

ESTIMATED ENTRAINMENT OF
STRIPED BASS EGGS AND LARVAE AT
STATE WATER PROJECT AND CENTRAL VALLEY PROJECT FACILITIES
IN THE SACRAMENTO-SAN JOAQUIN DELTA
1985 AND 1986

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ABSTRACT

A striped bass egg and larval sampling program was conducted in the southern Delta near the intakes of the State Water Project (SWP) and Central Valley Project (CVP) during spring 1985 and 1986. The information is being used to estimate entrainment of striped bass eggs and larvae by these diversions and will allow comparison of this method to Baracco's (1983) method.

Striped bass eggs and larvae entrained by the SWP were estimated to be 441.1 million in 1985 and 51.9 million in 1986. Baracco's method estimated 2.573 billion for 1985 and 727.6 million for 1986. Striped bass eggs and larvae entrained by the CVP were estimated to be 352.5 million in 1985 and 47.8 million in 1986. Baracco's method estimated 1.795 billion in 1985 and 95.1 million in 1986. Entrainment estimates based on densities taken near the points of diversion should provide more accurate estimates than those calculated by Baracco.

INTRODUCTION

Striped bass are entrained with water diverted by State Water Project (SWP) and Central Valley Project (CVP) pumping plant facilities in the southern Delta. To define SWP and CVP impacts on striped bass, numbers of striped bass eggs and larvae lost to these diversions were estimated based on densities of eggs and larvae available to be entrained and the amount of water being exported. Density estimates were obtained by sampling with an egg and larval net in

the channels immediately adjacent to each point of diversion. Additional stations were also sampled in the vicinity of the diversions to obtain information on the source of the eggs and larvae, but those samples are not dealt with in this report.

Losses of eggs and larvae were also calculated using the procedure described by Baracco (1983) to compare the two methods.

MATERIALS AND METHODS

An egg and larval survey was conducted from mid-April to mid-July in 1985 and 1986 at five locations in the southern Delta (Figure 1). A sixth location was added in 1986.

- * Station 91 (ROLD 38) is about 1/2 mile upstream of the Highway 4 bridge on Old River.
- * Station 92 (DHWST 0) is on West Canal about 650 feet downstream of the intake to Clifton Court Forebay.
- * Station 95 (CHNRT 0) is on North Canal about 300 feet downstream of the confluence of North Canal and Old River (where the canal becomes straight).
- * Station 96 (ROLD 47) is on Old River about 1,300 feet downstream of the intake to the CVP.
- * Station 97 (CHGRL 0) is on Grant Line Canal about 1,650 feet upstream of the confluence of Grant Line Canal and Old River (where the canal becomes straight).
- * Station 98 (CHGRL 11) (1986 addition) is on Grant Line Canal near the mouth of Salmon Slough.

In 1985, samples were taken at each station every other day from April 16 to May 22 and every fourth day from May 16 to July 13. In 1986, samples were taken at each station every other day from April 16 to July 11. Samples were taken by making a single 10-minute oblique tow, regardless of tidal stage, at each station with an egg and larval net mounted on a ski frame. When heavy blooms of filamentous algae occurred, 5-minute tows, and sometimes 2.5-minute tows, were made because of net clogging. Boat speed was adjusted to

maintain a towing cable angle declination of about 71 degrees. A cone-shaped net 30 inches in diameter at the opening and 10 feet long, made of 505-micron mesh Nitex netting was used. A 32-ounce plastic collecting jar, screened with 470-micron mesh bolting cloth, was attached at the cod end to collect samples. At the end of each tow, contents of the net were rinsed into the collecting jar, and the sample was preserved in a 5 percent formalin and rose bengal dye solution. The rose bengal dye makes eggs and larvae more visible and easy to distinguish from detritus. The sampling methods are essentially identical to those by Fish and Game in its Delta striped bass egg and larval sampling program.

A digital flowmeter (Oceanics Model 2030) was used to measure water flow through the net and subsequently compute the cubic meters of water sampled. The flowmeter was calibrated by the Hydraulic Laboratory at the University of California, Davis.

Surface water temperature, water transparency (secchi disc), and surface electrical conductivity were measured at each sampling site.

In the lab, samples were rinsed thoroughly with water through a No. 50 sieve (300-micron mesh) to remove formalin, excess dye, and algae. Samples were then placed in plexiglass trays, and fish eggs and larvae were sorted under a lighted magnifying lens. Samples with heavy detritus or large numbers of eggs and/or larvae were subsampled (either 1/2, 1/4, or 1/16 of the total sample was sorted). Eggs were identified to species, where possible, and counted; striped bass eggs were further classified as dead,

0-8 hours old, or 9-36 hours old. Fish larvae were classified to family and in some cases to species. Striped bass larvae were measured to the nearest millimeter standard length. Eggs and larvae in about 2.5 percent of the samples were identified and measured a second time as a quality control measure.

Daily amount of Clifton Court Forebay inflow (acre-feet) for the SWP (DWR 1985) and daily exports (acre-feet) for the CVP (DFG, Bay-Delta Project, unpublished data) for April through July were obtained from daily operation summaries for each facility (Appendixes A and B).

To estimate density of striped bass eggs and larvae entrained by the SWP and CVP facilities, densities at sample stations immediately in line with the intake of each facility (Stations 96 and 92, respectively) were used. Data were broken down into size groups (eggs and 3-6mm, 7-10mm, 11-14mm, 15-18mm, and 19-20mm larvae). Densities (eggs

or larvae per cubic meter) for each size group were calculated for each sample station by day. Daily inflow to Clifton Court Forebay for the SWP and daily export by the CVP were then multiplied by the appropriate density of eggs and larvae. For days when no samples were taken, the previous day's densities were used to calculate entrainment.

Baracco (1983) estimated entrainment by averaging densities at sample stations about one tidal excursion above and below the mouth of Old River, DFG stations 49, 51, 53, 55, 57, 59, and 60 (Figure 1). Data from these stations were broken down by the same size groups as for the 1985-1986 method. Mean densities for each size group were calculated by 10-day periods (encompassing 5 survey days) throughout the survey period.

Methods for estimating losses at the SWP and CVP facilities were compared for the 1985 and 1986 data.

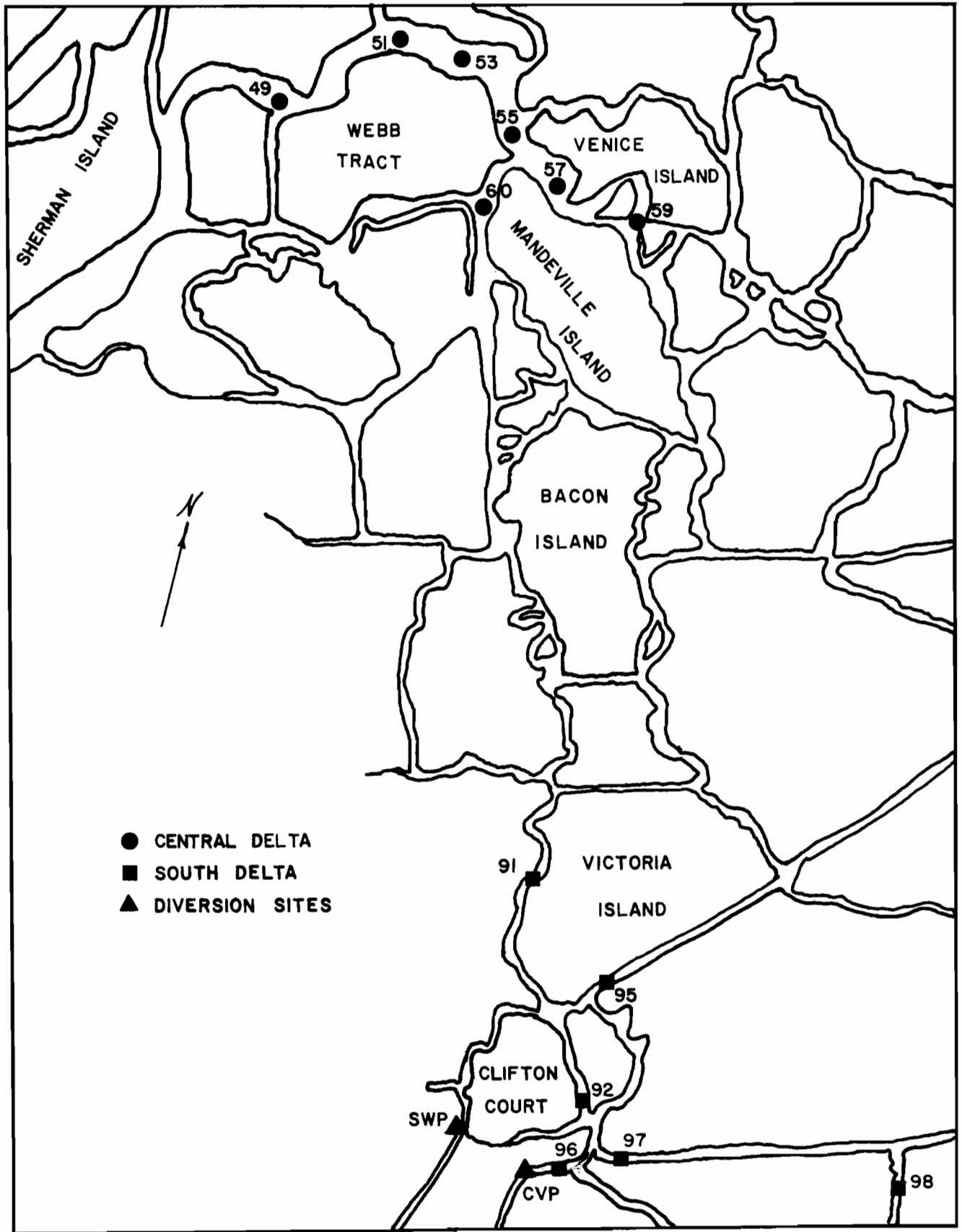


Figure 1. Central and south Delta egg and larval sampling stations and State Water Project and Central Valley Project Diversion sites.

RESULTS

Total estimated entrainment by the SWP and CVP of striped bass eggs and larvae less than 21mm in length as measured by an egg and larval survey near the intakes (our method) were 793.6 million in 1985 and 99.7 million in 1986. Combined exports during this time totaled 1.22 million acre-feet for 1985 and 1.1 million acre-feet for 1986.

State Water Project

In both 1985 and 1986, bimonthly average densities of striped bass eggs near the intake to the SWP were highest during the period May 1-15 (0.6064 eggs/m³ in 1985 and 0.027 eggs/m³ in 1986) (Table 1). Egg and larval densities in 1985 were considerably higher than those in 1986 for all size groups. No eggs were observed after June 6th. Bimonthly average densities of striped bass larvae were highest during May 16-31 of both years. Average densities of all larvae per cubic meter during this period were 0.3530 in 1985 and 0.0710 in 1986.

Striped bass eggs and larvae entrained by the SWP were estimated to be 441.1 million in 1985 and 51.9 million in 1986 (Table 2). In 1985, an estimated 85.9 million eggs were entrained; only 3.8 million were entrained in 1986. Entrainment was greatest for larvae in the 3-6mm size group in both years: 307.4 million in 1985 and 27.1 million in 1986.

Surface water temperature, water transparency (secchi disc), and surface electrical conductivity at the sampling

station near the intake to the SWP for both years were averaged on a bimonthly basis (Table 3).

Central Valley Project

Bimonthly average densities of striped bass eggs near the intake to the CVP were highest during May 1-15, 1985 (0.4832 eggs/m³), while in 1986 the high was during the May 16-31 period (0.0628 eggs/m³) (Table 4). Bimonthly average densities of striped bass larvae were highest during May 16-31 in both years. Average densities of all larvae per cubic meter during this period were 0.4477 in 1985 and 0.0511 in 1986. Egg and larval densities in 1985 were considerably higher than those in 1986 for larvae 10mm and less; densities for larvae greater than 10mm were higher in 1986.

Striped bass eggs and larvae entrained by the CVP were estimated to be 352.5 million in 1985 and 47.8 million in 1986 (Table 5). In 1985, an estimated 84.9 million eggs were entrained, while only 9.3 million eggs were entrained in 1986. Entrainment was greatest for larvae in the 3-6mm size group (237.2 million) in 1985; in 1986 the 7-10mm size group had the greatest entrainment (29.1 million).

Surface water temperature, water transparency (secchi disc), and surface electrical conductivity at the sampling station near the intake to the CVP for both years were averaged on a bimonthly basis (Table 6).

TABLE 1. STRIPED BASS EGG AND LARVAL 1985 AND 1986 AVERAGE DENSITY (FISH PER CUBIC METER) ESTIMATES NEAR THE INTAKE TO THE SWP.

| | SIZE GROUPS | | | | | |
|--------------|-------------|--------|---------|----------|----------|----------|
| | EGGS | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 1985 DENSITY | | | | | | |
| APR 16-30 | 0.0231 | 0.3285 | 0.0345 | 0 | 0 | 0 |
| MAY 1-15 | 0.6064 | 0.6052 | 0.1232 | 0 | 0 | 0 |
| MAY 16-31 | 0.0722 | 1.0399 | 0.0169 | 0.0023 | 0 | 0 |
| JUN 1-15 | 0.0085 | 0.4093 | 0.0799 | 0 | 0 | 0 |
| JUN 16-30 | 0 | 0.1569 | 0.1039 | 0.0120 | 0 | 0 |
| JUL 1-13 | 0 | 0.0030 | 0.0074 | 0.0059 | 0 | 0 |

$7-20\text{ mm Mean} = 0.6643 \text{ fish/m}^3 = 79.354 \text{ fish/AF}$

1986 DENSITY

| | | | | | | |
|-----------|--------|--------|--------|--------|--------|--------|
| APR 16-30 | 0.0025 | 0 | 0 | 0 | 0 | 0 |
| MAY 1-15 | 0.0277 | 0.0458 | 0.0167 | 0 | 0 | 0 |
| MAY 16-31 | 0.0045 | 0.1561 | 0.0513 | 0.0054 | 0 | 0 |
| JUN 1-15 | 0.0006 | 0.0118 | 0.0501 | 0.0301 | 0.0061 | 0 |
| JUN 16-30 | 0 | 0 | 0 | 0.0008 | 0 | 0 |
| JUL 1-11 | 0 | 0.0063 | 0.0025 | 0.0084 | 0.0016 | 0.0030 |

$7-20\text{ mm Mean} = 0.0293 \text{ fish/m}^3 = 36.182 \text{ fish/AF}$

TABLE 2. STRIPED BASS EGG AND LARVAL 1985 AND 1986 ENTRAINMENT ESTIMATES FOR THE SWP INTAKE.

| | SIZE GROUPS | | | | | |
|------------------|-------------|-----------|----------|----------|----------|----------|
| | EGGS | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 1985 ENTRAINMENT | | | | | | |
| APR 16-30 | 3161003 | 38461069 | 4289227 | 0 | 0 | 0 |
| MAY 1-15 | 72754238 | 69328241 | 13288904 | 0 | 0 | 0 |
| MAY 16-31 | 9186982 | 133014715 | 2281900 | 337231 | 0 | 0 |
| JUN 1-15 | 776332 | 42792309 | 8809719 | 0 | 0 | 0 |
| JUN 16-30 | 0 | 23174110 | 15141675 | 1919412 | 0 | 0 |
| JUL 1-13 | 0 | 455787 | 1090896 | 879193 | 0 | 0 |
| TOTAL | 85878556 | 307226231 | 44902321 | 3135835 | 0 | 0 |

GRAND TOTAL

441,142,942

$7-20\text{ mm} = 48,026,156$

1986 ENTRAINMENT

| | | | | | | |
|-----------|---------|----------|----------|---------|--------|--------|
| APR 16-30 | 232044 | 0 | 0 | 0 | 0 | 0 |
| MAY 1-15 | 2925636 | 4700959 | 1701729 | 0 | 0 | 0 |
| MAY 16-31 | 535473 | 20319317 | 6024493 | 622261 | 0 | 0 |
| JUN 1-15 | 78070 | 1278781 | 6191257 | 3839482 | 695104 | 0 |
| JUN 16-30 | 0 | 0 | 0 | 131636 | 0 | 0 |
| JUL 1-11 | 0 | 771049 | 296738 | 1022474 | 188306 | 353651 |
| TOTAL | 3772123 | 27070106 | 14214217 | 5615853 | 883410 | 353651 |

GRAND TOTAL

51,909,361

$7-20\text{ mm} = 21,067,131$

TABLE 3. BIMONTHLY ENVIRONMENTAL PARAMETERS AND EXPORT RATES NEAR THE INTAKE TO THE SWP, APRIL 16 THROUGH JULY 15, 1985 AND 1986.

| | EC (μ MHOS) | SECCHI (cm) | TEMP ($^{\circ}$ F) | EXPORT (ac-ft) |
|-----------|---------------------|----------------|-------------------------|-------------------|
| 1985 | | | | |
| APR 16-30 | 336 | 61 | 63 | 6758 |
| MAY 1-15 | 291 | 40 | 54 | 6280 |
| MAY 16-31 | 353 | 35 | 69 | 6002 |
| JUN 1-15 | 263 | 38 | 72 | 5744 |
| JUN 16-30 | 342 | 36 | 75 | 7750 |
| JUL 1-15 | 337 | 49 | 75 | 9218 |
| 1986 | | | | |
| APR 16-30 | 232 | 37 | 62 | 5631 |
| MAY 1-15 | 288 | 41 | 62 | 5982 |
| MAY 16-31 | 315 | 38 | 67 | 6621 |
| JUN 1-15 | 303 | 34 | 71 | 6779 |
| JUN 16-30 | 287 | 30 | 73 | 5364 |
| JUL 1-15 | 246 | 31 | 75 | 8652 |

TABLE 4. STRIPED BASS EGG AND LARVAL 1985 AND 1986 AVERAGE DENSITY (FISH PER CUBIC METER ESTIMATES NEAR THE INTAKE TO THE CVP).

| | EGGS | SIZE | | GROUPS | | |
|--------------|--------|--------|---------|----------|----------|----------|
| | | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 1985 DENSITY | | | | | | |
| APR 16-30 | 0.0095 | 0.2491 | 0.0368 | 0 | 0 | 0 |
| MAY 1-15 | 0.4833 | 0.4933 | 0.0595 | 0 | 0 | 0 |
| MAY 16-31 | 0.2457 | 0.8754 | 0.0200 | 0 | 0 | 0 |
| JUN 1-15 | 0 | 0.3707 | 0.0132 | 0 | 0 | 0 |
| JUN 16-30 | 0 | 0.0645 | 0.0596 | 0 | 0 | 0 |
| JUL 1-13 | 0 | 0 | 0.0070 | 0.0062 | 0 | 0 |
| 1986 DENSITY | | | | | | |
| APR 16-30 | 0.0074 | 0 | 0 | 0 | 0 | 0 |
| MAY 1-15 | 0.0070 | 0.0026 | 0.0006 | 0.0006 | 0 | 0 |
| MAY 16-31 | 0.0628 | 0.0998 | 0.0712 | 0.0282 | 0.0052 | 0 |
| JUN 1-15 | 0.0019 | 0.0087 | 0.0393 | 0.0215 | 0.0011 | 0 |
| JUN 16-30 | 0 | 0.0031 | 0.0129 | 0.0116 | 0.0042 | 0.0043 |
| JUL 1-11 | 0 | 0.0028 | 0.0121 | 0 | 0.0013 | 0.0018 |

TABLE 5. STRIPED BASS EGG AND LARVAL 1985 AND 1986 ENTRAINMENT ESTIMATES FOR THE CVP INTAKE.

| | EGGS | SIZE GROUPS | | | | |
|------------------|----------|-------------|----------|----------|----------|-------------|
| | | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 1985 ENTRAINMENT | | | | | | |
| APR 16-30 | 1441386 | 36453707 | 5358129 | 0 | 0 | 0 |
| MAY 1-15 | 53133878 | 50714312 | 5878537 | 0 | 0 | 0 |
| MAY 16-31 | 30287795 | 107676719 | 2467556 | 0 | 0 | 0 |
| JUN 1-15 | 0 | 42307228 | 1475222 | 0 | 0 | 0 |
| JUN 16-30 | 0 | 6977666 | 6392579 | 0 | 0 | 0 |
| JUL 1-13 | 0 | 0 | 1008369 | 887339 | 0 | 0 |
| TOTAL | 84863059 | 244129632 | 22580392 | 887339 | 0 | 0 |
| GRAND TOTAL | | | | | | 352,460,422 |
| 1986 ENTRAINMENT | | | | | | |
| APR 16-30 | 897433 | 0 | 0 | 0 | 0 | 0 |
| MAY 1-15 | 781887 | 307790 | 73543 | 73543 | 0 | 0 |
| MAY 16-31 | 7368537 | 11917849 | 8468814 | 3389458 | 631474 | 0 |
| JUN 1-15 | 234260 | 937747 | 4031236 | 2458346 | 372145 | 0 |
| JUN 16-30 | 0 | 347403 | 1452850 | 1272731 | 397805 | 527523 |
| JUL 1-11 | 0 | 283243 | 1245136 | 0 | 135265 | 217030 |
| TOTAL | 9272117 | 13794033 | 15271579 | 7194078 | 1536689 | 744553 |
| GRAND TOTAL | | | | | | 47,813,048 |

TABLE 6. BIMONTHLY ENVIRONMENTAL PARAMETERS AND EXPORT RATES NEAR THE INTAKE TO THE CVP, APRIL 16 THROUGH JULY 15, 1985 AND 1986.

| | EC (µMHOS) | SECCHI (cm) | TEMP (°F) | EXPORT (ac-ft) |
|-----------|---------------|----------------|--------------|-------------------|
| 1985 | | | | |
| APR 16-30 | 318 | 55 | 63 | 8196 |
| MAY 1-15 | 343 | 38 | 65 | 5607 |
| MAY 16-31 | 442 | 28 | 68 | 6237 |
| JUN 1-15 | 318 | 36 | 72 | 6108 |
| JUN 16-30 | 341 | 32 | 75 | 5792 |
| JUL 1-15 | 409 | 36 | 75 | 9032 |
| 1986 | | | | |
| APR 16-30 | 238 | 38 | 61 | 6191 |
| MAY 1-15 | 293 | 36 | 62 | 6272 |
| MAY 16-31 | 320 | 33 | 67 | 5643 |
| JUN 1-15 | 303 | 31 | 71 | 5891 |
| JUN 16-30 | 284 | 23 | 73 | 5980 |
| JUL 1-15 | 315 | 29 | 75 | 6865 |

Central Delta Densities
and Entrainment Estimates

Mean striped bass egg densities for 1985 at the central Delta stations (Baracco's method) were highest during the period May 11-20 (2.02692 eggs/m³) (Table 7). Highest larval densities were in the 3-6mm size group (3.71548 fish/m³). Mean densities for 1985 at the central Delta stations were considerably higher than those measured at the SWP and CVP intakes (Table 7 and Figures 2-5). Mean striped bass egg densities for 1986 at the central Delta stations were highest during the period May 11-20 (0.21772 eggs/m³) (Table 8). Highest larval densities were in the 3-6mm size group (1.18947 fish/m³) during the period May 21-30. Mean densities for 1986 at the central Delta stations were lower than those at the SWP and CVP intakes (Table 8 and Figures 6-9).

Mean densities of eggs and larvae for the central Delta stations were considerably higher in 1985 than in 1986.

Entrainment estimates of striped bass eggs and larvae for 1985 using Baracco's (1983) method were 2.573 billion for the SWP and 1.795 billion for the CVP (Table 9). Entrainment losses of eggs were estimated to be 789.6 million for the SWP and 503.3 million for the CVP. Entrainment losses of larvae were highest in the 3-6mm size group: 1.659 billion for SWP and 1.208 billion for CVP.

Entrainment estimates of striped bass eggs and larvae for 1986 using Baracco's method were 727.6 million for SWP and 95.1 million for CVP (Table 10). Entrainment losses of eggs were estimated to be 101.6 million for SWP and 5.5 million for CVP.

In both years, entrainment estimates using Baracco's method were higher than those calculated from densities near the SWP and CVP intakes (our method). Using either method, entrainment estimates for 1985 were considerably higher than those for 1986.

Yearling Equivalent Losses

Entrainment losses for striped bass eggs and larvae during 1985 and 1986 were converted to an equivalent number of one-year-old fish using Baracco's (1983) survival rates (Tables 11 and 12). Striped bass yearling equivalent losses based on central Delta densities (Baracco's method) were:

| | <u>SWP</u> | <u>CVP</u> |
|------|------------|------------|
| 1985 | 293,559 | 207,413 |
| 1986 | 148,916 | 32,874 |

Yearling equivalent losses based on densities taken near the SWP and CVP intakes (our method) were:

| | <u>SWP</u> | <u>CVP</u> |
|------|------------|------------|
| 1985 | 65,177 | 42,861 |
| 1986 | 35,315 | 50,415 |

TABLE 7. STRIPED BASS EGG AND LARVAL 1985 AVERAGE DENSITY (FISH PER CUBIC METER) ESTIMATES IN THE CENTRAL DELTA, AND ADJACENT TO THE SWP AND CVP INTAKES.

DENSITIES IN THE CENTRAL DELTA

| TIME PERIOD | EGGS | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
|-------------|--------|--------|---------|----------|----------|----------|
| 4/11-20 | 0.3281 | 0.5398 | 0.0160 | 0 | 0 | 0 |
| 4/21-30 | 0.6113 | 0.7868 | 0.1148 | 0 | 0 | 0 |
| 5/ 1-10 | 1.4474 | 1.4510 | 0.1072 | 0.0004 | 0 | 0 |
| 5/11-20 | 2.0269 | 2.9408 | 0.1468 | 0 | 0 | 0 |
| 5/21-30 | 0.3908 | 3.7155 | 0.1022 | 0 | 0 | 0 |
| 5/31-6/9 | 0.0436 | 0.9839 | 0.0456 | 0.0007 | 0 | 0 |
| 6/10-19 | 0.0156 | 0.5949 | 0.1124 | 0.0008 | 0 | 0.0002 |
| 6/20-29 | 0.0023 | 0.1256 | 0.1061 | 0.0011 | 0 | 0.0002 |
| 6/30-7/9 | 0 | 0.0068 | 0.0106 | 0.0002 | 0 | 0 |
| 7/10-19 | 0 | 0.0006 | 0.0017 | 0 | 0 | 0 |

DENSITIES NEAR THE SWP INTAKE

| | | | | | | |
|----------|--------|--------|--------|--------|---|---|
| 4/11-20 | 0.0338 | 0.0695 | 0.0082 | 0 | 0 | 0 |
| 4/21-30 | 0.0160 | 0.4631 | 0.0473 | 0 | 0 | 0 |
| 5/ 1-10 | 0.6573 | 0.6391 | 0.1402 | 0 | 0 | 0 |
| 5/11-20 | 0.2102 | 1.1375 | 0.0232 | 0.0046 | 0 | 0 |
| 5/21-30 | 0.0381 | 0.6878 | 0.0134 | 0 | 0 | 0 |
| 5/31-6/9 | 0.0106 | 0.4997 | 0.0918 | 0 | 0 | 0 |
| 6/10-19 | 0 | 0.1973 | 0.0827 | 0 | 0 | 0 |
| 6/20-29 | 0 | 0.0572 | 0.0730 | 0.0182 | 0 | 0 |
| 6/30-7/9 | 0 | 0.0032 | 0.0080 | 0.0064 | 0 | 0 |
| 7/10-19 | 0 | 0 | 0 | 0 | 0 | 0 |

DENSITIES NEAR THE CVP INTAKE

| | | | | | | |
|----------|--------|--------|--------|--------|---|---|
| 4/11-20 | 0.0058 | 0.0559 | 0.0080 | 0 | 0 | 0 |
| 4/21-30 | 0.0108 | 0.2637 | 0.0385 | 0 | 0 | 0 |
| 5/ 1-10 | 0.4586 | 0.5590 | 0.0818 | 0 | 0 | 0 |
| 5/11-20 | 0.4314 | 0.6761 | 0.0232 | 0 | 0 | 0 |
| 5/21-30 | 0.0612 | 0.7199 | 0.0112 | 0 | 0 | 0 |
| 5/31-6/9 | 0 | 0.4450 | 0.0135 | 0 | 0 | 0 |
| 6/10-19 | 0 | 0.1029 | 0.0383 | 0 | 0 | 0 |
| 6/20-29 | 0 | 0.0357 | 0.0655 | 0 | 0 | 0 |
| 6/30-7/9 | 0 | 0 | 0.0067 | 0.0067 | 0 | 0 |
| 7/10-19 | 0 | 0 | 0.0054 | 0 | 0 | 0 |

STRIPED BASS EGGS

1985 DENSITIES

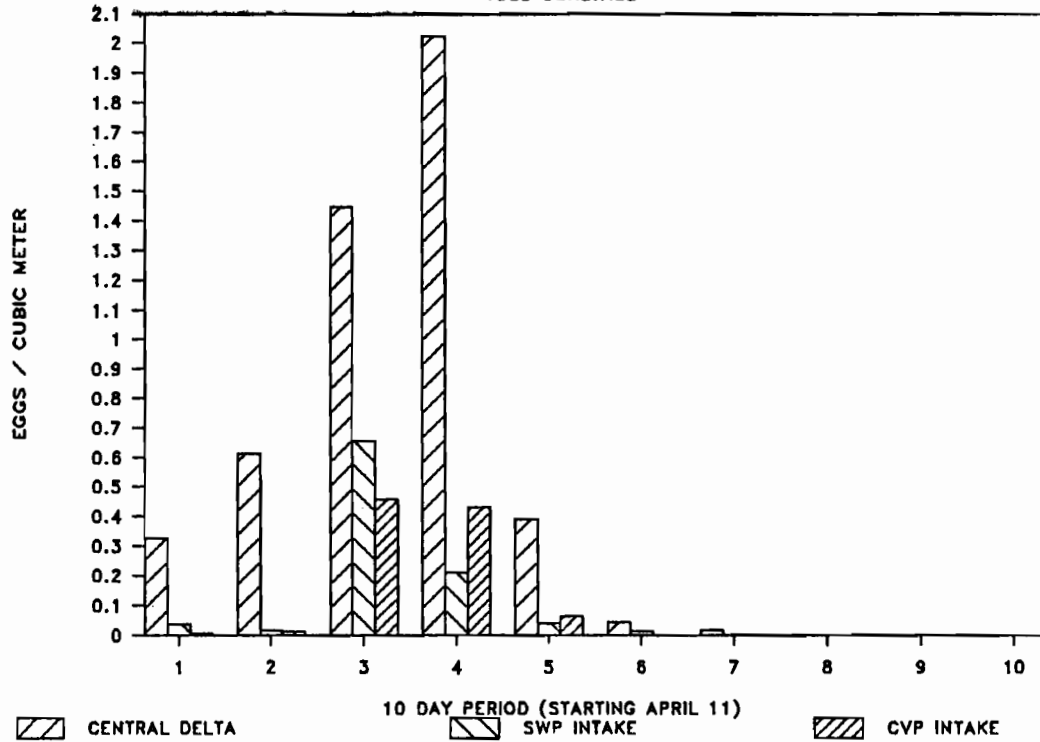


Figure 2. Average densities of striped bass eggs in 1985 in the Central Delta and adjacent to the SWP and CVP intakes.

STRIPED BASS <7MM

1985 DENSITIES

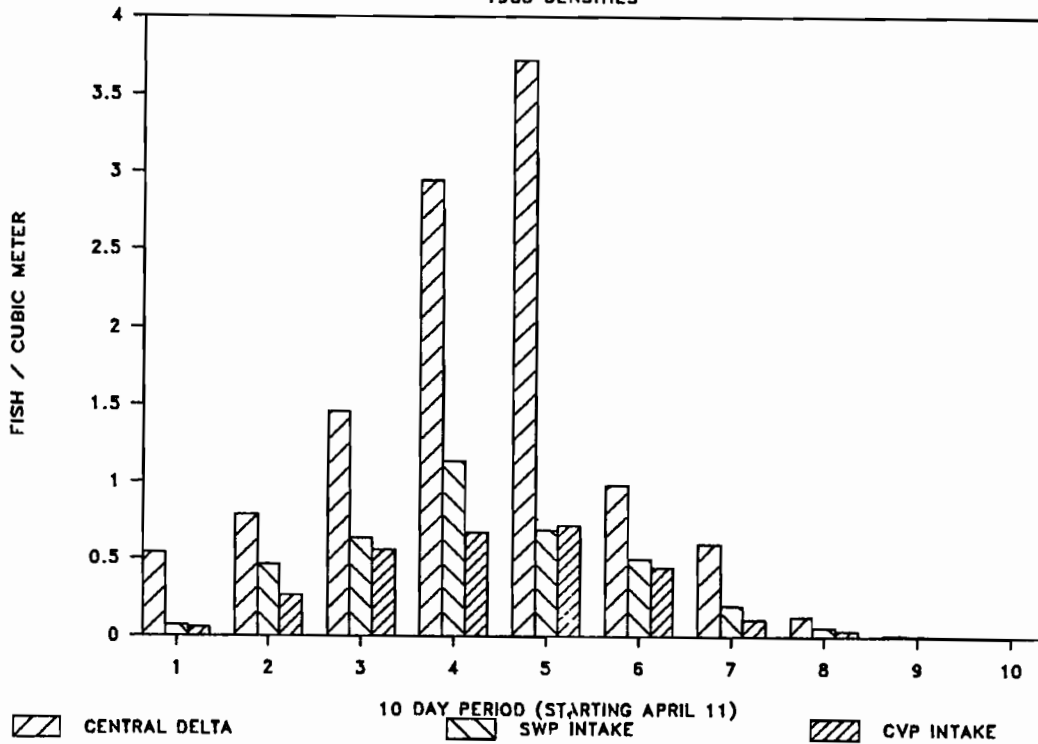


Figure 3. Average densities of striped bass larvae less than 7 mm in length in 1985 in the Central Delta, and adjacent to the SWP and CVP intakes.

STRIPED BASS 7-10MM

1985 DENSITIES

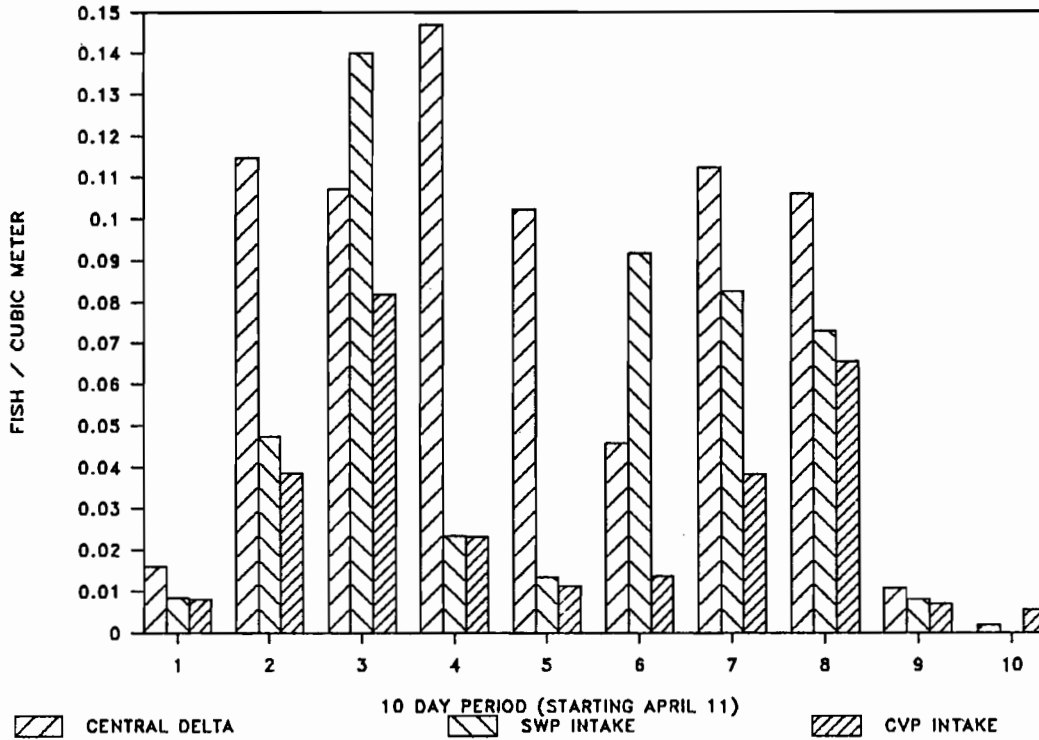


Figure 4. Average densities of striped bass larvae 7 to 10 mm in length in 1985 in the Central Delta, and adjacent to the SWP and CVP intakes.

STRIPED BASS 11-14MM

1985 DENSITIES

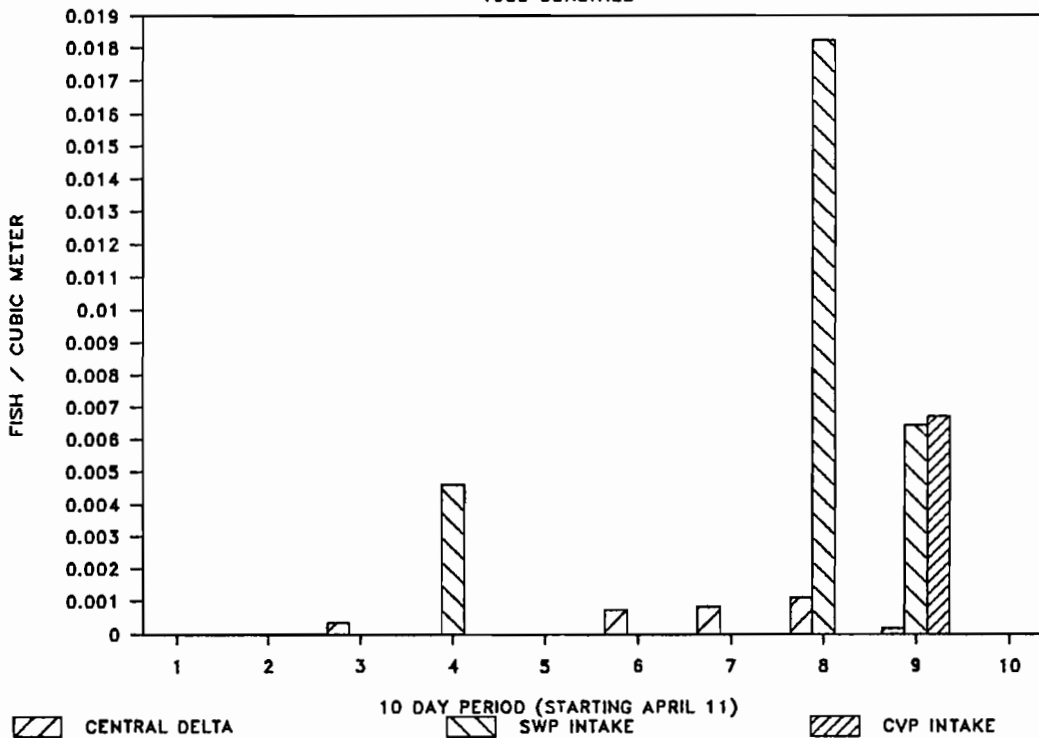


Figure 5. Average densities of striped bass larvae 11 to 14 mm in length in 1985 in the Central Delta, and adjacent to the SWP and CVP intakes.

TABLE 8. STRIPED BASS EGG AND LARVAL 1986 AVERAGE DENSITY (FISH PER CUBIC METER) ESTIMATES IN THE CENTRAL DELTA, AND ADJACENT TO THE SWP AND CVP INTAKES.

| TIME PERIOD | DENSITIES IN THE CENTRAL DELTA | | | | | |
|-------------|--------------------------------|--------|---------|----------|----------|----------|
| | EGGS | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 4/11-20 | 0.0010 | 0.0105 | 0 | 0 | 0 | 0 |
| 4/21-30 | 0.0666 | 0.1911 | 0.0084 | 0 | 0 | 0 |
| 5/ 1-10 | 0.1417 | 0.1817 | 0.0169 | 0.0001 | 0 | 0 |
| 5/11-20 | 0.2177 | 0.5481 | 0.0341 | 0.0005 | 0.0001 | 0 |
| 5/21-30 | 0.1779 | 1.1895 | 0.3734 | 0.0033 | 0.0001 | 0 |
| 5/31-6/9 | 0.0180 | 0.7891 | 0.3416 | 0.0100 | 0.0005 | 0.0002 |
| 6/10-19 | 0.0119 | 0.0811 | 0.0911 | 0.0127 | 0.0005 | 0.0002 |
| 6/20-29 | 0 | 0.1078 | 0.0714 | 0.0110 | 0 | 0 |
| 6/30-7/9 | 0.0018 | 0.0157 | 0.0228 | 0.0046 | 0.0016 | 0.0035 |
| 7/10-19 | 0 | 0.0031 | 0.0007 | 0 | 0 | 0 |

| TIME PERIOD | DENSITIES NEAR THE SWP INTAKE | | | | | |
|-------------|-------------------------------|--------|---------|----------|----------|----------|
| | EGGS | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 4/11-20 | 0.0044 | 0 | 0 | 0 | 0 | 0 |
| 4/21-30 | 0.0328 | 0 | 0 | 0 | 0 | 0 |
| 5/ 1-10 | 0.2542 | 0.1338 | 0.0663 | 0 | 0 | 0 |
| 5/11-20 | 0.2229 | 0.5939 | 0.2672 | 0 | 0 | 0 |
| 5/21-30 | 0.0097 | 2.4565 | 0.7338 | 0.0869 | 0 | 0 |
| 5/31-6/9 | 0.0089 | 0.1707 | 0.8150 | 0.1743 | 0.0551 | 0 |
| 6/10-19 | 0 | 0.0057 | 0.0760 | 0.2898 | 0.0359 | 0 |
| 6/20-29 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/30-7/9 | 0 | 0.0638 | 0.0279 | 0.0922 | 0.0135 | 0.0279 |
| 7/10-19 | 0 | 0.0055 | 0 | 0 | 0.0042 | 0.0055 |

| TIME PERIOD | DENSITIES NEAR THE CVP INTAKE | | | | | |
|-------------|-------------------------------|--------|---------|----------|----------|----------|
| | EGGS | 3-6 mm | 7-10 mm | 11-14 mm | 15-18 mm | 19-20 mm |
| 4/11-20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4/21-30 | 0.1109 | 0 | 0 | 0 | 0 | 0 |
| 5/ 1-10 | 0.0840 | 0.0045 | 0.0045 | 0.0045 | 0 | 0 |
| 5/11-20 | 0.0204 | 0.0546 | 0.0045 | 0.0045 | 0 | 0 |
| 5/21-30 | 0.9960 | 1.5663 | 1.1397 | 0.4461 | 0.0787 | 0 |
| 5/31-6/9 | 0.0383 | 0.1402 | 0.4685 | 0.2772 | 0.0660 | 0 |
| 6/10-19 | 0 | 0.0232 | 0.2507 | 0.1828 | 0 | 0.0649 |
| 6/20-29 | 0 | 0.0232 | 0.0634 | 0.0866 | 0.0634 | 0 |
| 6/30-7/9 | 0 | 0.0306 | 0.1275 | 0 | 0.0095 | 0.0196 |
| 7/10-19 | 0 | 0 | 0.0053 | 0 | 0.0053 | 0 |

STRIPED BASS EGGS

1986 DENSITIES

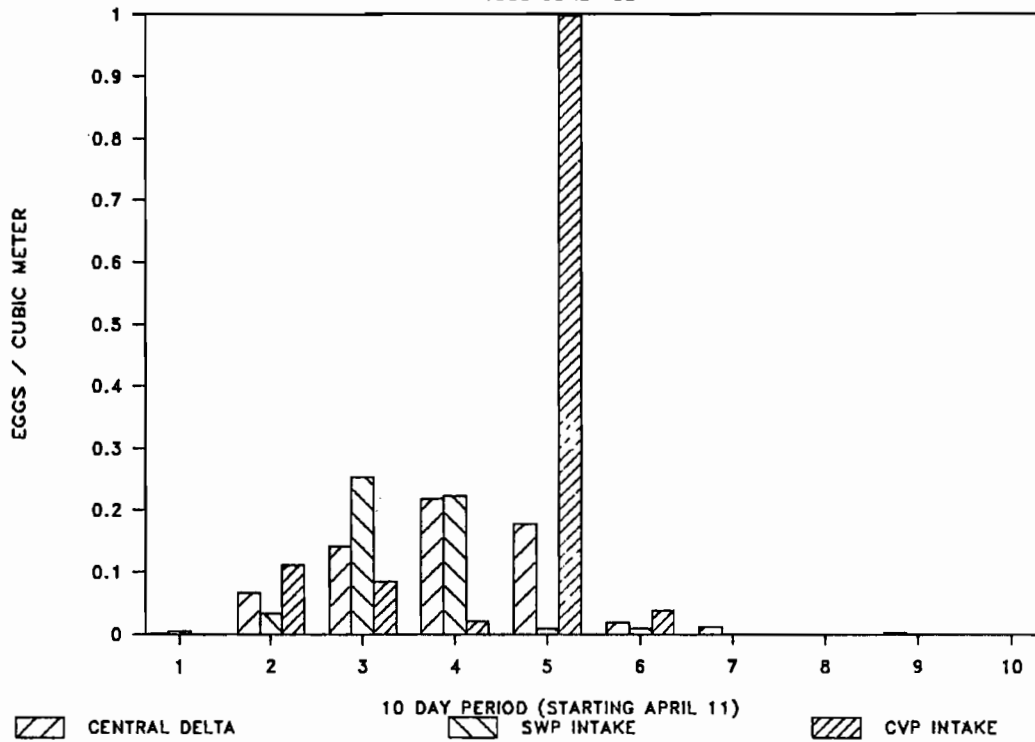


Figure 6. Average densities of striped bass eggs in 1986 in the Central Delta and adjacent to the SWP and CVP intakes.

STRIPED BASS <7MM

1986 DENSITIES

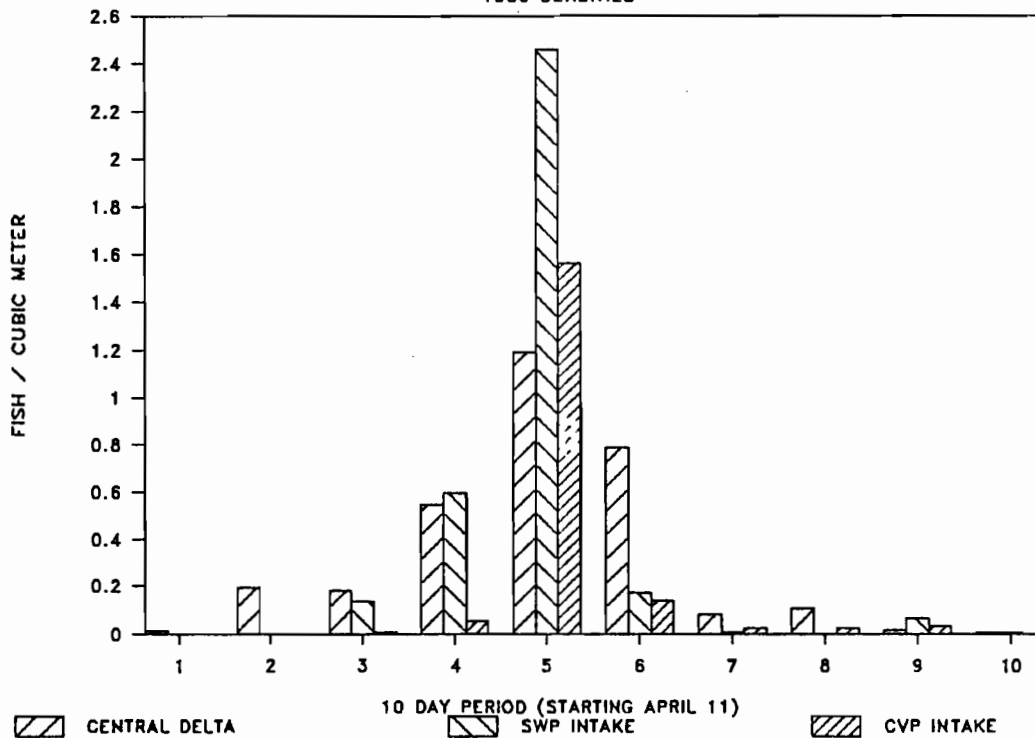


Figure 7. Average densities of striped bass larvae less than 7 mm in length in 1986 in the Central Delta, and adjacent to the SWP and CVP intakes.

STRIPED BASS 7-10MM

1986 DENSITIES

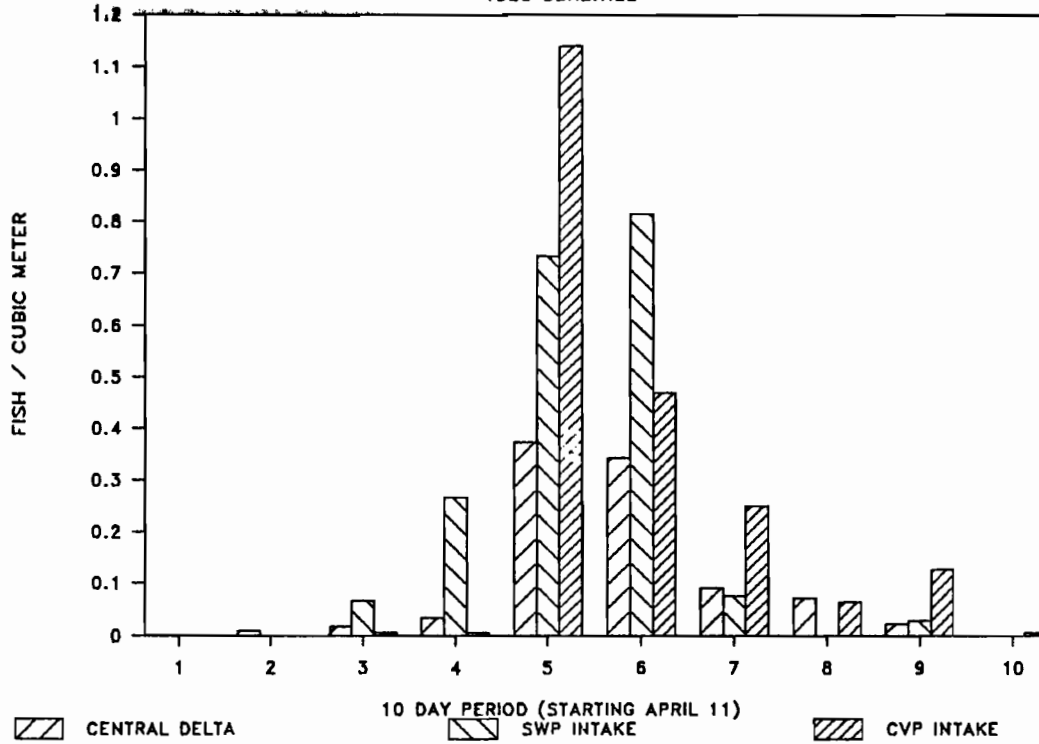


Figure 8. Average densities of striped bass larvae 7 to 10 mm in length in 1986 in the Central Delta, and adjacent to the SWP and CVP intakes.

STRIPED BASS 11-14MM

1985 DENSITIES

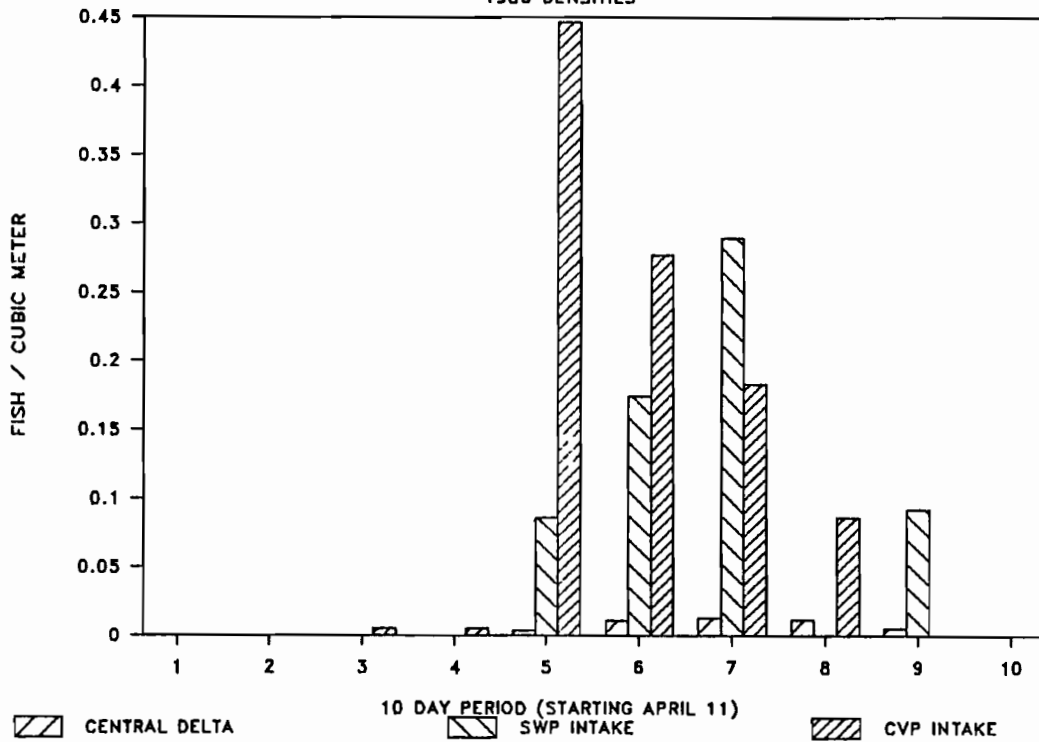


Figure 9. Average densities of striped bass larvae 11 to 14 mm in length in 1985 in the Central Delta, and adjacent to the SWP and CVP intakes.

TABLE 9. COMPARISON OF ENTRAINMENT LOSSES OF STRIPED BASS EGGS AND LARVAE LESS THAN 21 MM AT THE SWP AND CVP EXPORT FACILITIES BASED ON DENSITIES IN THE CENTRAL DELTA AND NEAR THE INTAKES, APRIL 16 THROUGH JULY 13, 1985.

| SIZE GROUP | CENTRAL DELTA | | NEAR INTAKES | |
|------------|---------------|---------------|--------------|-------------|
| | SWP | CVP | SWP | CVP |
| EGGS | 789,577,296 | 503,274,911 | 85,878,556 | 84,863,059 |
| 3-6 mm | 1,659,081,764 | 1,208,012,470 | 307,226,231 | 244,129,632 |
| 7-10 mm | 123,261,237 | 83,449,454 | 44,902,321 | 22,580,392 |
| 11-14 mm | 543,186 | 344,540 | 3,135,835 | 887,339 |
| 15-18 mm | 0 | 0 | 0 | 0 |
| 19-20 mm | 75,282 | 45,917 | 0 | 0 |
| TOTAL | 2,572,538,765 | 1,795,127,292 | 441,142,943 | 352,460,422 |

TABLE 10. COMPARISON OF ENTRAINMENT LOSSES OF STRIPED BASS EGGS AND LARVAE LESS THAN 21 MM AT THE SWP AND CVP EXPORT FACILITIES BASED ON DENSITIES IN THE CENTRAL DELTA AND NEAR THE INTAKES, APRIL 16 THROUGH JULY 11, 1986.

| SIZE GROUP | CENTRAL DELTA | | NEAR INTAKES | |
|------------|---------------|------------|--------------|------------|
| | SWP | CVP | SWP | CVP |
| EGGS | 101,559,822 | 5,474,795 | 3,772,123 | 9,272,117 |
| 3-6 mm | 474,525,846 | 59,149,497 | 27,070,106 | 13,794,033 |
| 7-10 mm | 143,709,919 | 27,685,758 | 14,214,217 | 15,271,579 |
| 11-14 mm | 6,448,309 | 2,079,894 | 5,615,853 | 7,194,078 |
| 15-18 mm | 540,802 | 229,996 | 883,410 | 1,536,689 |
| 19-20 mm | 836,640 | 452,148 | 353,651 | 744,553 |
| TOTAL | 727,621,338 | 95,072,088 | 51,909,360 | 47,813,049 |

TABLE 11. STRIPED BASS YEARLING EQUIVALENT LOSS AT THE SWP AND CVP EXPORT FACILITIES BASED ON CENTRAL DELTA DENSITIES AND DENSITIES NEAR THE INTAKES AND WATER EXPORTS DURING APRIL 16 THROUGH JULY 13, 1985.

| SIZE GROUP | SURVIVAL RATE TO AGE 1 * | CENTRAL DELTA | | NEAR INTAKES | |
|------------|-----------------------------|---------------|---------|--------------|--------|
| | | SWP | CVP | SWP | CVP |
| EGGS | 0.000047 | 37,109 | 23,437 | 4,036 | 3,989 |
| 3-6 mm | 0.000124 | 205,726 | 149,794 | 38,096 | 30,272 |
| 7-10 mm | 0.000338 | 47,826 | 32,378 | 15,177 | 7,632 |
| 11-14 mm | 0.002509 | 1,362 | 866 | 7,868 | 2,226 |
| 15-18 mm | 0.006415 | 0 | 0 | 0 | 0 |
| 19-20 mm | 0.020414 | 1,536 | 938 | 0 | 0 |
| TOTAL | | 293,559 | 207,413 | 65,177 | 44,119 |

* SURVIVAL RATES TO AGE 1 FOR DIFFERENT SIZE GROUPS WERE CALCULATED BY ECOLOGICAL ANALYSTS 1981. EGG SURVIVAL RATE WAS ESTIMATED BY CALCULATING THE POTENTIAL NUMBER OF EGGS SPAWNED COMPARED TO THE ESTIMATED NUMBER OF AGE 1 FISH IN THE ESTUARY.

TABLE 12. STRIPED BASS YEARLING EQUIVALENT LOSS AT THE SWP AND CVP EXPORT FACILITIES BASED ON CENTRAL DELTA DENSITIES AND DENSITIES NEAR THE INTAKES AND WATER EXPORTS DURING APRIL 16 THROUGH JULY 11, 1986.

| SIZE GROUP | SURVIVAL RATE TO AGE 1 * | CENTRAL DELTA | | NEAR INTAKES | |
|------------|-----------------------------|---------------|--------|--------------|--------|
| | | SWP | CVP | SWP | CVP |
| EGGS | 0.000047 | 4,773 | 257 | 177 | 436 |
| 3-6 mm | 0.000124 | 58,841 | 7,335 | 3,357 | 1,710 |
| 7-10 mm | 0.000338 | 48,574 | 9,358 | 4,804 | 5,162 |
| 11-14 mm | 0.002509 | 16,179 | 5,218 | 14,090 | 18,050 |
| 15-18 mm | 0.006415 | 3,469 | 1,475 | 5,667 | 9,858 |
| 19-20 mm | 0.020414 | 17,079 | 9,230 | 7,219 | 15,199 |
| TOTAL | | 148,916 | 32,874 | 35,315 | 50,415 |

* SURVIVAL RATES TO AGE 1 FOR DIFFERENT SIZE GROUPS WERE CALCULATED BY ECOLOGICAL ANALYSTS 1981. EGG SURVIVAL RATE WAS ESTIMATED BY CALCULATING THE POTENTIAL NUMBER OF EGGS SPAWNED COMPARED TO THE ESTIMATED NUMBER OF AGE 1 FISH IN THE ESTUARY.

DISCUSSION

In spring 1985 and 1986, the loss of striped bass eggs and larvae was estimated based on direct measurement of densities of eggs and larvae at points near the diversions and the volume of water being exported during the survey. To date, this method appears to represent the most accurate means of estimating the magnitude of entrainment. However, several potential biases may result in underestimates:

- * Nets may not be totally efficient, especially for larger size larvae.
- * Spatial distribution of larvae within the channel may be different than at midchannel where sampling was done using an oblique tow.
- * Towing during daylight hours may decrease efficiency due to increased net avoidance.
- * Net efficiency may be greatly reduced during algal blooms.

The estimated entrainment based on densities taken near the intakes was slightly more than 10 times greater in 1985 than in 1986. This is most likely because high flow rates in Old River during early spring 1986 forced eggs and larvae farther downstream, out of the influence of the two pumping facilities. (Mean mid-April through mid-July flow was 2,280 cfs for 1985 and 5,952 cfs for 1986.)

Entrainment estimates were higher for the SWP than for the CVP in both years. This difference is probably because water from West Canal passes in front of the SWP first or because of dilution by San Joaquin River water. Estimates of combined SWP/CVP entrainment losses compared as follows:

| | <u>Baracco's Method</u> | <u>Our Method</u> |
|------|-----------------------------|-----------------------|
| 1985 | 4.368 billion | 793.6 million |
| 1986 | 822.7 million | 99.7 million |

The difference is probably due to the higher central Delta densities.

Combined SWP/CVP entrainment losses for striped bass yearling equivalents compared as follows:

| | <u>Baracco's Method</u> | <u>Our Method</u> |
|------|-----------------------------|-----------------------|
| 1985 | 500,972 | 109,296 |
| 1986 | 181,790 | 85,730 |

Baracco estimated a combined SWP/CVP average annual entrainment loss for 1968 through 1977 of 227,000 striped bass yearling equivalents.

It is not surprising that there is a large difference in our estimates and Baracco's estimates, since they are a direct function of the densities used. Entrainment estimates based on densities taken nearer the points of diversion should provide more accurate estimates than those calculated by Baracco.

REFERENCES

Baracco, A. 1983. Estimated entrainment of striped bass eggs and larvae less than 19mm in length at State Water Project and Central Valley Project facilities in the Sacramento-San Joaquin Delta, California, 1968-1977. Memorandum dated July 12, 1983.

Department of Water Resources. 1985. Dayflow Summary, April 1 - July 31, 1985. Central District.

APPENDIX A. DAILY INFLOW (arce-feet) INTO CLIFTON COURT FOREBAY
 APRIL THROUGH JULY, 1985 AND 1986.

| DAY | 1985 | | | | 1986 | | | |
|-----|-------|------|-------|-------|-------|-------|------|-------|
| | APRIL | MAY | JUNE | JULY | APRIL | MAY | JUNE | JULY |
| 1 | 4969 | 5318 | 5060 | 6942 | 0 | 10089 | 6627 | 8718 |
| 2 | 6874 | 4955 | 4921 | 8925 | 0 | 5746 | 7550 | 9718 |
| 3 | 5209 | 5919 | 4950 | 9917 | 0 | 5527 | 4686 | 8786 |
| 4 | 6216 | 6561 | 4958 | 9917 | 2028 | 5219 | 5775 | 7907 |
| 5 | 6942 | 8119 | 4958 | 10909 | 1031 | 6269 | 5906 | 10552 |
| 6 | 6744 | 7899 | 4959 | 9917 | 3435 | 5141 | 5922 | 7863 |
| 7 | 6744 | 6567 | 5951 | 8661 | 4202 | 5526 | 4978 | 8739 |
| 8 | 6744 | 5972 | 5950 | 8926 | 413 | 6431 | 9558 | 9997 |
| 9 | 7708 | 5943 | 5950 | 8857 | 3045 | 6279 | 6687 | 8921 |
| 10 | 6819 | 4959 | 5355 | 8926 | 0 | 5155 | 7205 | 8925 |
| 11 | 6425 | 4959 | 6348 | 8925 | 1407 | 5925 | 7427 | 8319 |
| 12 | 5713 | 4959 | 6942 | 8918 | 0 | 4938 | 6167 | 6942 |
| 13 | 5740 | 6002 | 5951 | 8923 | 2030 | 5423 | 8027 | 7537 |
| 14 | 7226 | 8926 | 6942 | 9684 | 5013 | 5650 | 6357 | 8132 |
| 15 | 7000 | 7140 | 6964 | 9916 | 3757 | 6412 | 8806 | 8727 |
| 16 | 5645 | 7532 | 6920 | 9520 | 251 | 5851 | 8928 | 7339 |
| 17 | 6910 | 7347 | 6942 | 9322 | 6514 | 7929 | 7961 | 6149 |
| 18 | 9698 | 8882 | 6671 | 10271 | 1570 | 10502 | 5300 | 5087 |
| 19 | 9189 | 8919 | 7934 | 10895 | 7583 | 10050 | 5651 | 5508 |
| 20 | 9124 | 8884 | 7924 | 10909 | 5967 | 8950 | 5144 | 5554 |
| 21 | 8952 | 5919 | 8524 | 10909 | 4780 | 6929 | 4760 | 5663 |
| 22 | 8799 | 4939 | 7932 | 8638 | 5669 | 7748 | 2294 | 4959 |
| 23 | 8920 | 3894 | 7920 | 9242 | 5022 | 8089 | 1981 | 5762 |
| 24 | 6946 | 3967 | 8923 | 8279 | 4208 | 9927 | 4748 | 7621 |
| 25 | 3993 | 4457 | 7207 | 9038 | 4268 | 10607 | 4557 | 9718 |
| 26 | 6742 | 4959 | 10494 | 8900 | 8307 | 10507 | 4953 | 9316 |
| 27 | 4958 | 4959 | 8837 | 8864 | 8778 | 4061 | 5548 | 6774 |
| 28 | 3967 | 5541 | 6940 | 8896 | 6921 | 119 | 4958 | 9539 |
| 29 | 3954 | 4959 | 6541 | 8924 | 6906 | 1443 | 5950 | 8909 |
| 30 | 3572 | 4959 | 6545 | 10305 | 7728 | 2591 | 7725 | 9505 |
| 31 | | 5917 | | 9918 | | 639 | | 9917 |

APPENDIX B. DAILY EXPORT RATES (acre-feet) BY THE CVP APRIL THROUGH JULY, 1985 AND 1986.

| DAY | 1985 | | | | 1986 | | | |
|-----|-------|------|------|------|-------|------|------|------|
| | APRIL | MAY | JUNE | JULY | APRIL | MAY | JUNE | JULY |
| 1 | 8361 | 6150 | 6207 | 9147 | 4080 | 5895 | 6632 | 9146 |
| 2 | 7048 | 6111 | 6247 | 8891 | 3440 | 6039 | 6610 | 8931 |
| 3 | 6955 | 5260 | 6176 | 8882 | 4544 | 6031 | 6580 | 8899 |
| 4 | 6533 | 4955 | 6230 | 8860 | 6021 | 6019 | 6623 | 8905 |
| 5 | 6247 | 4955 | 6241 | 8929 | 6455 | 6019 | 5145 | 9036 |
| 6 | 6016 | 4744 | 6237 | 8950 | 6422 | 6330 | 4845 | 9096 |
| 7 | 5999 | 4965 | 5781 | 8925 | 5636 | 6539 | 4859 | 8820 |
| 8 | 5965 | 4927 | 6250 | 9050 | 4864 | 6541 | 4867 | 4501 |
| 9 | 5976 | 4987 | 6212 | 9072 | 4112 | 6544 | 4869 | 4478 |
| 10 | 6013 | 5905 | 6214 | 9081 | 3527 | 6567 | 4854 | 4481 |
| 11 | 8558 | 6241 | 6219 | 9069 | 4277 | 6559 | 6115 | 4443 |
| 12 | 9192 | 6233 | 6048 | 9135 | 4736 | 6546 | 6597 | 4465 |
| 13 | 8867 | 6237 | 5848 | 9159 | 4696 | 6289 | 6604 | 4455 |
| 14 | 9062 | 6212 | 5859 | 9159 | 4847 | 6078 | 6589 | 4434 |
| 15 | 9047 | 6228 | 5846 | 9166 | 5062 | 6087 | 6582 | 8884 |
| 16 | 8893 | 6307 | 5637 | 9161 | 5979 | 5344 | 6572 | 8714 |
| 17 | 8929 | 6292 | 5901 | 9186 | 6566 | 5031 | 6601 | 8887 |
| 18 | 8951 | 6281 | 5906 | 9169 | 5613 | 5027 | 6587 | 8932 |
| 19 | 8992 | 6212 | 5899 | 9142 | 5015 | 5051 | 6591 | 8944 |
| 20 | 8951 | 6210 | 5923 | 9130 | 5046 | 5042 | 5532 | 8924 |
| 21 | 8956 | 6209 | 5883 | 9094 | 5054 | 4819 | 5075 | 8683 |
| 22 | 7925 | 6220 | 5835 | 9188 | 5980 | 5062 | 5105 | 8029 |
| 23 | 7965 | 6214 | 5924 | 9046 | 6565 | 5075 | 5118 | 8393 |
| 24 | 7929 | 6244 | 5835 | 9233 | 6551 | 5780 | 5078 | 8343 |
| 25 | 7952 | 6254 | 5623 | 9258 | 6540 | 6102 | 5107 | 8485 |
| 26 | 7940 | 6245 | 5706 | 9247 | 6558 | 6070 | 6295 | 8555 |
| 27 | 7886 | 6268 | 5735 | 8793 | 6263 | 6101 | 6722 | 8540 |
| 28 | 7625 | 6232 | 5631 | 9232 | 6535 | 6370 | 6512 | 8723 |
| 29 | 7137 | 6222 | 5995 | 9060 | 6678 | 6394 | 6414 | |
| 30 | 6910 | 6194 | 5446 | 8902 | 7924 | 6633 | 6395 | |
| 31 | | 6188 | | 8871 | | 6386 | | |