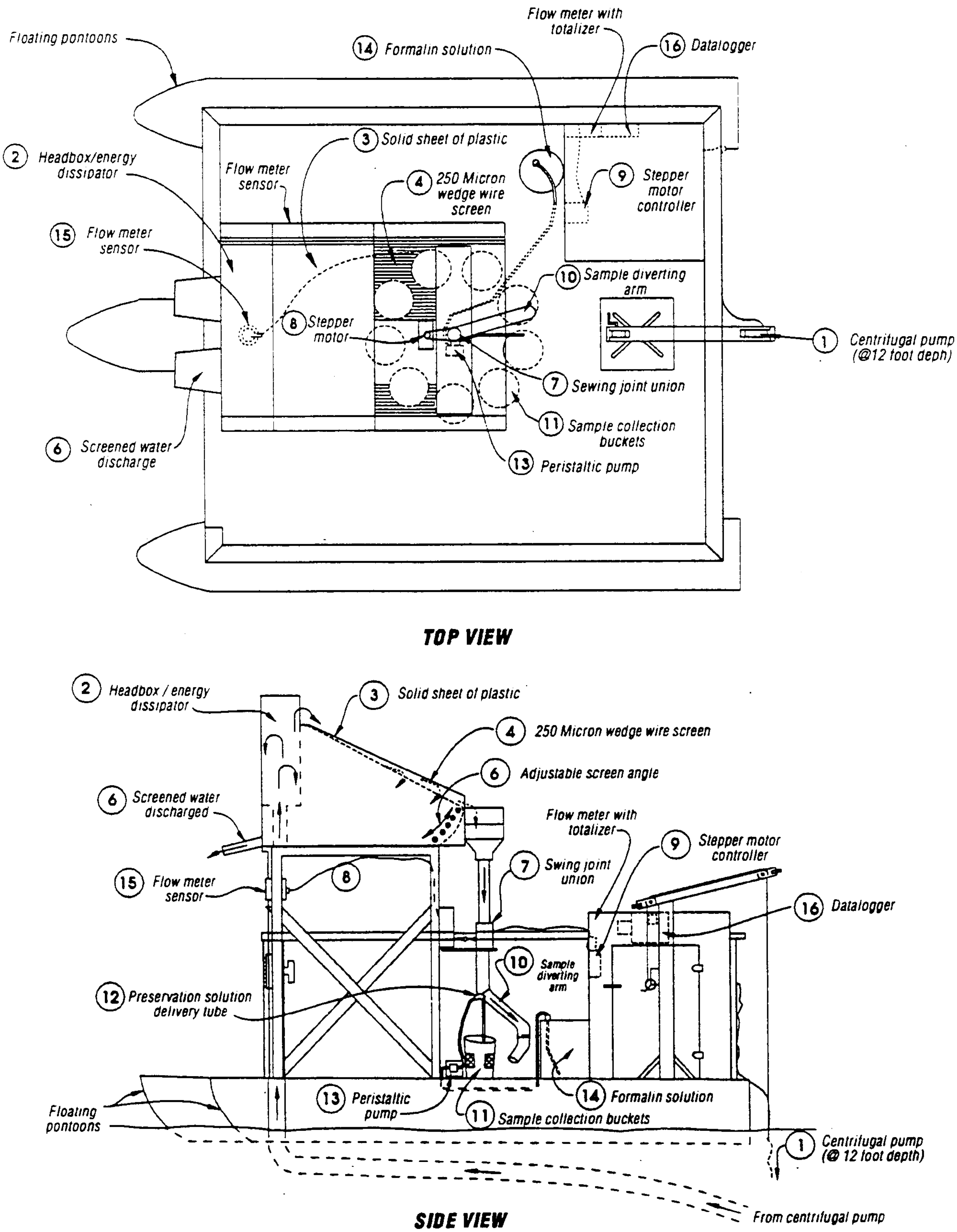


Figure 3. Schematic of the helical impeller and pump case used in 1993 continuous pumped sampling at Tracy Fish Collection Facility

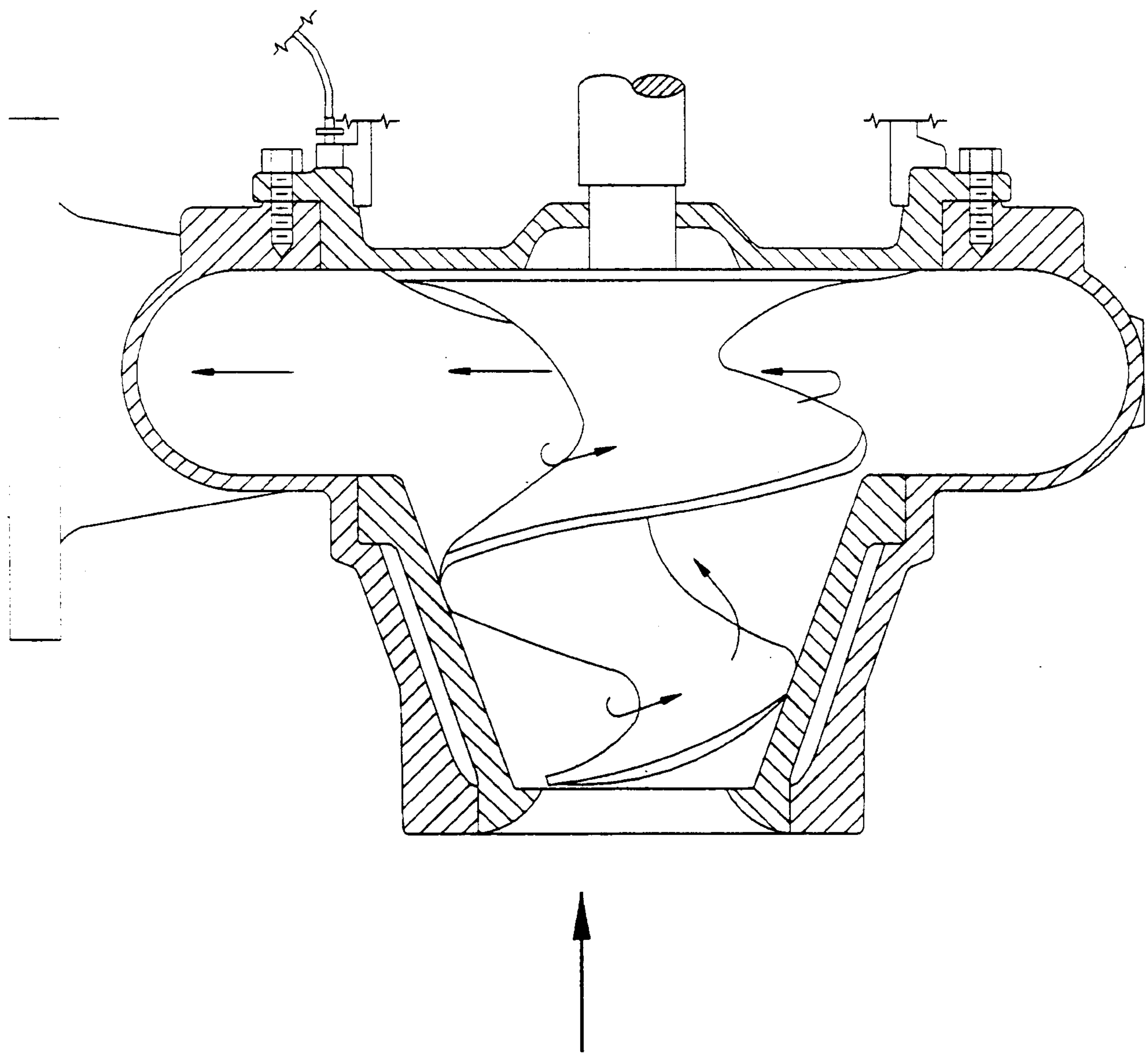


Figure 4. Estimated 1991 striped bass egg and larvae numbers entrained per day calculated from the continuous sampled data

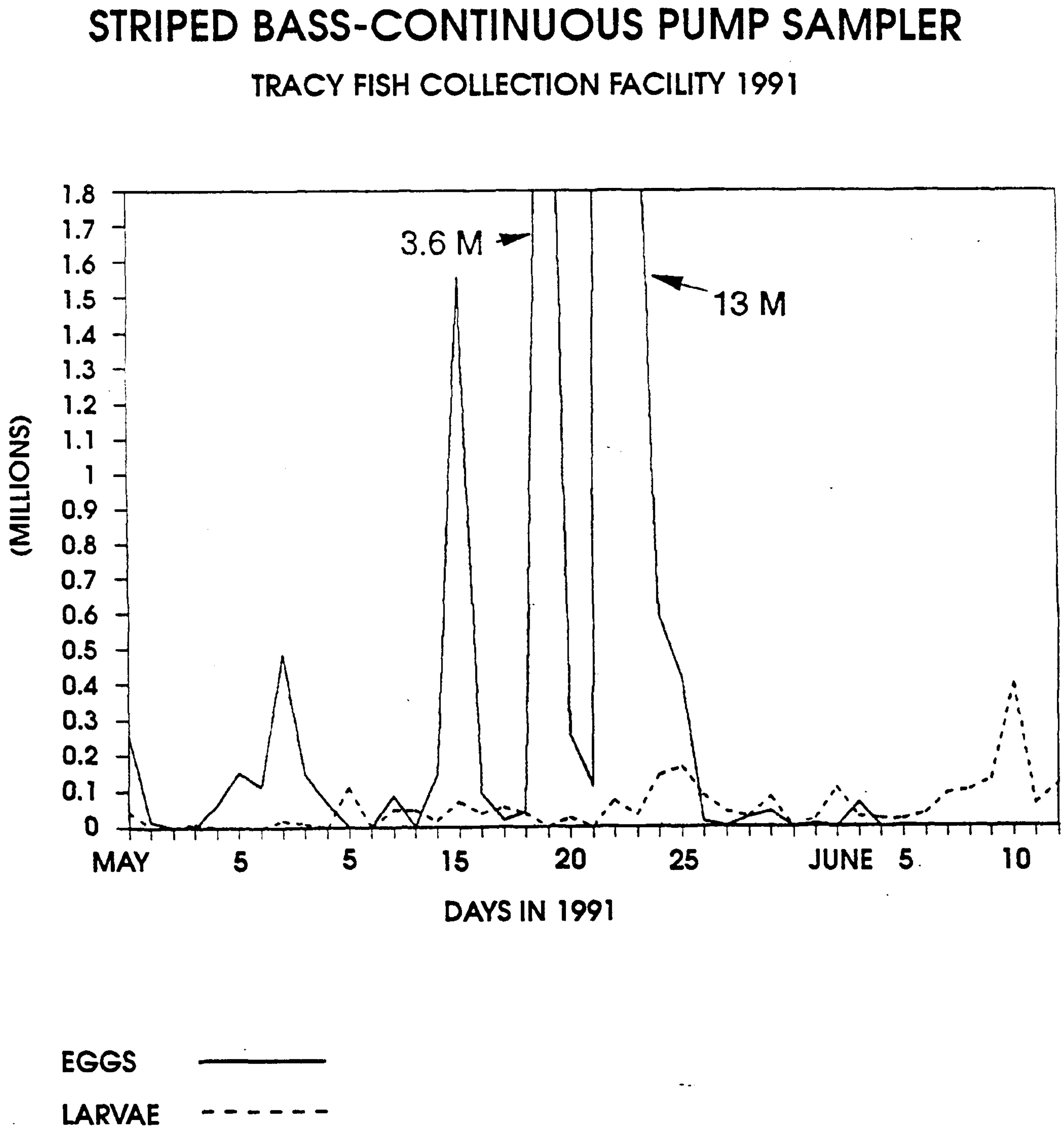


Figure 5. Diel striped bass egg densities from May 6 to May 10, 1991, collected with the continuous pumped sampler

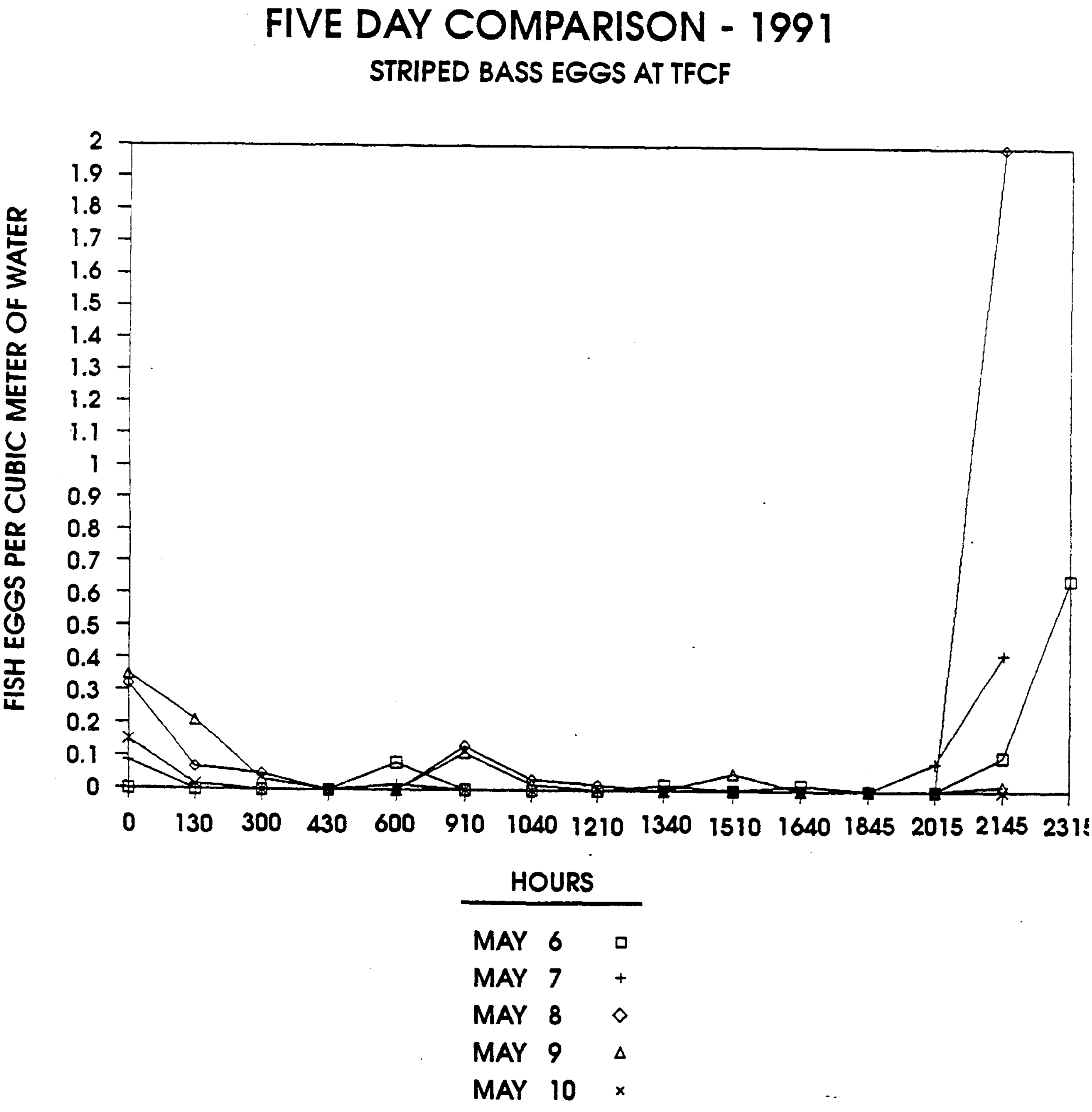


Figure 6. Estimated 1992 striped bass egg and larvae numbers entrained per day calculated from the continuous sampled data

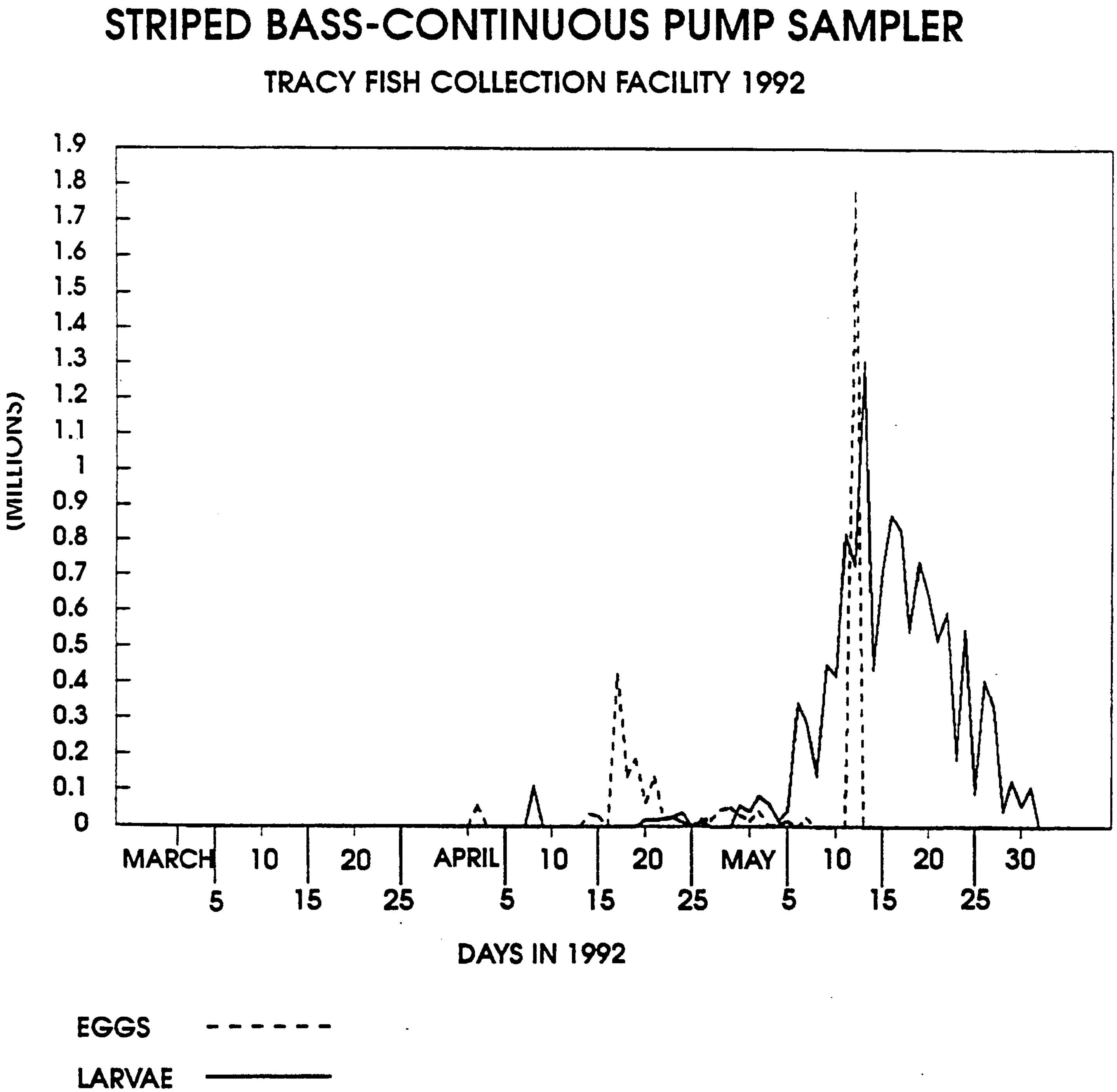


Figure 7. Striped bass larvae daily average, maximum, and minimum densities from April 1 to May 31, 1992, collected with the continuous pump sampler at the Tracy Fish Collection Facility

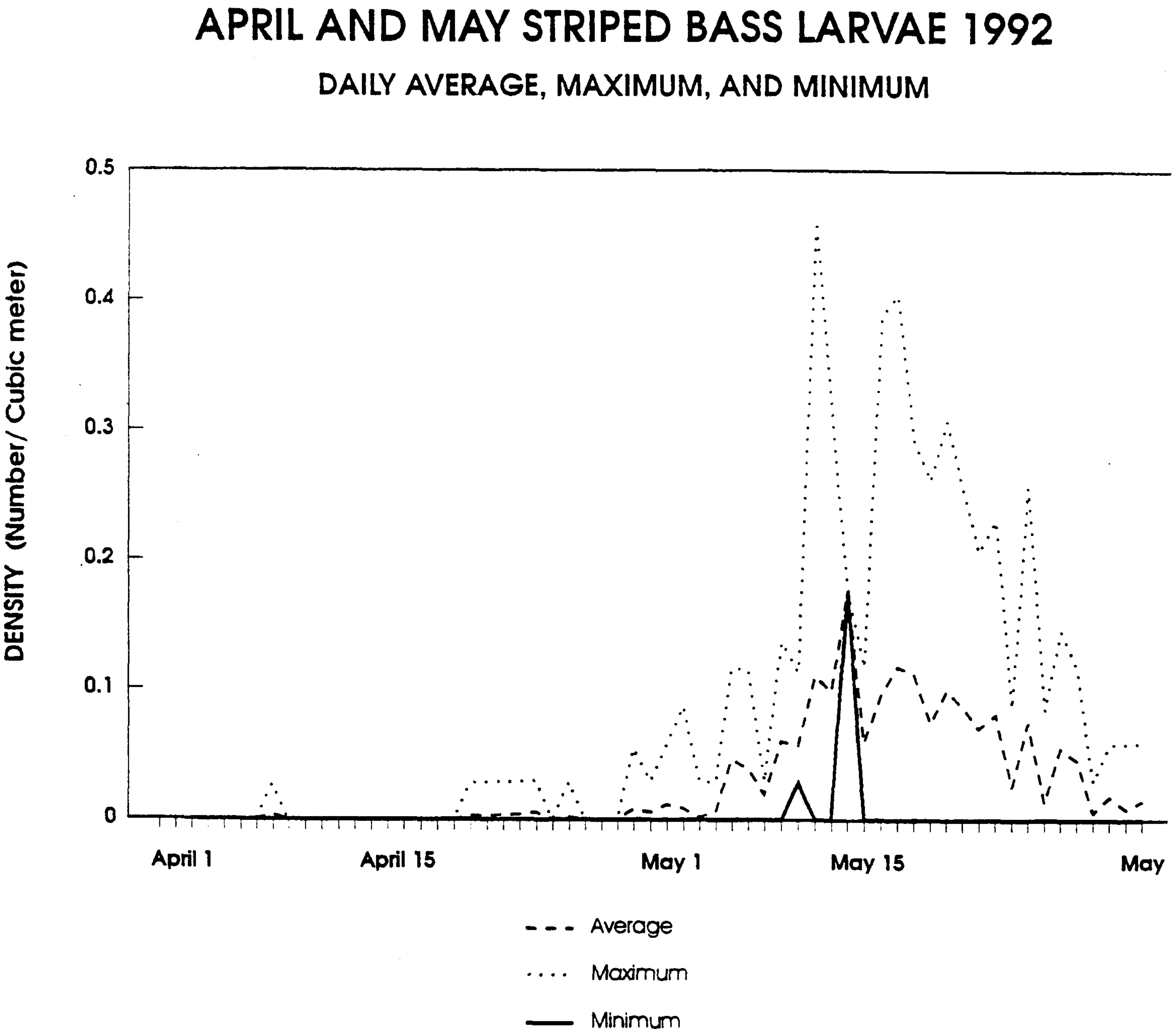


Figure 8 Average Daily Water Temperatures at Tracy Fish Collection Facility During the Spring of 1991 and 1992

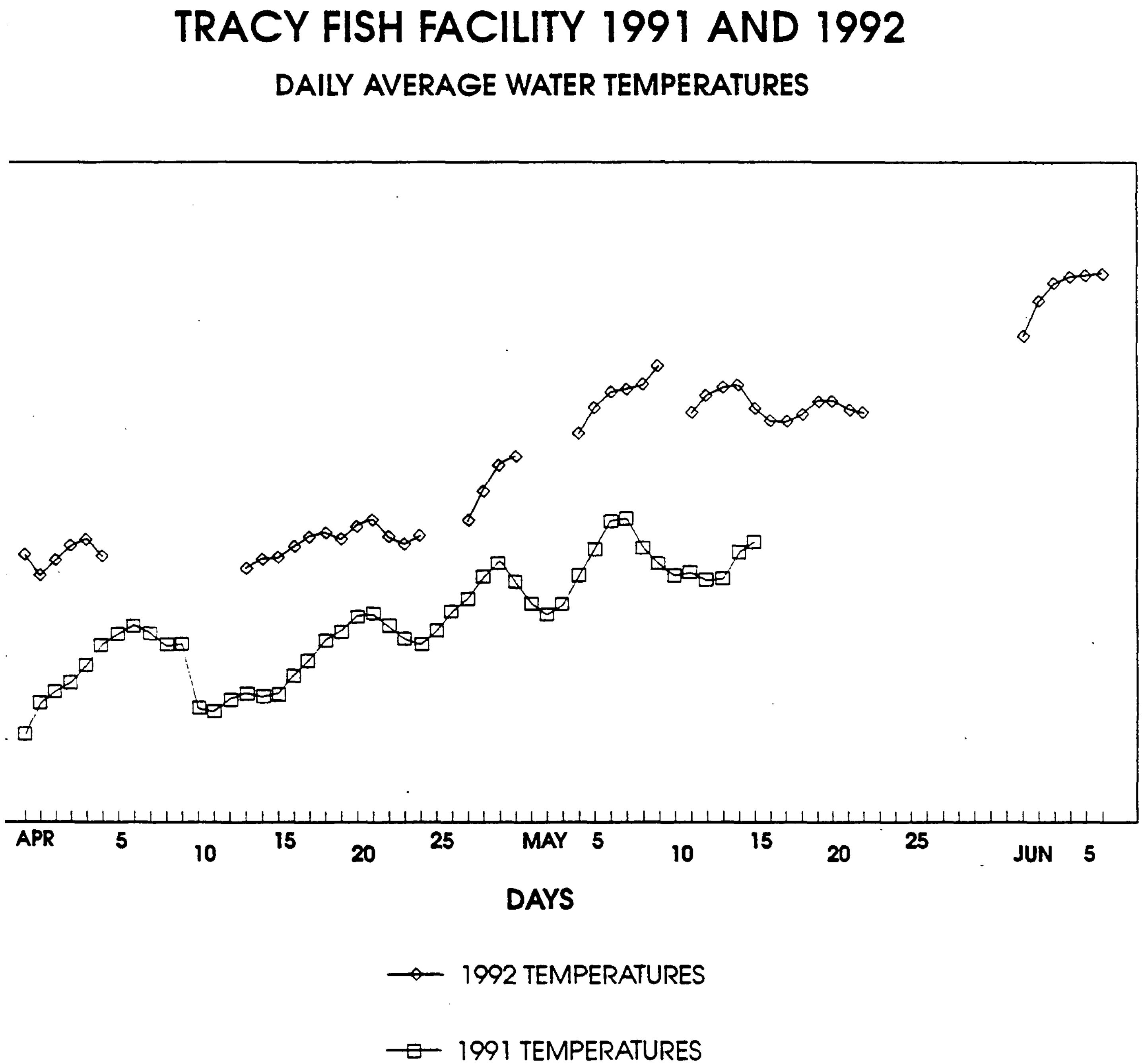


Figure 9. Hourly conductance measurements from March 1 to May 15, 1991, at Tracy Fish Collection Facility

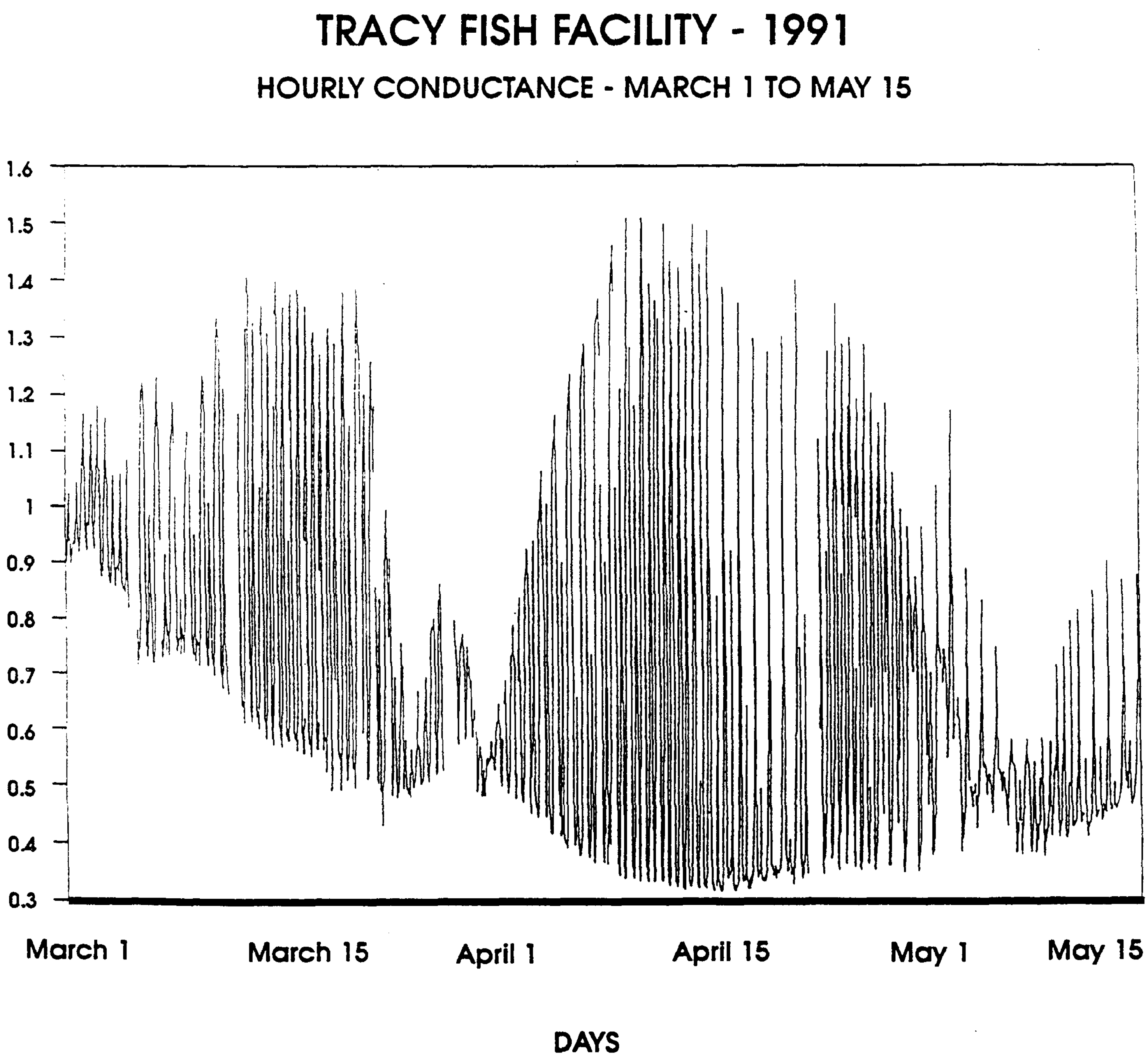


Figure 10. Hourly conductance measurements overlaid on tidal fluctuations from May 1 through May 6, 1991, at Tracy Fish Collection Facility

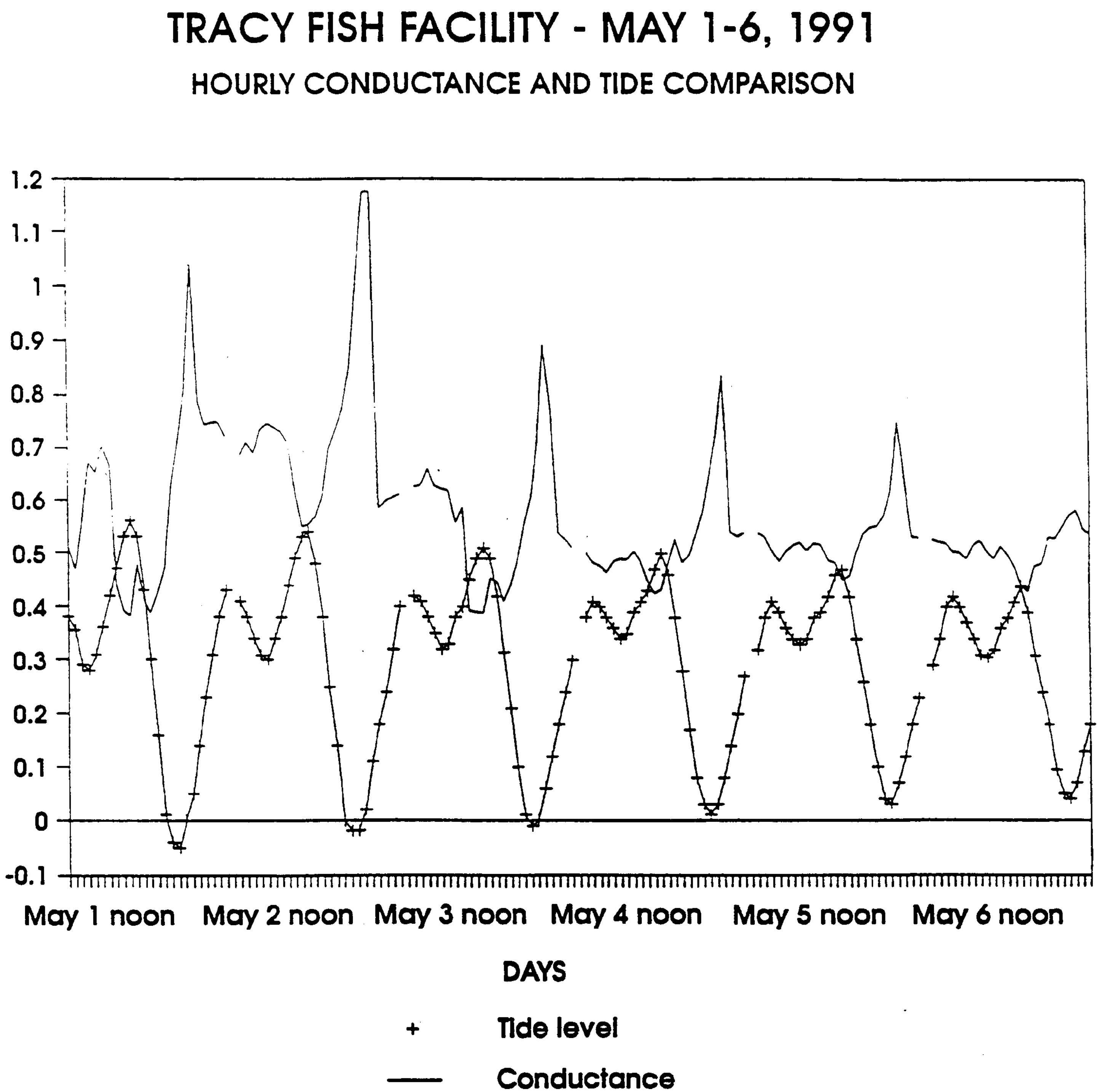
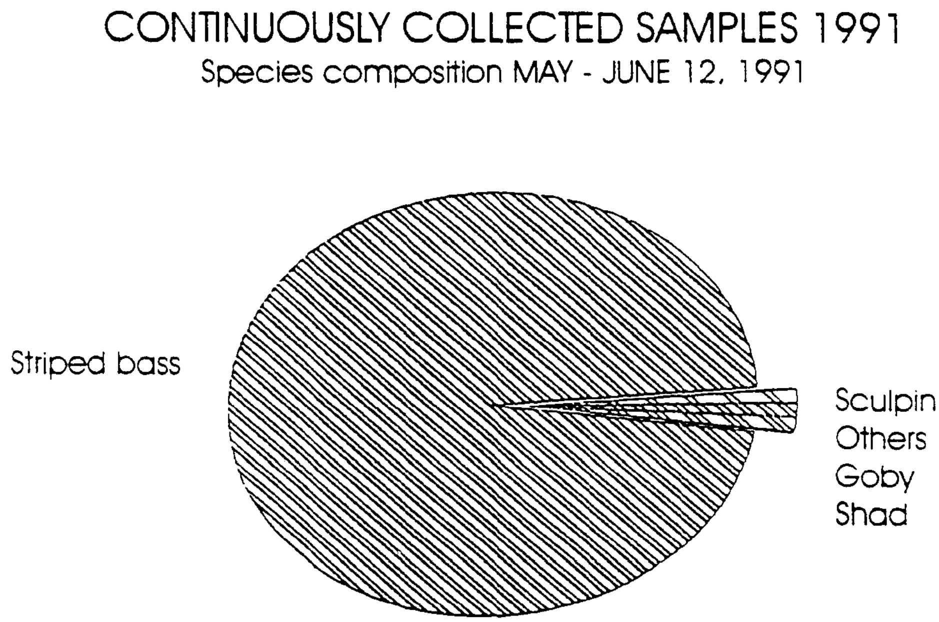


Figure 11. Continuous and net sampled fish species composition from May 1 through June 12, 1991, at the Tracy Fish Collection Facility



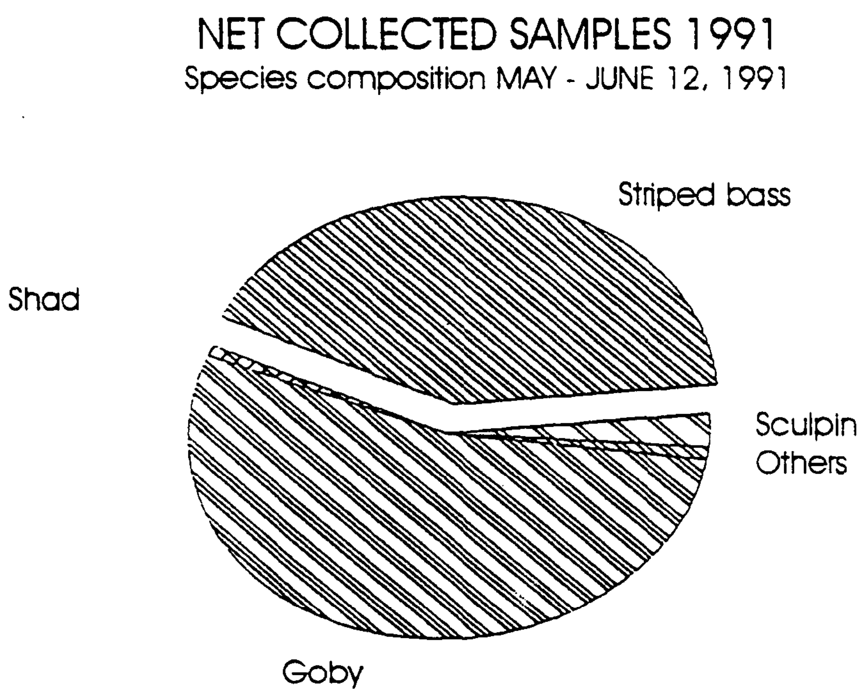
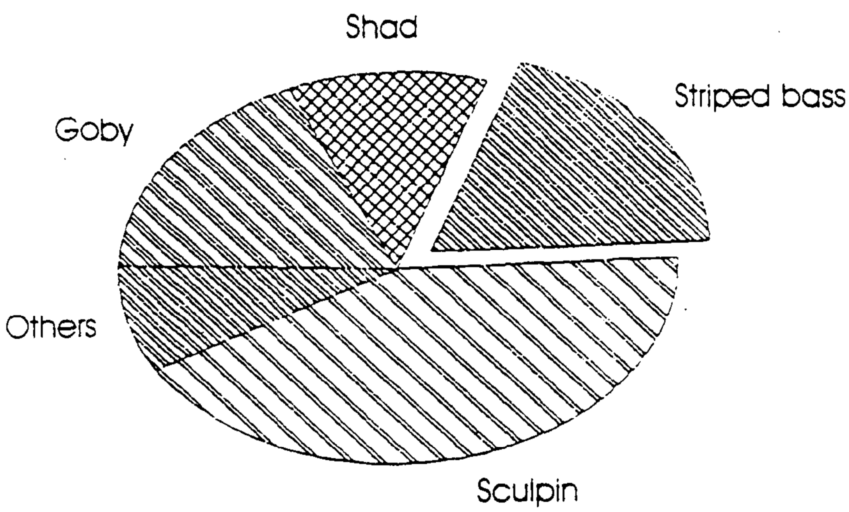


Figure 12. Continuous and net sampled fish species composition from March 1 through May 31, 1991, at the Tracy Fish Collection Facility

CONTINUOUSLY COLLECTED SAMPLES 1992

SPECIES COMPOSITION MARCH - MAY 1992



NET COLLECTED SAMPLES 1992

SPECIES COMPOSITION MARCH - MAY 1992

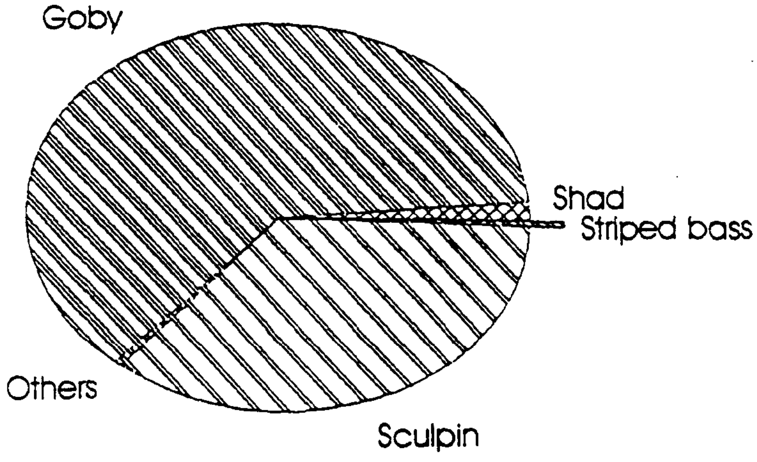
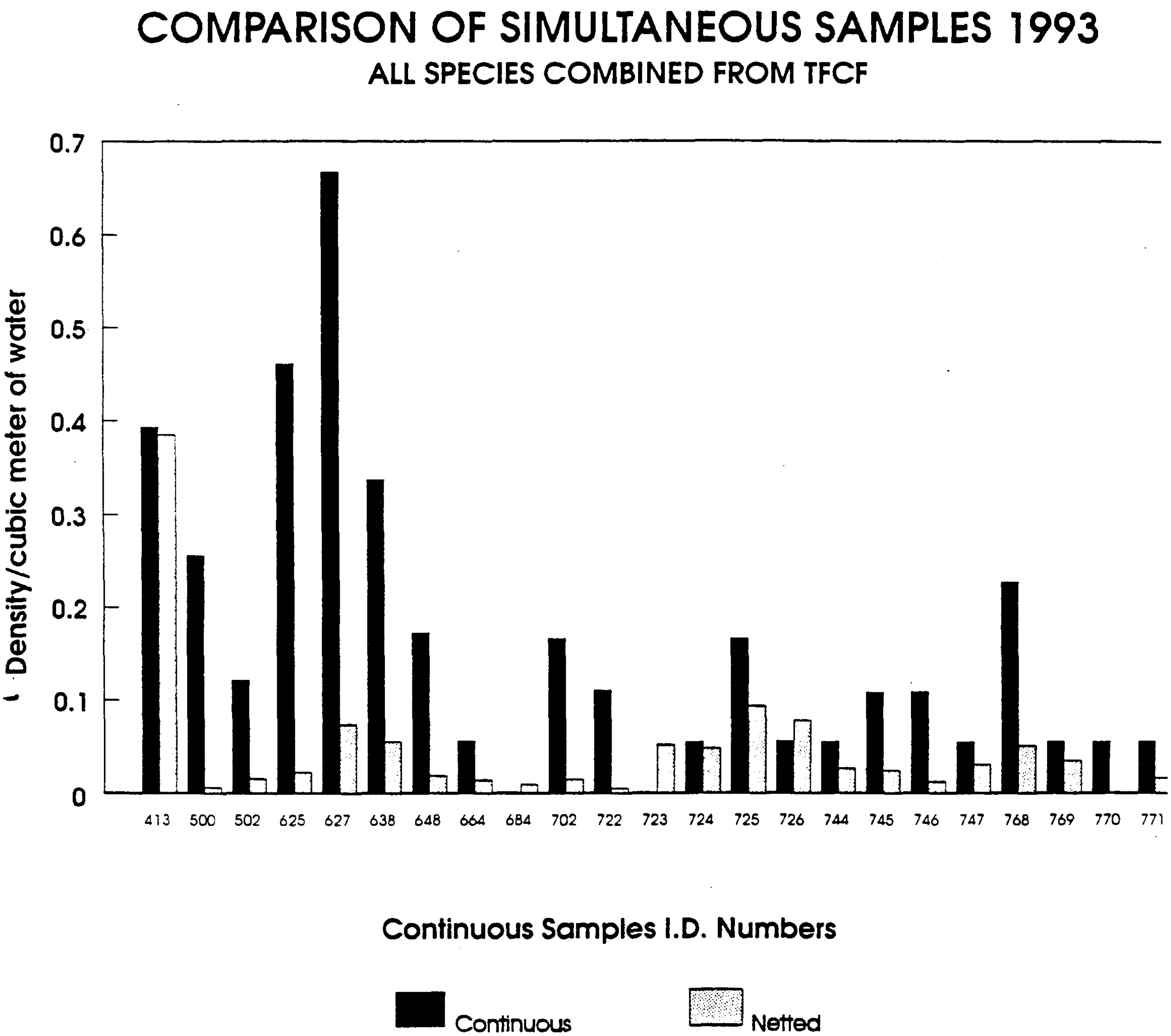


Figure 13. Comparison of densities from simultaneously collected samples using continuous and net methods at Tracy Fish Collection Facility, 1993 (all fish species combined)



Appendix A. Daily average flows (CFS) through the Tracy Fish Collection Facility (Tracy Pumping Plant) from February 1 to June 15, 1991 and 1992.

	1991					1992				
Day	Feb.	March	April	May	June	Feb.	March	April	May	June
1	2991	1123	3980	898	1393	938	4091	4112	845	761
2	3215	795	4014	903	1698	934	4094	4114	847	807
3	3216	1289	3967	900	1189	935	4094	4101	847	809
4	3224	3094	3994	895	833	932	4094	4097	850	807
5	3229	4083	4019	895	825	940	4088	3931	852	799
6	3520	4071	4036	893	825	932	4099	3630	851	792
7	4036	4068	3835	891	827	935	4096	3315	849	789
8	4051	4067	4039	892	1212	933	4104	3322	844	776
9	3317	4069	3997	891	1243	935	4101	2940	851	747
10	3229	4070	3888	1916	927	389	4096	1674	845	749
11	2776	4075	3902	2408	665	0	4098	913	845	761
12	2483	4067	3887	2458	552	0	4094	913	844	763
13	2477	4037	3900	2460	788	0	4096	911	845	760
14	2475	4041	3902	1432	797	1392	4099	889	849	761
15	2481	4047	3900	870	793	3784	4091	766	848	758
16	2480	4026	3932	870		4075	4094	766	845	
17	2480	4028	3426	867		4122	4089	792	844	
18	2458	4034	2760	867		4139	4085	794	844	
19	2480	4051	2517	862		4119	4084	771	844	
20	2458	4053	2512	1851		4115	4103	761	843	
21	2429	3943	2538	2451		4115	4106	779	843	
22	1833	3988	2026	2465		4102	4100	766	842	
23	1603	4035	1217	1947		4103	4113	771	844	
24	1603	4023	905	1122		4093	4121	790	844	
25	1604	4054	898	831		4099	4106	789	844	
26	1608	4053	897	828		4101	4114	788	842	
27	1607	4069	893	824		4094	3922	825	844	
28	1608	4033	893	830		4086	4100	839	847	
29		3982	895	1393		4091	4127	847	846	
30		4008	900	1149			4123	844	848	
31		4019		826		4078		850		
Overall AVG	2606	3722	2882	1277	971	2747	4094	1718	846	776

Appendix B. Volume Calculations for Determining Egg and Larval Densities

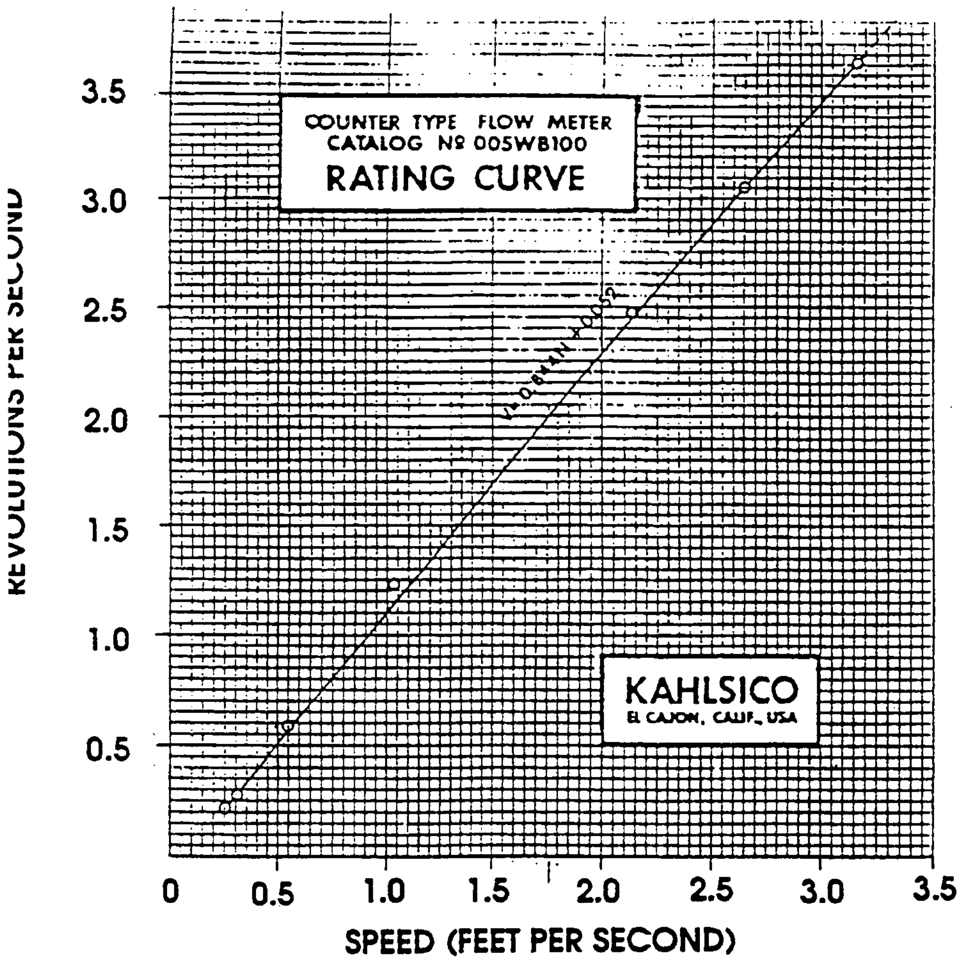
Calculations Used in Analysis of Netted Samples

Calculations used to obtain egg and larvae densities from net data were: Mouth area of the net multiplied by the number of linear feet that passed through the net during the sample period. The number of meters of water filtered was obtained by using the specific flowmeter counts in the calibrated regression calculation. In 1992, the calibration was: Feet = 0.8766 * total counts on flow meter + 0.152 ($Y = 0.8766 \times revs + 0.152$). Conversion to meters was performed by dividing by 3.281; this result was then multiplied by the square meter area of the net mouth to provide number of cubic meters of water filtered per sample.

Calculations Used in Analysis of Continuous Sampled Eggs and Larvae

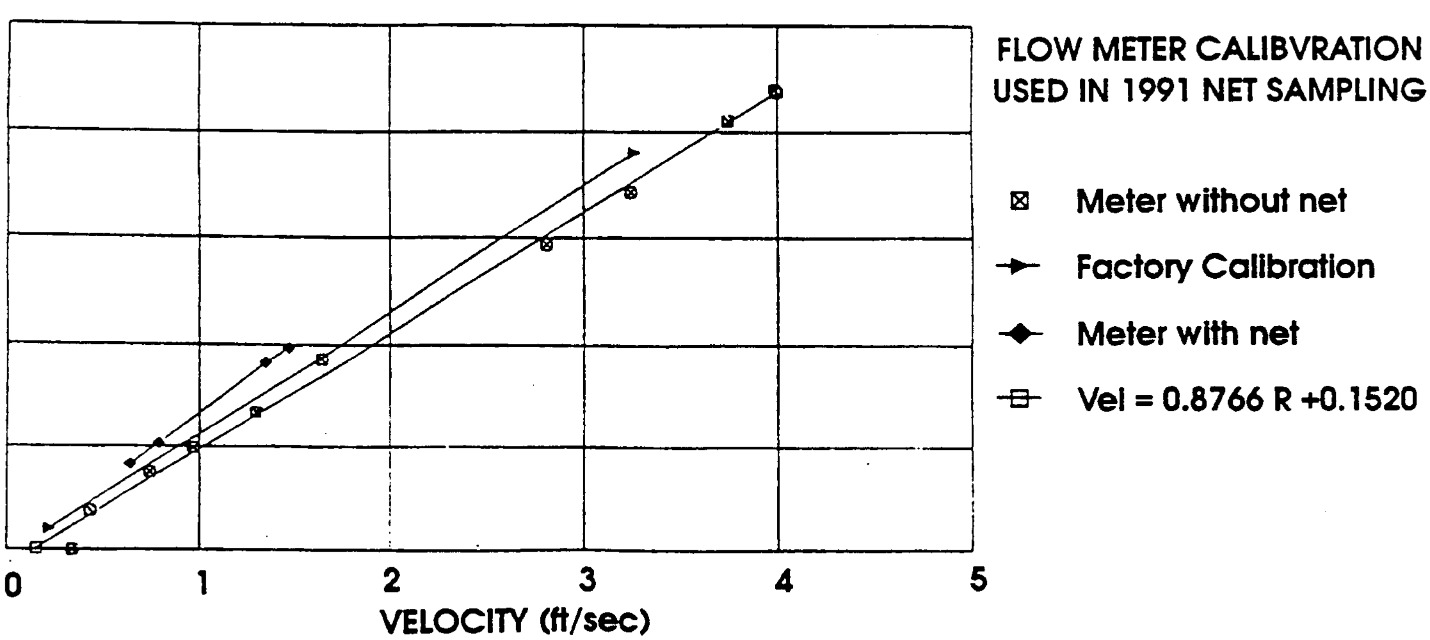
Calculations to obtain egg and larval densities from the continuous sampler data were: The rate in GPM (gallons per minute) x the duration in minutes. This result was multiplied times 0.003785 to convert to cubic meters per sample. The density was obtained by dividing the numbers of organisms in the sample by the cubic meters of water pumped for that sample.

Appendix C. Flow meter calibration



FLOW METER CALIBVRATION
USED IN 1991 NET SAMPLING

KAHLSICO FLOW METER #A



Appendix D. Results from egg and larvae collection efficiency tests conducted with the continuous sampling device at TFCF, Spring 1991.

	Test Type	Test Duration	Recovery Counts
Test A	Eggs through pump	5 minutes	37 eggs
Test F	Eggs through pump	5 minutes	45 eggs
Test #3	Eggs through pump	90 minutes	40 eggs
Test #4	Eggs in headbox	5 minutes	45 eggs
Test C	Larvae through pump	5 minutes	28 larvae
Test D	Larvae through pump	5 minutes	13 larvae
Test JJ	Larvae through pump	5 minutes	27 larvae
Test J	Larvae through pump	5 minutes	2 larvae
Test #31	Larvae through pump	90 minutes	9 larvae
Test N	Larvae through pump	90 minutes	0 larvae
Test P	Larvae introduced into headbox	5 minutes	30 larvae
Test S	Larvae introduced into headbox	5 minutes	36 larvae
Test M	Larvae introduced into headbox	5 minutes	33 larvae
Test L	Preserved larvae through pump	90 minutes	21 larvae

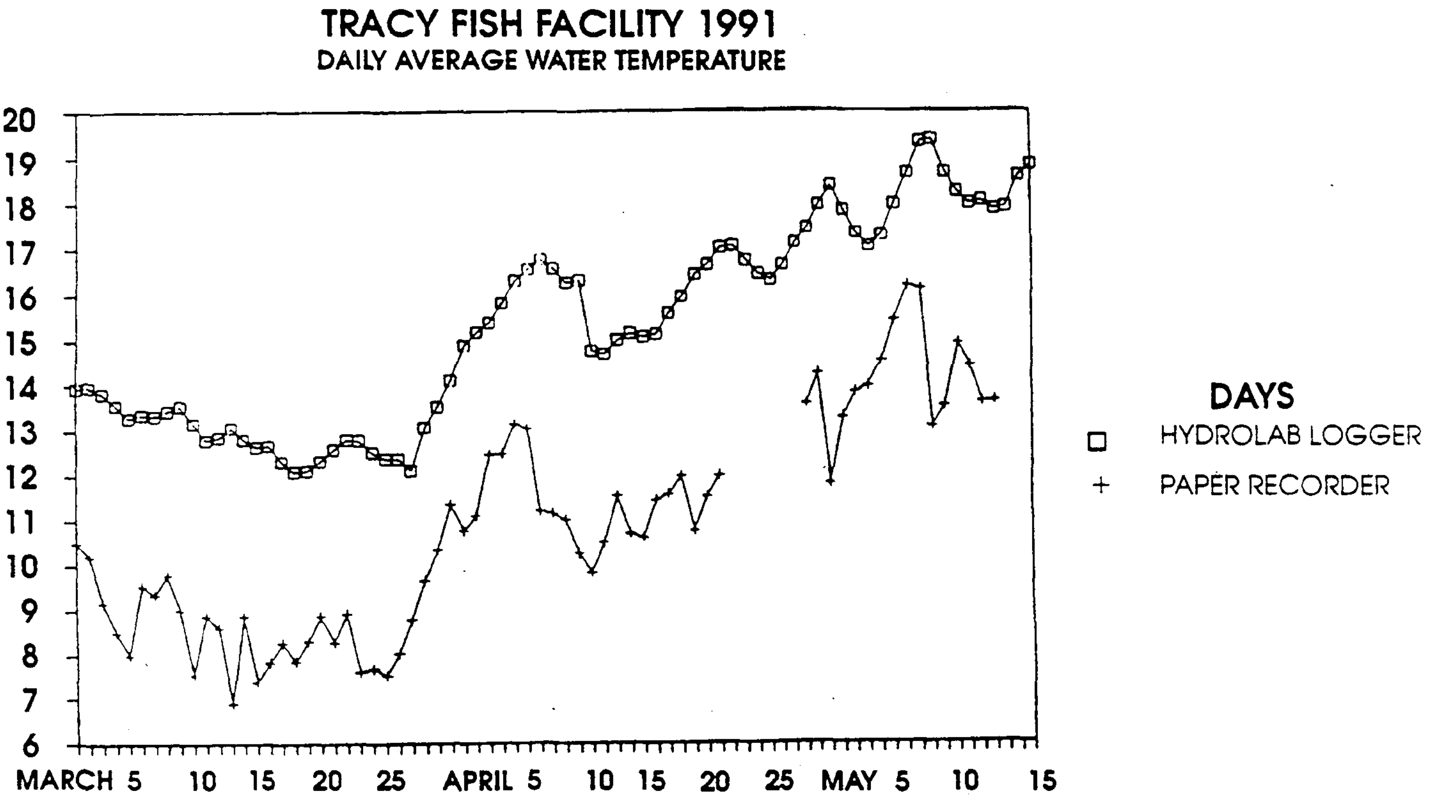
Appendix E. Percent total of each species collected during day and night samples in 1991. Asterisk (*) indicates a species with small (<20) sample size.

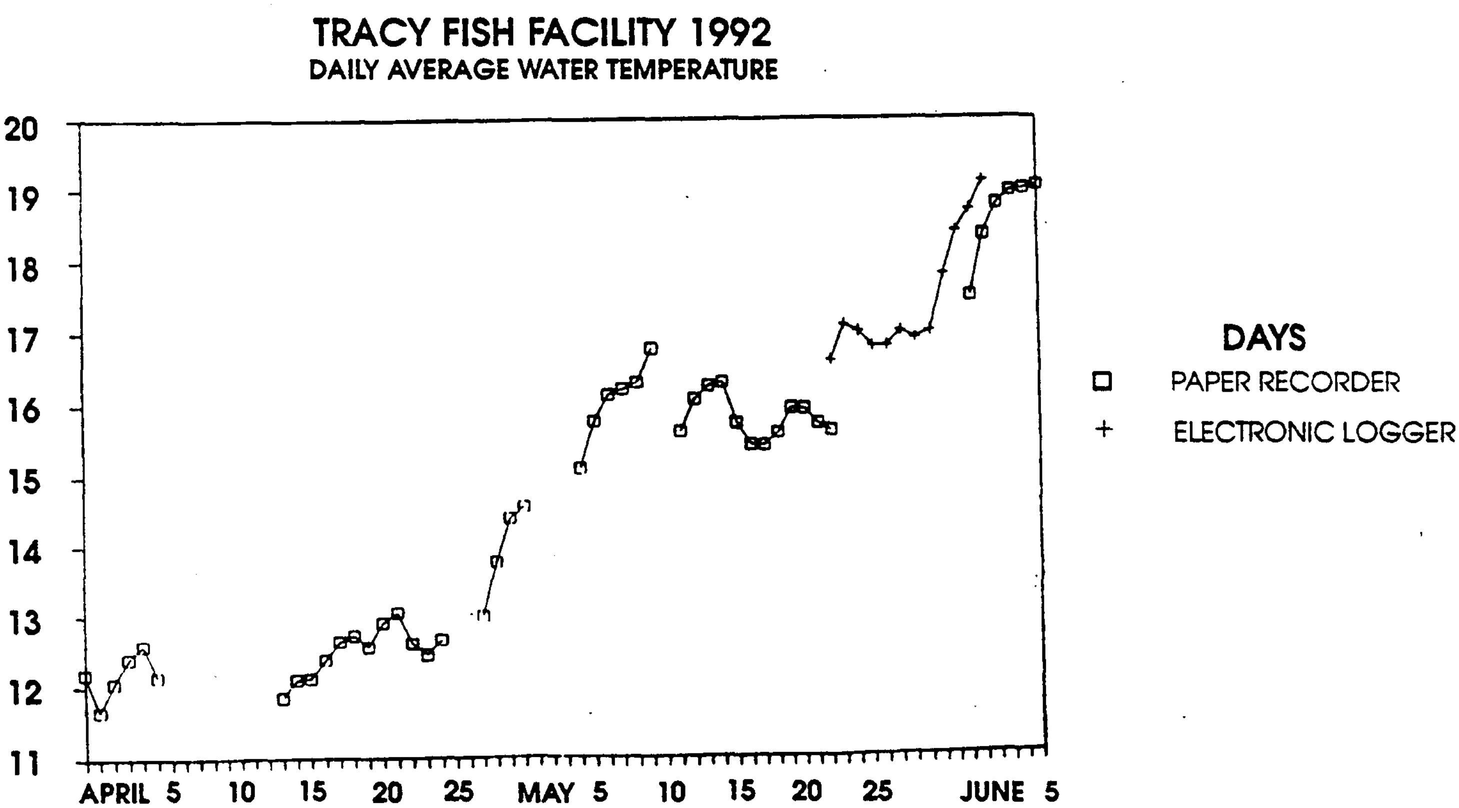
Species	DARK Midnight to 6 am	LIGHT 6 am to 8 pm	DARK 8 pm to Midnight
Striped bass eggs	25%	10%	65%
Striped bass larvae	56%	32%	12%
Prickly sculpin larvae	40%	28%	33%
Chameleon Goby Larvae	18%	69%	12%
Centrachidae larvae *	0%	100%	0%
Bigscale logperch larvae *	0%	100%	0%
Splittail larvae *	43%	14%	43%
Delta Smelt larvae *	0%	100%	0%
Cyprinidae eggs	0%	99%	1%
Cyprinidae larvae	14%	71%	14%
Threadfin shad larvae *	50%	0%	50%
White Catfish larvae *	50%	50%	0%
Yellowfin Goby Larvae *	0%	100%	0%

Appendix F. Percent total of each species collected during day and night samples in 1992. Asterisk (*) indicates a species with small (<20) sample size.

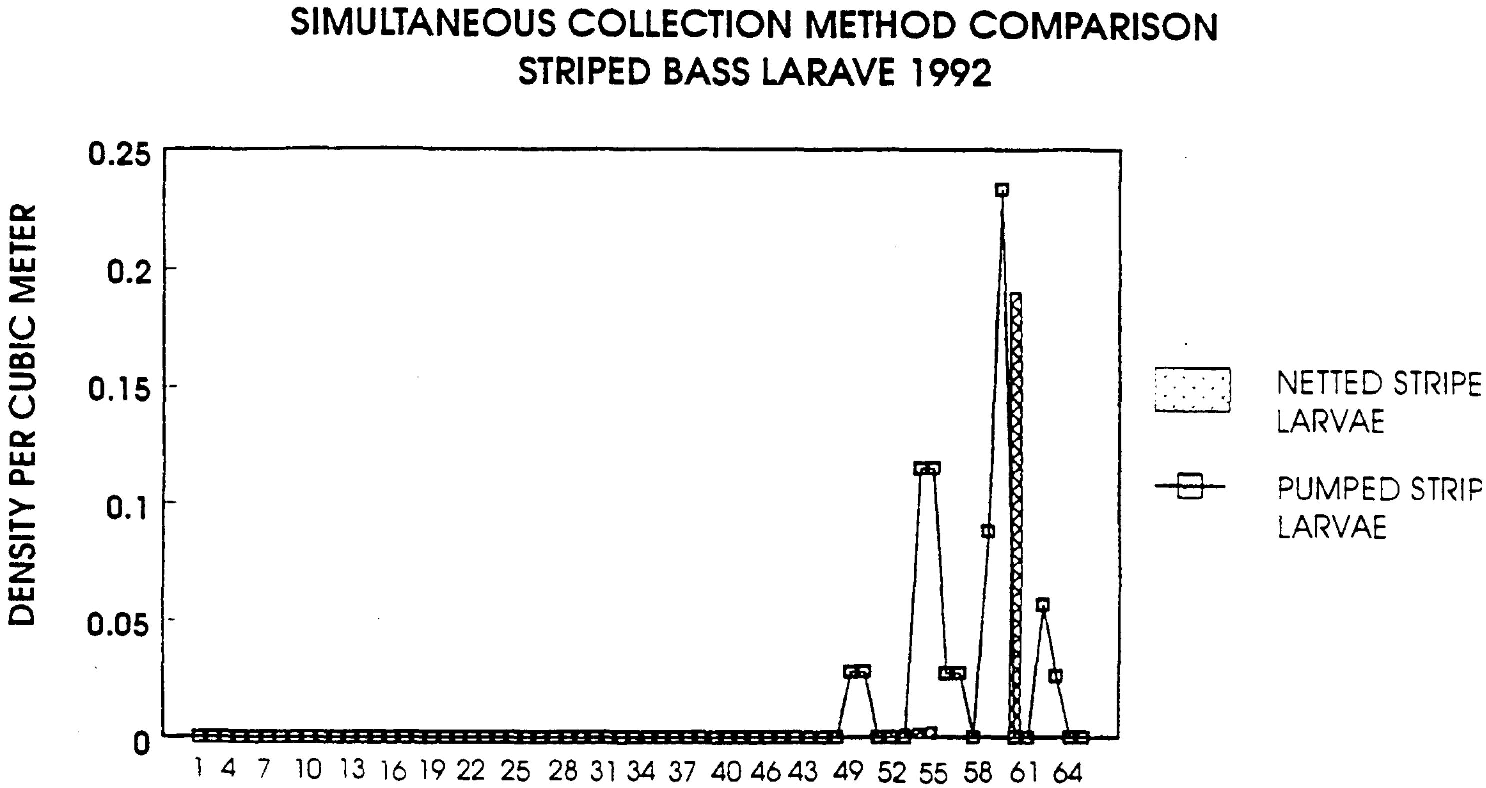
Species	DARK Midnight to 6 am	LIGHT 6 am to 8 pm	DARK 8 pm to Midnight
Striped bass eggs	71%	22%	8%
Striped bass larvae	34%	46%	20%
Striped bass juveniles	23%	60%	17%
Prickly Sculpin eggs	3%	90%	7%
Prickly Sculpin larvae	4%	77%	18%
Chameleon goby eggs	22%	58%	20%
Chameleon goby larvae	7%	76%	16%
Centrarchidae eggs *	0%	14%	86%
Centrachidae larvae	56%	33%	10%
Bigscale logperch larvae	5%	90%	5%
Inland silverside larvae	99%	0%	1%
Delta Smelt larvae *	0%	100%	0%
Cyprinidae eggs *	0%	100%	0%
Cyprinidae larvae	12%	75%	12%
Threadfin shad larvae	44%	28%	27%
Sacramento sucker larvae *	0%	100%	0%
Carp larvae	16%	80%	4%
Longfin smelt larvae *	0%	100%	0%
Ictalurus larvae *	17%	17%	66%

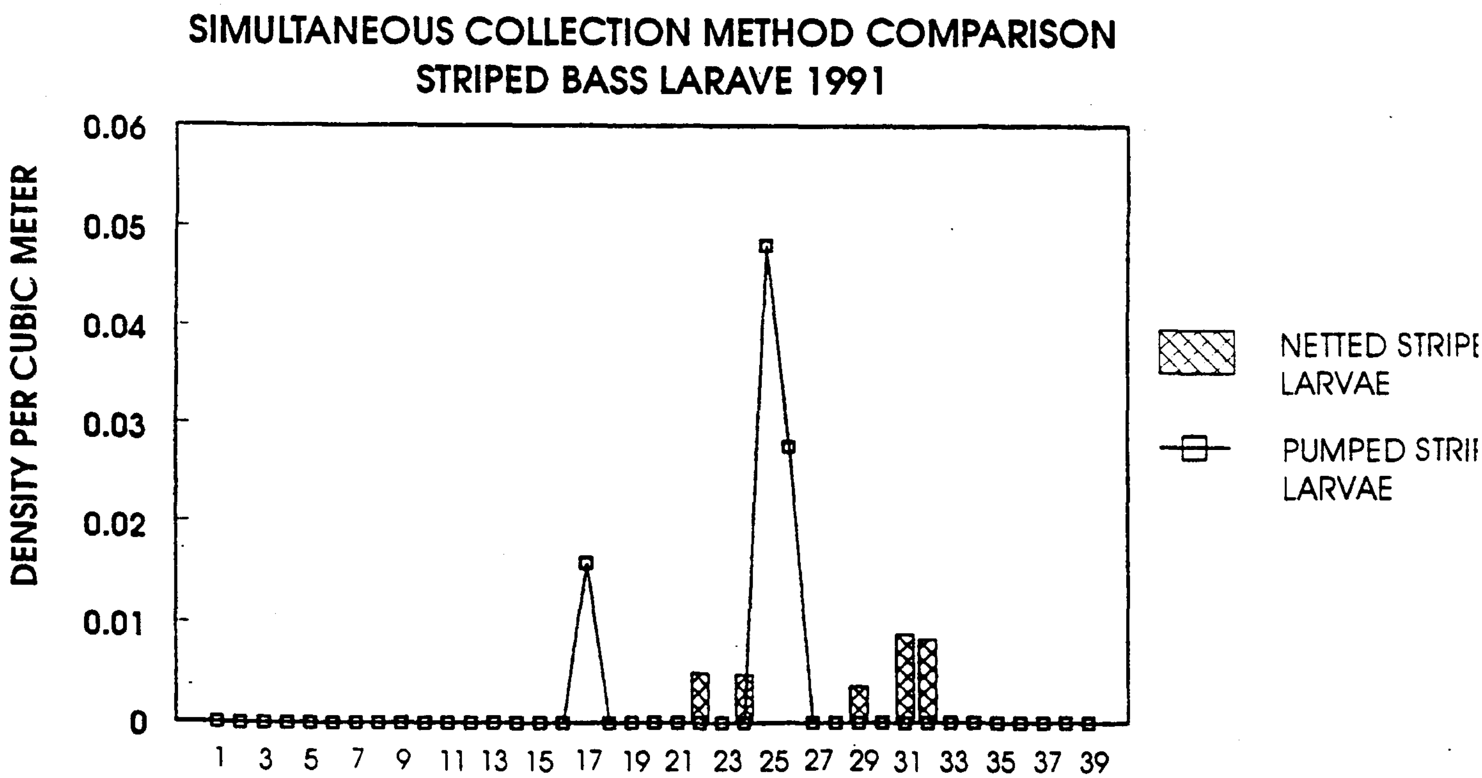
Appendix G. Daily average water temperature comparisons between the electronic and paper recorders.



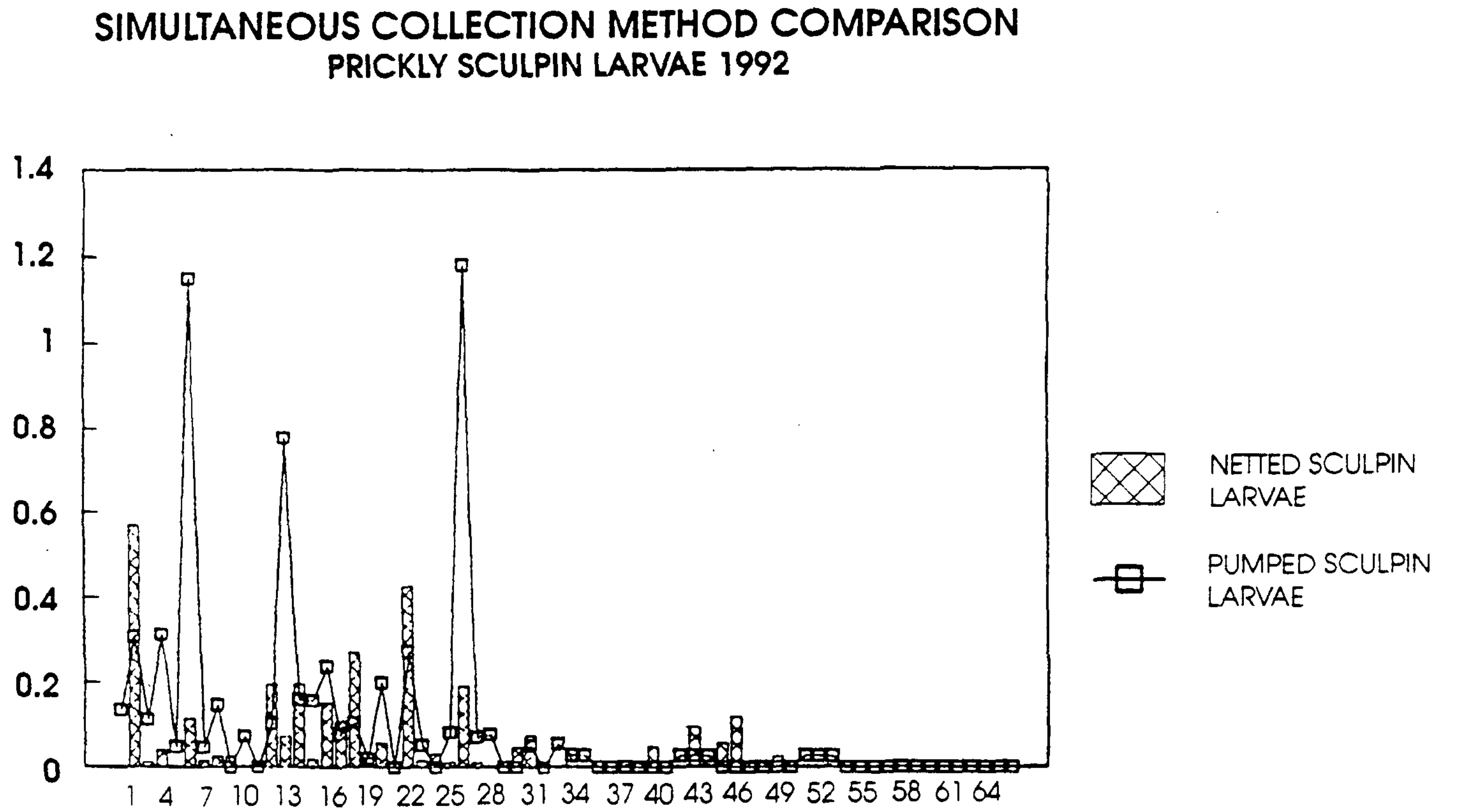


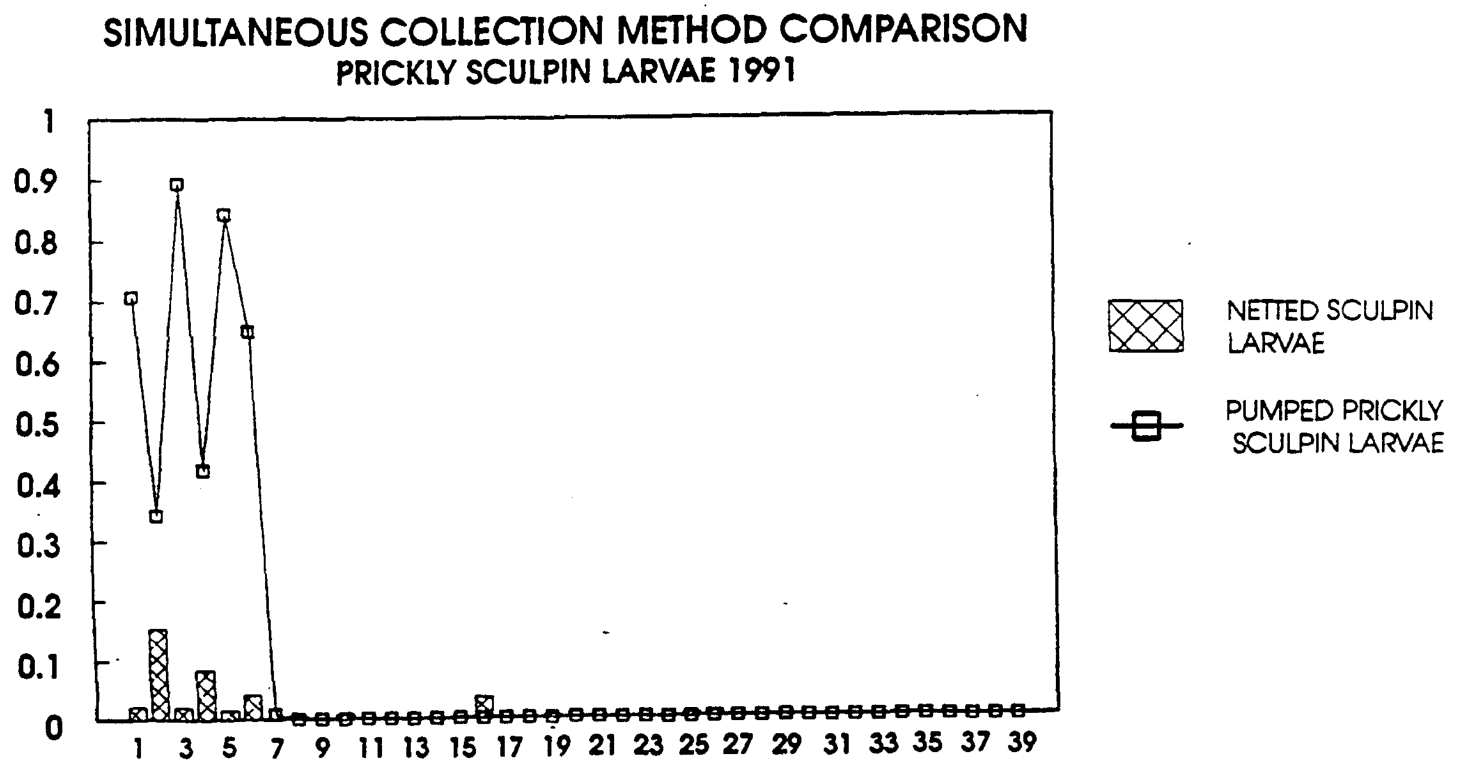
Appendix H. Figures illustrating comparisons of sampling gear by species.





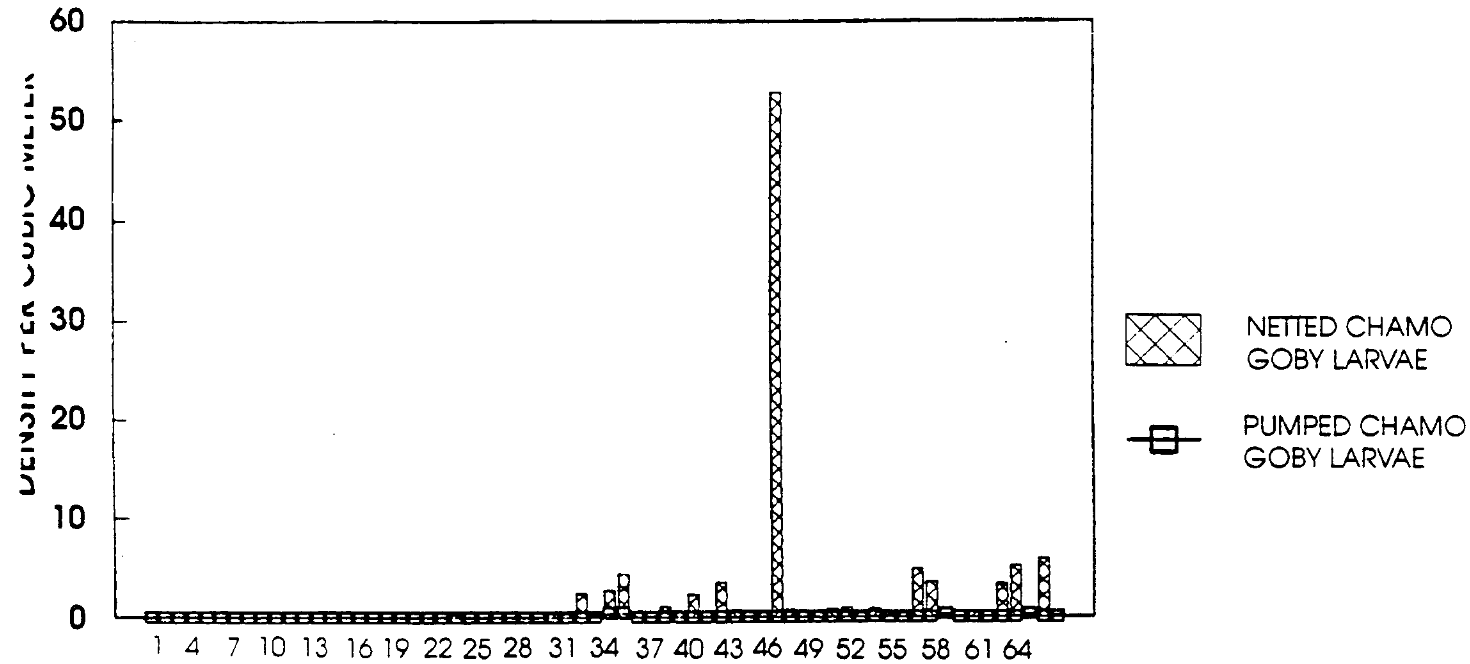
Appendix H. (Continued)



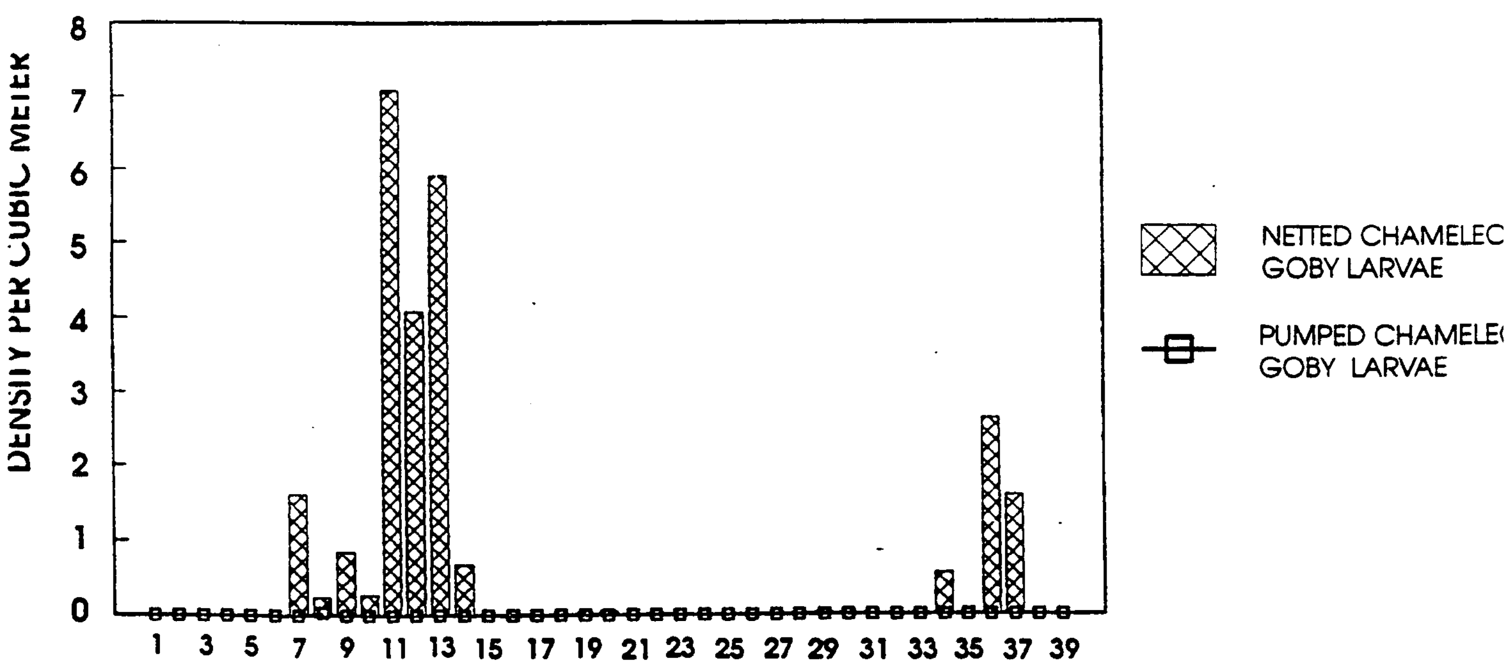


Appendix H. (Continued)

SIMULTANEOUS COLLECTION METHOD COMPARISON
CHAMELEON GOBY LARVAE 1992

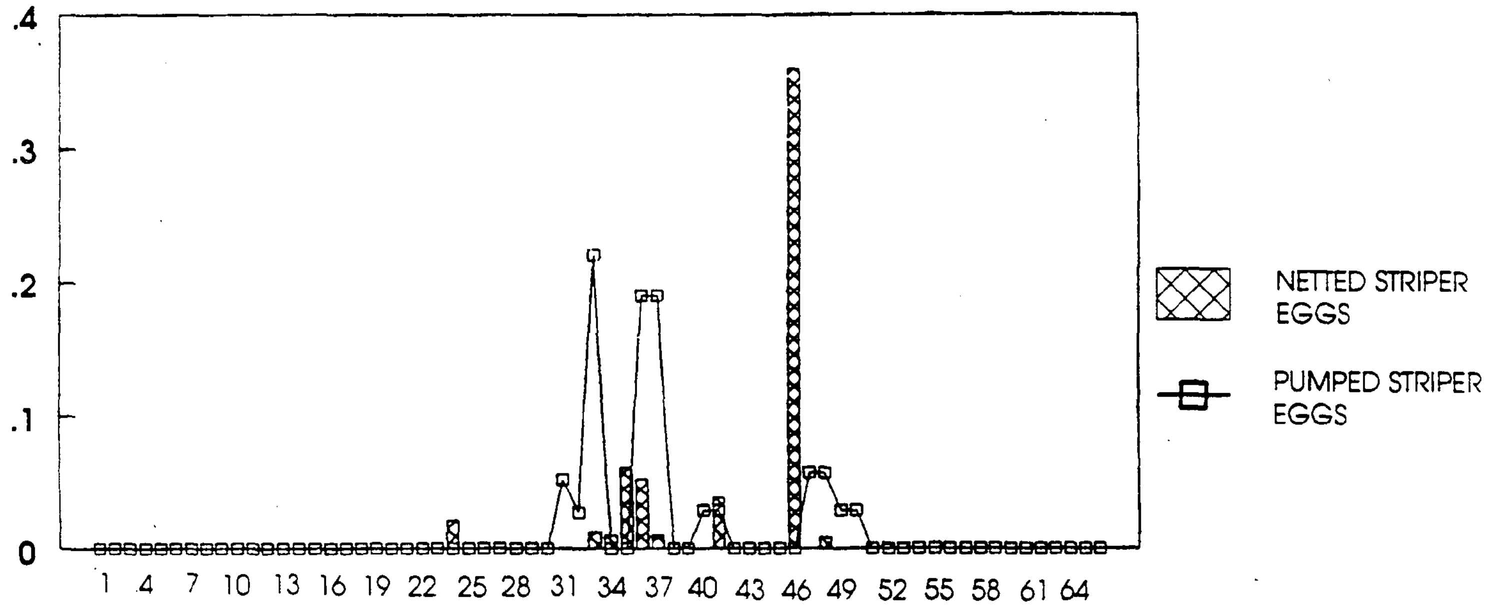


SIMULTANEOUS COLLECTION METHOD COMPARISON
CHAMELEON GOBY LARVAE 1991

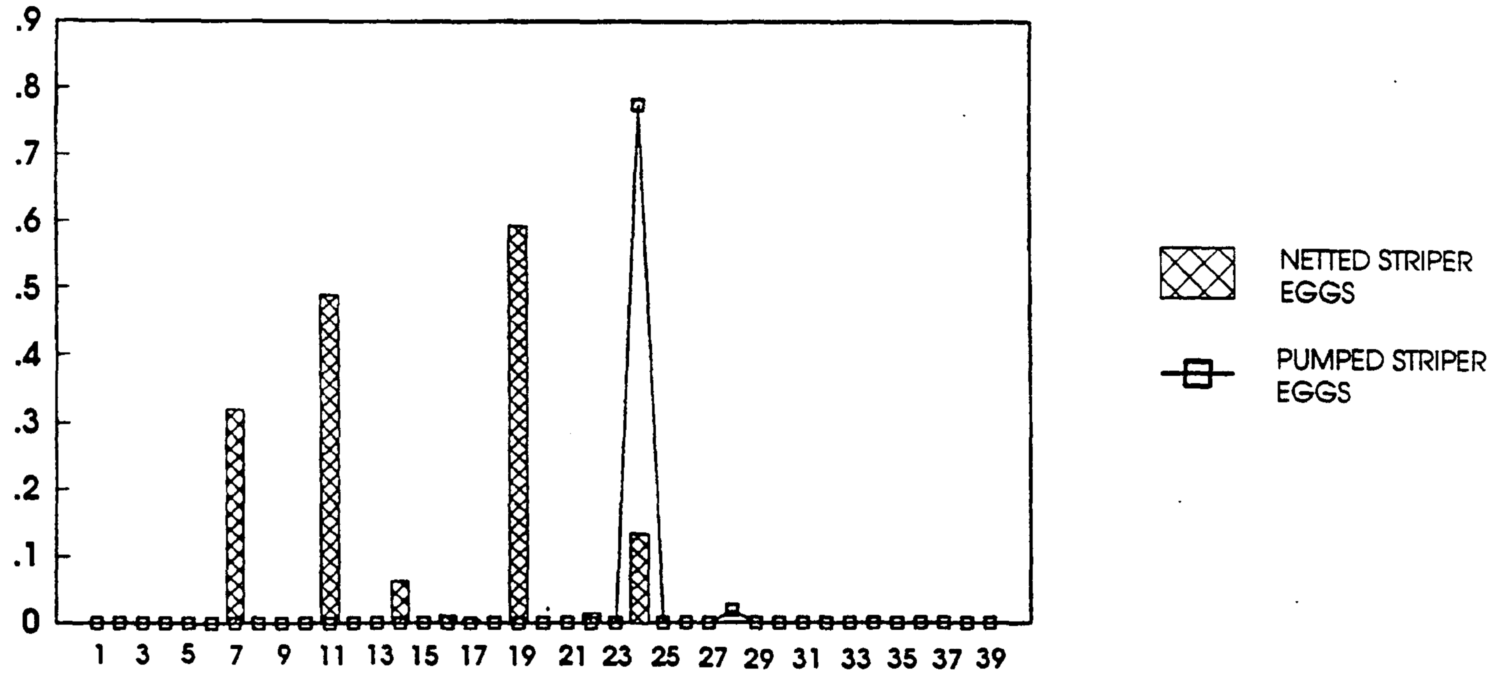


Appendix H. (Continued)

SIMULTANEOUS COLLECTION METHOD COMPARISON
STRIPED BASS EGGS 1992



SIMULTANEOUS COLLECTION METHOD COMPARISON
STRIPED BASS EGGS 1991



Appendix I. Estimated entrainment of striped bass eggs and larvae through the Tracy Fish Collection Facility using continuous sampler data and DWR data, 1991 and 1992.

1991

DATE	Continuous Sampled Striped Bass EGGS Total	DWR Sampled Striped Bass EGGS Total	Continuous sampled Striped Bass LARVAE Total	DWR Sampled Striped Bass LARVAE Total
May 1-15, 1991	1,544,700	2,784,000	304,624	7,892,000
May 16-31, 1991	22,331,834	1,951,000	889,808	8,614,000
June 1-12, 1991	75,981	0	1,149,113	822,000
Grand Totals	23,952,515*	4,735,000	2,343,545	17,328,000

* This table only uses dates of continuous sampler operation. DWR samples were collected earlier and later than this time period.

1992

DATE	Continuous sampled STRIPED BASS EGGS Total	DWR Sampled STRIPED BASS EGGS Total	Continuous sampled STRIPED BASS LARVAE Total	DWR Sampled STRIPED BASS LARVAE Total
Feb 20-29, 1992	0	0	0	0
March 1-15, 1992	0	0	0	0
March 16-31, 1992	0	0	0	0
April 1-15, 1992	118,528	0	110,224	1,025,000
April 16-30, 1992	1,181,956	8,578,000	195,056	1,515,000
May 1-15, 1992	1,887,635	0	5,916,141	4,603,000
May 16-31, 1992	0	0	6,666,170	3,608,000
June 1-3, 1992	0	0	142,481	na
Grand totals	3,188,119	8,578,000	13,029,97	10,751,000

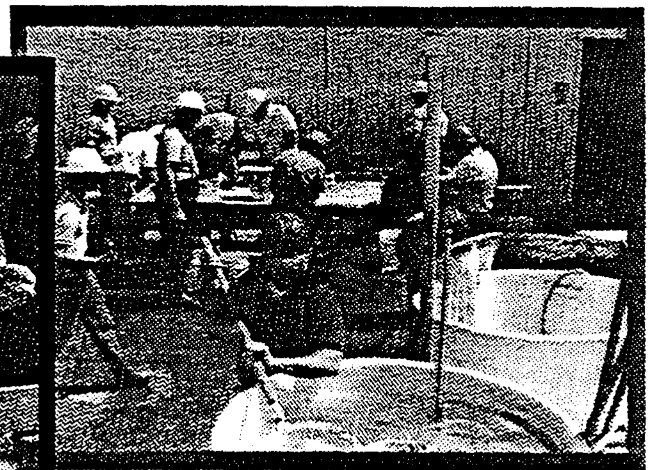
* This table only uses dates of continuous sampler operation. DWR samples were collected later than this time period

Appendix J. Results from egg and larvae collection efficiency tests conducted with the continuous pump sampling device at Tracy Fish Collection Facility, Spring 1993.

	Test Type	Test Duration	Recovery Counts	% of Total
Test A	Larvae through pump	5 minutes	15 larvae	30 %
Test B	Larvae through pump	5 minutes	11 larvae	22 %
Test C	Larvae through pump	5 minutes	26 larvae	52 %
Test D	Larvae through pump	5 minutes	21 larvae	42 %
Test E	Larvae through pump	5 minutes	21 larvae	42 %
Test F	Larvae through pump	5 minutes	7 larvae	14 %
Test G	Larvae through pump	5 minutes	28 larvae	56%
Test H	Larvae through pump	5 minutes	27 larvae	54%
Test I	Larvae through pump	5 minutes	17 larvae	34%
Test J	Larvae introduced into headbox	5 minutes	24 larvae	48%
Test K	Larvae introduced into headbox	5 minutes	10 larvae	20%
Test L	Larvae introduced into funnel after screen	5 minutes	57 larvae	100% +
Test M	Larvae through pump	5 minutes	22 larvae	44%
Test N	Larvae through pump	5 minutes	18 larvae	36%
Test O	Larvae introduced into headbox	5 minutes	38 larvae	76%
Test P	Larvae through pump collected in exhaust water	10 minutes	45 larvae out of about 500	
Test Q	Larvae through pump	60 minutes	46 larvae	92%
Test R	Larvae through pump	60 minutes (held overnight)	32 larvae*	32%
Test S	Eggs through pump	5 minutes	52 eggs	100%
Test T	Eggs through pump	5 minutes	47 eggs	94%
Test U	Eggs introduced into headbox	5 minutes	50 eggs	100%
Test V	Eggs introduced into headbox	5 minutes	56 eggs	100%

Test W	Eggs through pump	60 minutes	50 eggs	100%
Test X	Eggs through pump	60 minutes	52 eggs	100%

* Malfunction of preservation solution injection system overnight



Tracy Fish Collection Facilities